Clinton Aigbavboa
Wellington Thwala
Douglas Aghimien *Editors*

Towards a Sustainable Construction Industry: The Role of Innovation and Digitalisation

Proceedings of 12th Construction Industry Development Board (CIDB) Postgraduate Research Conference

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Editors
Clinton Aigbavboa
Construction Management and Quantity Surveying
University of Johannesburg
Johannesburg, Gauteng, South Africa

Wellington Thwala
Department of Civil Engineering
University of South Africa (UNISA)
Pretoria, Gauteng, South Africa

Douglas Aghimien
Civil Engineering Technology
University of Johannesburg
Johannesburg, Gauteng, South Africa

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Contents

Adding Resilience to a Building Using Lightning Information Modeling

Shadreck Mpanga(✉), Ackim Zulu, and Mabvuto Mwanza

School of Engineering, Department of Electrical and Electronic Engineering, University of Zambia, P. O. Box 32379, 10101 Lusaka, Zambia
{shadreck.mpanga,ackim.zulu,mabvuto.mwanza}@unza.zm

Abstract. Lightning protection system (LPS) designs are avoided in many architectural 3-D models for a number of buildings in Sub-Saharan countries like Zambia. The omission of the LPS is due to lack of local standards and their enforcement on the lightning protection of buildings. This can exacerbate the external forces experienced by a building that can lead to more internal forces. Lightning introduces electrical forces into the building materials and if their design, selection and construction are not carefully followed, the building fatigue can increase a few years down the line. Careful observation of a building reveals whether or not the designers paid attention to the lightning protection aspect. In a number of situations, only civil engineers are available at the foundation stage of a building construction, but this is the stage where a full LPS of a building begins. Thus, this paper seeks to show how cardinal lightning information modeling (LIM) is to the resilience of a building by showing how the model can inform decisions about lightning risk assessment and LPS design, and how it can be part of Building Information Modeling (BIM) for an all-weather building. BIM is about any information that can contribute to a robust building and LIM just happens to be one of the ingredients. Lightning data were obtained from a lightning detection network, modeled in ArcGIS and then applied to construction of buildings. AutoCAD, Revit and Blender software were used for conceptualization of buildings. The approach shows how LIM adds resilience to a building.

Keywords: Resilience · Lightning information · Building information modeling · Standards · Sub-Saharan Africa

1 Introduction

A lightning protection system (LPS) protects a building against the consequences of lightning currents like electrical stresses that in turn can lead to chemical stresses. These stresses can compromise the mechanical strength of the building in the short or long-term depending on the material types used [1]. An external LPS consists of an air-termination system (ATS), a down conductor termination system (DTS) and an earth termination system (ETS) that provide a Faraday cage and ensures the contents of a building are well protected against this random phenomenon [1–5]. The trend by many building designers is to concentrate on external and internal mechanical forces alone, without necessarily

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paying attention to the electrical forces that lightning can impress on a building. What this results in is a building with no external LPS or fragmented work processes that may cause cost overruns. For countries with no local standards on the LPSs of buildings in Sub-Saharan Africa, it is easy to observe that some buildings have the external LPS and others do not have. That is why studies [6–13] show that 90% of buildings in Sub-Saharan Africa are not lightning safe.

Lightning information modeling (LIM) involves every structure built on an area with distinct coordinates and it is on this same area on earth that lightning strikes. By tracking the lightning trend over an area for a period, it is possible to establish a lighting pattern using ArcGIS software in order to determine the lightning flash density whose units are events/km^2/year. This is the starting point of lightning risk assessment [2] that helps electrical engineers to decide if there is a need for an LPS installation on the building. One feature about the LPS's ETS is that it makes use of the soil's electrical property, conductivity. Thus, the soil should not be thought of as something to be tilled for agricultural use and building material only but as something with electrical properties that are put to practical use every day in industries [14].

In one webinar organized by the Engineering Institute of Technology (EIT), Australia, the presenter discussed recent trends in evaluation and monitoring of concrete structures on 28 September 2021. One of the things that came to the fore was that cracking is one of the most common defects monitored on a building. Cracks can be due to early thermal contraction or corrosion of rebars. She explained that electrical resistivity (ER) method is used to detect moisture content in concrete structures and this gives a sign if there are cracks developing. Bearing in mind that a lightning strike to a building can induce more thermal stresses in addition to the external and internal mechanical stresses can enhance the knowledge about building resilience. For instance, the lightning thunderous blast is heard because of the violent rapid rise in temperature around the region where positive and negative charges meet, or a tree is left ripped apart because of the same sudden inducement of heat into it [1–5]. Thus, structural degradation has a bearing on the lifespan of a general building that is expected to be about 60–80 years.

The Bavarian building regulations stipulate that if lightning can easily strike a structure due to its location, type of construction or its use, then a permanent effective LPS must be installed [4]. Some damages that can result from the strike are fire and explosion, which in turn, can result in losses such as injury or death of a person, loss of services, loss of cultural heritage and loss of economic value [2–4]. Knowing all these factors calls for a more resilient and sustainable approach to construction of our buildings. One green engineering trend to adopt is using sustainable construction materials such as eco-friendly windows that are able to produce solar energy for energy efficient buildings [15]. What this means is that many future buildings will be able to generate and store energy, and this will definitely need a robust approach to the protection of the electrical systems in these buildings against lightning strikes.

Plant-based building materials are now available on the market. This will aid in establishing zero-energy buildings whose facades are inspired by plants [15]. The electrical property of the soil used to nurture these plants on top of the buildings can be taken advantage of to easily conduct lightning current away from the building when a strike happens. With Building Information Modeling (BIM), it is now possible to include all the valuable information about the environment so as to have an insight into the kind of structure properly suited to stand up to lightning strikes. Suffice to say that engineering education now needs to take note of the green engineering trends that are shaping the world through curriculum development [16, 17], and it is a requirement that buildings must remain sustainable ecosystems for many years. Thus, this paper shows that it is possible to add resilience to a building by first analyzing both the mechanical and electrical forces impressed on a building and then by LIM using ArcGIS software.

2 Methodology

Literature on lightning protection of buildings such as standards, journals and conference papers were consulted. Survey of architectural drawings was done as well as interaction with architects and civil engineers to understand the implementation of their designs in Southern Africa. To show the lightning occurrence pattern in Zambia, ArcGIS was used to map the activities after accessing the data from the global lightning dataset (GLD360), a lightning detection network owned and operated by Vaisala Inc., a company based in Tucson, Arizona, USA. Resilience in this paper means the ability of a building to exhibit toughness when struck by lightning and avoid structural degradation. This is ensured by an external LPS installed in such a way that it quickly conducts the dangerous lightning energy from the ATS through the DTS to the ETS and finally into the soil. The ETS attracts the lightning current by having a very low resistance and thus appearing as a short circuit to the lightning current. This prevents the currents from entering other structures of the building and thus prevents their degradation that may speed up due to the heating effect of the currents. Google earth was used to get the images and orientation of the school of engineering buildings whose ETSs are not connected. To show how architectural drawings that conform to LPS standards must look like, 2-D and 3-D models were developed in AutoCAD and given an architectural rendering using Revit and blender. In short, 2-D drawings were done using AutoCAD and ArcGIS whereas the 3-D drawings were done using Revit and blender.

3 Forces Impressed onto the Building Materials

In this climate change era, when we listen to news, the natural disasters mostly talked about are tornadoes, tsunamis, cyclones, typhoons, earthquakes, floods and avalanches. These are powerful external forces that push our buildings to the limit. The interesting aspect is that, to a common observer, lightning doesn't come into the picture when some of these natural disasters occur. Lightning detection networks are actually a source of valuable information needed to monitor the development of some of these powerful forces of nature. For instance, live total lightning information can be used to monitor the development of cyclones and tornadoes and alert messages can be sent to communities well before they strike [18].

External forces such as wind, water and vibrations in the earth do expose structures to internal forces like shear, tension and compression even when buildings are made of strong steel and concrete. So, one may ask, 'how does lightning protection come into the picture?' Well, lightning currents range between 2 and 200 kA that are expected to hit a structure [1–3]. These are high currents, which, when allowed to flow through the structural components can cause heating to occur, and heat does speed up structural degradation. Design of steel structures usually follows the following order: selection of the general configuration and type of structure, determination of the service loads, computation of the internal forces, apportioning the members and connections, checking the performance characteristics like deflection of beams, general overall review, and preparing complete design drawings [19–21]. It is at this stage that designers of different trades can work together and appreciate the needs of other disciplines in the construction.

The mechanical stress experienced by a structure is given as force divided by area as in Eq. (1) where σ is stress in Newtons per square metres, F force in Newtons and A area in square metres. Beam deflection (Δ) can be calculated using Eq. (2) where W is the loading on the beam, L the span of the beam, E the Young's Modulus and I the moment of inertia. A deflection can be due to live loads and the deflection can worsen if the beams are heated up by the lightning currents [19–21].

$$\sigma = \frac{F}{A}. \tag{1}$$

$$\Delta = \frac{WL^3}{48EI}. \tag{2}$$

Equation (3) is used to analyze maximum bending moment M of a beam where I is the moment of inertia (Eq. 4) about the neutral axis, σ is the tensile strength of the material and y is the distance of the neutral axis from the maximum stress [19–21]. In Eq. (4), B is the breadth and D the depth of the beam.

$$\frac{M}{I} = \frac{\sigma}{y}. \tag{3}$$

$$I = \frac{BD^3}{12}. \tag{4}$$

The rebars used in concrete structures are liable to buckle and they have to be checked for compression and buckling strength. The calculation can be done using Euler's formula [19–21] as shown in Eq. (5) where both ends of the bar are fixed. E is the elasticity modulus of the material, J maximum axial angular impulse, F maximum permissible force, L length of the bar, s factor of safety which is 8 for cast iron, 5 mild carbon steel and 10 wood [21]. Equation (6) gives the heat transfer in materials used in construction where Q is the heat content, V the volume of the material, ρ the density of the material, C the specific heat capacity and ΔT the temperature difference. The heat flow φ measured in watts (J/s) is then the enthalpy Q per unit time t [19–21] calculated as $\varphi = Q/t$.

$$F = \frac{4\pi^2 EJ}{sL^2}. \tag{5}$$

$$Q = V \cdot \rho \cdot C \cdot \Delta T \tag{6}$$

The specific energy W/R of a lightning stroke, frequently referred to as the current square impulse, is calculated as shown in Eq. (7) and is responsible for the temperature rise in metallic conductors that are hit by lightning. *W* is the lightning energy, *R* the temperature-dependent DC resistance of the material and *i* the lightning current. The electrodynamic forces *F(t)* generated by the lightning current in a conducting material with a long, parallel sectional length of *L* and separation distance *d* between conductors can be approximated using Eq. (8) where μ_0 is the magnetic field constant [2, 4].

$$\frac{W}{R} = \int i^2(t)dt. \tag{7}$$

$$F(t) = \frac{\mu_0}{2\pi} \cdot i^2(t) \cdot \frac{L}{d}. \tag{8}$$

4 Lightning Information Modeling (LIM)

LIM involves knowing the lightning pattern of an area and this kind of data can be obtained from lightning detection networks [18] around the world. One of the most prominent detection companies, Vaisala Inc., a Finnish company based in Tucson, Arizona, USA, provided the lightning data for 2016 to 2020, but total lightning data for each country can easily be found in its annual reports published online every year. For the six-year period from 2016 to 2021, the events per year over Zambia are shown in Table 1. From these, one-third of them are expected to be cloud-to-ground lightning as shown in the last column of Table 1. These are the ones that aid in mapping of the lightning activities around the country so as to establish ground lightning flash densities.

Table 1. Lightning events over Zambia from 2016 to 2021 [22]

Year	Total lightning counts	Theoretical cloud-to-ground counts
2016	6,637,324	2,212,441
2017	12,101,048	4,033,683
2018	14,825,779	4,941,926
2019	16,954,455	5,651,485
2020	12,647,634	4,215,878
2021	13,193,767	4,397,922

The values in the third column of Table 1 show that it is possible to establish generalized values of cloud-to-ground (C-G) lightning flash densities per year. Only 2016 showed a pronounced departure from what seems to be an expected pattern as the years 2017–2021 depict. In fact, 2016 is on record as one of the years when Zambia experienced very little rainfall and the country succumbed to massive load shedding as the main source of electricity is hydro. The rainfall patterns are recorded by automated weather stations spread around the country as shown in Fig. 1 as of 2021. Going by what happened in 2016, it is possible to say that lightning levels do relate to rainfall levels of a particular region. In fact, total lightning is very useful when it comes to monitoring the development of storms in a rain season [18].

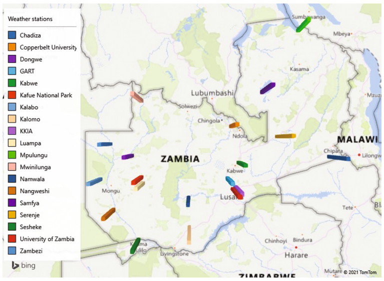


Fig. 1. Weather stations in Zambia.

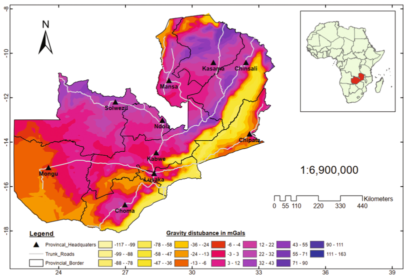
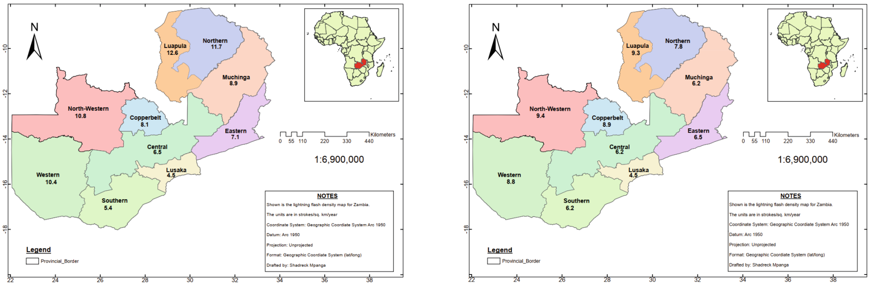


Fig. 2. Gravity map of Zambia.

The rainfall pattern of a country does relate to the gravity map of a country too as shown in Fig. 2 where the regions of Western province and the northern parts of the country do receive more rainfall than the Southern parts of the country. Moreover, gravity affects the builder's level alignment, the global positioning system (GPS) and the earth's geomagnetic field. All these aspects affect the construction of a building.

Figure 3 shows the ground lightning flash densities for the year 2019 and 2020. The average values per province for the two years are: North Western province 10.1, Copperbelt 8.5, Luapula 10.9, Northern 9.7, Muchinga 7.6, Eastern 6.8, Central 6.4, Lusaka 4.5, Southern 5.8 and Western 9.6, in events/km^2/year. These are C-G lightning flashes, an improvement from the values given in [22] that are for total lightning.

LIM is used in Fig. 1 through Fig. 3 to arrive at average C-G lightning flash densities per province of Zambia. The density value, N_g, is then used for lightning risk assessment to decide if a building requires an LPS installation or not. Equations (9–12) are used for the lightning risk assessment of any building. In the Eqs. (9–12).4, A_e is the area of the building, L the length of the building, W the width of the building, H the height of the building, N_d the expected yearly lightning strike frequency, N_C the tolerable number of lightning strikes to the structure, C_1 the environmental coefficient, C_2 the



(a) 2019 flash densities (b) 2020 flash densities

Fig. 3. Lightning flash densities for 2019 and 2020 in events/km^2/year.

structure coefficient, C_3 the structure contents coefficient, C_4 the structure occupancy coefficient, C_5 the lightning consequence coefficient and N_{LP} the lightning protection (LP) efficiency.

$$A_e = LW + 6H(L + W) + 9\pi H^2. \tag{9}$$

$$N_d = N_g A_e C_1 \times 10^{-6}. \tag{10}$$

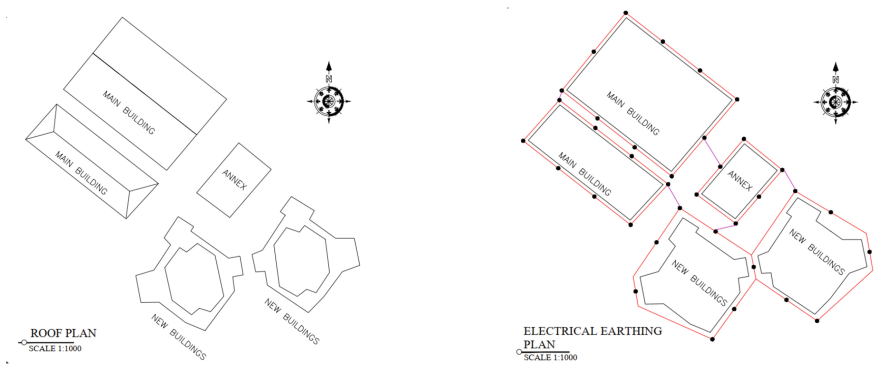
$$N_C = \frac{1.5 \times 10^{-3}}{C_2 \times C_3 \times C_4 \times C_5}. \tag{11}$$

$$N_{LP} = 1 - \frac{N_C}{N_d}. \tag{12}$$

When $N_d > N_C$ LPS is needed whereas when $N_d \leq N_C$ LPS is optional. The lightning protection efficiency N_{LP} determines the capture probability of the lightning strike to the building. The constants C_1–C_5 are found in Tables provided in standards [2, 4]. Thus, thorough knowledge concerning the lightning phenomenon about an area and its risk assessment can contribute to the safety and resilience of the buildings.

5 Lightning Safe Buildings

As articulated in Sect. 1 through Sect. 4, LIM helps to have a clear picture of how buildings must look like from the lightning protection (LP) point of view. When LP is not paid attention to as shown in Fig. 4 (a) where the ETSs of the four buildings are not connected together, LP enhancement is done as in Fig. 4 (b) where interconnection of the ETSs is made around the structure with earth rods incorporated at regular intervals. This is similar to adding resistors in parallel. The earthing enhancement of the building is shown in red colour in Fig. 4 (b) and the dotted dark spots on it are the earth rods. The ETS is then connected to the ATS via the DTS. This establishes a Faraday cage for the building and when lightning strikes, the huge currents are divided into these conductors and easily move safely to the ground, leaving the contents of the building unaffected.



(a) Separate ETSs for the buildings (b) Interconnected ETSs for the buildings

Fig. 4. LPS enhancement for buildings through interconnection of earth termination system (ETS) for each building.

For an architectural drawing to a customer, it's not enough to present the 3-D view as shown in Fig. 5 (a) as most designers do. It instills the sense of lightning awareness when the drawing is presented to the customer as shown in Fig. 5 (b). When lightning is prevented from directly or indirectly striking the natural building materials like in this case, it is easy to see how resilience can be added to the whole installation. This is because lightning currents cause heating up of the materials to high temperatures and this is detrimental to the lifespan of the structures.

(a) No LPS showing (b) LPS showing in the design

Fig. 5. 3-D architectural models designed for a customer.

It is undeniable that a good lightning protection program (LPP) shown in Fig. 4 (b) and Fig. 5 (b) makes the buildings more lightning safe as they are now able to withstand this natural force in the environment [23]. With good maintenance of the installation, it is possible to make the building durable and resilient to external forces. This in the long run prolongs the lifespan of these structures. Ensuring electrical safety and sustainable building operation are key ingredients, not only for the owners but increasingly regulated by the local standards as well.

6 Discussion

Section 3 has shown the relationship between electrical and mechanical stresses through the heat transfer modeling. Lightning currents can cause structures to heat up which can lead to chemical stresses thereby weakening the mechanical strength of structures. These models help when selecting rebars used in concrete structures since these are prone to buckling which can worsen when lightning currents flow through them. To avoid the direct flow of high currents in rebars, stronger steel columns or separate conductors for an LPS can be used if economics allow. This approach can prolong the lifespan of the structures of the building as they are made more resilient to external forces. However, before a decision is made about the type of LP to use, it is important to have the LIM about an area in order to have the right parameters for the LPS design.

Lightning flash densities per region are the starting point of lightning risk assessment for any building undertaking. The risk assessment results establish whether or not an LPS must be installed on a building. If the LPS is not required it implies the building is already shielded by a lightning mast or the natural roofing materials are used as air termination if there is a metallic continuation from the ATS to the ETS. However, many buildings in Sub-Saharan Africa are yet to be fully lightning safe and this paper shows that knowledge about rainfall levels as shown in Figs. 1 and 2 is necessary for planning of settlements and economic activities of the country.

The ETS can be enhanced by incorporating the foundation reinforcement steel through exothermic welding lightning protection. This is practiced in Botswana on large buildings especially according to an interview with a civil engineer based there. It is expected that South Africa does the same since they even have their own local standard [24] on the protection of buildings. Although the exothermic welding lightning protection seems to be optional among practitioners, it results in significant improvements to the ETS of buildings.

Some building owners have allowed the roofing material to serve as the ATS where there is a metallic continuation to the ETS of the building. However, others have gone a step further to still install the LPS on the structure to prevent it from direct or indirect lightning strikes. This protects the construction materials used and prolongs their lifespan as they avoid the heating up caused by lightning currents. In certain cases where large crowds are found, the building may just have to be retrofitted with the LPS irrespective of the outcome of the lightning risk assessment [25]. In fact, adding an LPS to a building makes it visibly safer.

7 Conclusion

This research work has shown that LPSs protect buildings against the effects of lightning currents such as electrical, chemical and mechanical stresses. These stresses exacerbate the deterioration of building materials when hit directly thereby shortening their life span. Since it is not just one engineering field that can contribute to the resilience of a building, all concerned engineers must take interest in what colleagues in other branches do. For instance, the current engineering trends such as BIM, robotics, self-healing concrete, smart buildings, connected homes, artificial intelligence, energy efficiency, computer aided design, sustainability, etc., are fields that all civil, electrical and mechanical engineers can embrace to ensure resilience of their products. However, the limitation of this work is that there is still a need to articulate the lightning safety of buildings that do not seem to have an external LPS convincingly.

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Evaluating the Influence of Floor Heights on Thermal Comfort in Multi-storey Office Buildings in Temperate-Dry Climate of Nigeria

Muhammad Aminu Musa(✉)

Department of Architecture, Faculty of Environmental Design, Ahmadu Bello University, Zaria, Nigeria
ammusa@abu.edu.ng

Abstract. One of the main predicament in attaining thermal comfort in multi-story office buildings is the dissimilarities of micro-climate with building height. The research aimed to evaluate the influence of building floor levels on thermal comfort in a multi-storey office building in the temperate dry climate of Nigeria. This was done by discovering the influence of building floor heights on operative temperature and relative humidity on four facades and comparing the values among the floor levels**.** The OpenStudio simulation tool was used to assess nine (9) sets of offices in a prototype Bank of Industry in Jalingo, Nigeria, from January to December 2021. The data collected was then examined using MANOVA with a maximum p-value of 0.05, tables, graphs, column charts and bar charts. The MANOVA test for the combined effect of the facades and floor levels, shows a statistically significant difference, $F (48, 72) = 1.892$, $p = .007$; Pillai's $\Lambda = 1.115$, partial $\eta2 = 0 .595$. The study concluded that two (2) floors in the northern, southern, eastern, and western façades are only significantly different in operative temperature when they are 11m; 11m; 12m; and 12m apart, respectively, while for relative humidity are 10m; 10m; 11.4m; and 10.5m respectively.

Keywords: MANOVA · Mid-rise office · OpenStudio · Operative temperature · Relative humidity

1 Introduction

The term Multi-storey office building in this research is simply a midrise office building as classified by Alcox [1]. The classifications of office buildings vary from Engineering, Estate managers to Architecture points of view. For example, BOMA [2], has identified three types of office buildings pending on the location and level of luxury, while Alcox [1], classified the multi-story buildings as low-rise office buildings with less than 4 floors; mid-rise building, which has a range of 4–12 floors; high-rise building, with 12–40 floors; skyscraper, which has more than 40 floors but less than 300m high; super tall buildings, which has a height of 300–600m; and mega tall building, with a height greater than 600m. The study adopted the BOMA [2] and Freedman [3], office classification.

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Many researches have revealed that building occupants prefer to stay in a wider altitude of temperature than the contrary [4] and [5], and one of the possibilities is the passive environmental setting. Consequently, passive indoor thermal comfort (PITC) becomes very important in multi-storey office buildings in developing countries like Nigeria, where people spend eight (8) hours indoors. One of the key glitches of accomplishing PITC in multi-storey office buildings is the dissimilarities of micro-climate with building height as noted by [6]. A study by Aflaki [7], observed that the indoor temperature of high-rise buildings reduces as the floor levels increases. It was found out that, there was a difference of 1.2 °C between rooms on the thirteen floor and that of the third floor. Lack of adequate attention on this effect by the building professionals might have been the cause of poor thermal comfort in most multi-story office buildings in temperate-dry climates of Nigeria, as observed by several studies [8], and it is also responsible for dampness, pollution and Sick Building Syndrome [9]. [10] has noted that temperature fall off with height at an average rate of 6.50C per kilometer in the troposphere. This is in consonant with the findings from [11] which established that building height has a significant influence on building surface temperature.

The research aimed to evaluate the influence of building height on thermal comfort in a multii-storey office building in the temperate dry climate of Nigeria. This was done by discovering the influence of building floor heights on mean maximum operative temperature and the corresponding values of relative humidity on four facades and comparing the values among the floor heights**.** In realising the aim, the research questions raised were: to what degree do the diverse floor heights vary in thermal comfort indicators (operative temperature and relative humidity) in the four (4) frontages of a prototype single-banked midrise office building in a temperate dry climate of Nigeria?

2 Literature Review

The [12], defined Climate, as the average weather conditions of a particular place viewed over a very long period. Climate has a significant influence in determining passive indoor thermal comfort (PITC), especially in multi-story buildings. There are many ways to classify climate, such as based on agriculture as in Köppen's classification [13]; vegetation, such as Miller's classification; ecology such as Thornthwaites' classification [14]; or based on human comfort such as Atkinson's classification. Human comfort Climates classifications are usually originated from Atkinson's classification [15]. The study has adopted [14] because it factored wind velocity, temperature, mean radiant temperature and relative humidity in its method of grouping. It also considered the gradual transition from one climatic zone to another. [14] Classified Nigerian climates into five zones: - temperate-dry with cool climate zones, temperate humid, temperate dry, hot humid and hot-dry as shown in Fig. 1.

Thermal comfort as defined by [5], is the state of mind that expresses fulfilment with the thermal surroundings. The air temperature, mean radiant temperature, air velocity, clothing insulation, relative humidity and metabolic rate are the six (6) factors of thermal comfort. Since the office work involves sedentary activity and the occupants are usually in Kaftan or shirt and trousers, 1.2Met metabolic rate and 1.0Clo clothing insulation were kept constant throughout the study.

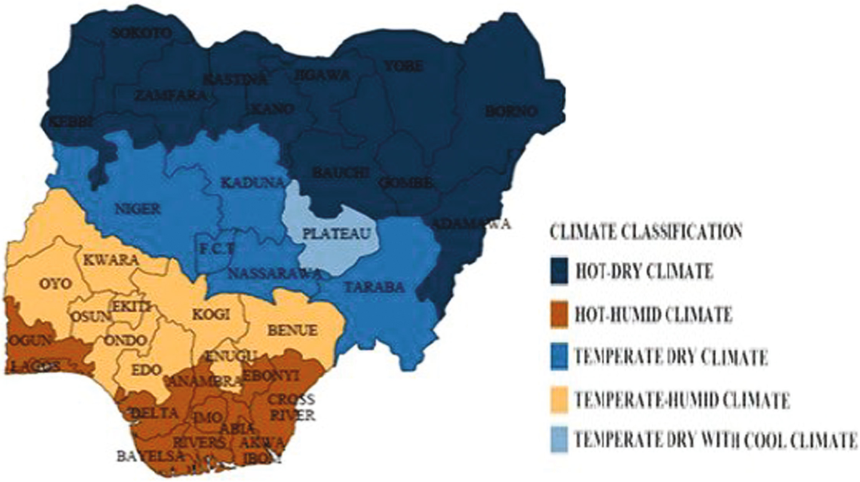

Fig. 1. Classification of the Nigerian climate Mobolade and Pourvahidi. *Source* [14].

The study has adopted an adaptive thermal comfort model because heat balance relies on climate chambers for all its indexes. ASHRAE standard was also adopted due to its data coverage to about four (4) continents, cutting across different climate zones when compared to European Committee for Standardization, which covered only five Western European countries [16], or Indian Model for Adaptive Thermal Comfort which covers only five (5) Indian cities, or Guobiao Standards which covers only nine (9) china cities. The [5] has recommended a temperature range of 24.3–29.3 °C within a humidity of 30–65% for a space to be in thermal comfort.

There are several ways of evaluating PITC, such as analytical testing which depends on the heat balance concept, laboratory testing which is vulnerable to errors [17], field testing which takes a long time, and computer simulation which reduces risk, saves time, increase accuracy, and handle uncertainty [18]. Therefore the simulation method was adopted for this study. Ecotec, Design Builder, and OpenStudio are some of the leading means of assessing energy simulation tools in today's world. The [19] noted that, timely results are associated with EnergyPlus and DOE-2 nevertheless have clear precincts in their daylight simulation algorithms. The [20] found out that, the differences between DOE-2 and Radiance-based DAYSIM in predicted interior illuminances were statistically significant, causing an exaggeration of the possible energy savings of agreed strategy. Whereas, [21] have observed that Ecotec has limitations in predicting passive thermal comfort. Moreover, Design Builder is not fast in analysing many simulations when compare to OpenStudio. OpenStudio is simpler to see the building form and do some basic editing compared to the other three. OpenStudio is therefore chosen for this study.

3 Methodology

A quantitative research design using an explorative design approach was used in the research and experimental research strategy through simulation method was employed to evaluate the effects of PITC on a single-banked midrise buildings in the temperate-dry climate of developing country like Nigeria. The study used iterative prototyping of the Federal Secretariat to produce the prototype of a single-banked midrise office building. The OpenStudio simulation tool which is a plugin in a google sketch-up 2017 was used to evaluate the prototype building from January to December 2021. The data collected was then examined using many statistical tools, such as MANOVA, ANOVA, t-test, bar charts, column charts, graphs, and tables. The principles applied in choosing the building was grounded on the quantity of stories, right of entry to structures and HVAC method. The eight collections of offices were chosen, each from first to ninth levels successively, making seventy-two (72) offices, for simulation and exploration. For each set of offices has equal measurements, angle, WWR, openable window to floor area ratio (OFR), and arrangement.

The procedure of this study was based on the following documents: [22] and [23]. Based on those documents the following steps were followed:

- A single-banked prototype (Bank of Industry) was modeled in google sketch-up (including all properties of materials and ground reflectance).
- An Open-studio was used to set a weather files of Jalingo from weather Analytic.
- Space types, thermal zones, and construction materials were selected.
- Zone Air Relative humidity, Zone Air change Rate, and Zone Operative Temperature were selected from output variables.
- The Simulation button was pressed for January to December of 2022 from Simulation settings

4 Results and Data Analysis

The results of the study are presented in Table 1 and the analysis was done based on the benchmark put forward by [24].

For Hypothesis testing, the SPSS was used to analyse data from the OpenStudio to find out the value of statistical significance of the effects of floor level (height) on thermal comfort in a single-banked structure. The study was examined based on the research question earlier raised as follows.

Research question:

> To what degree do the floor heights vary in thermal comfort indicators (operative temperature and relative humidity) in the four (4) frontages of a prototype single-banked midrise office building in a temperate dry climate of Nigeria?

The descriptive statistics showed that facade elevations affect the thermal comfort of the midrise office buildings in the temperate dry climate of Nigeria. The offices in the northern facade have the lowest mean value of operative temperature and the highest mean value of relative humidity, followed by those in the southern facade, then eastern

Table 1. Simulation Results for the Influence of Floor heights on Thermal Comfort of a prototype single-banked office building.

Latitude and longitude	11^0 09^1 03.11" N/7^0 39^1 20.32" E, 11^0 09^1 01.98" N/7^0 39^1 21.21" E, 11^0 09^1 02.95" N/7^0 39^1 22.33" E, 11^0 09^1 03.96" N/7^0 39^1 21.41" E									
Office dimension	4.5 × 6.6 × 3.048m									
WWR	25.04%									
Facade	Metrics	Floor levels								
		1st floor	2nd floor	3rd floor	4th floor	5th floor	6th floor	7th floor	8th floor	^{9}th floor
West Elevation	OT (C)	27.8	29.2	29.2	29.4	29.4	29.4	29.4	29.3	29.45
	RH (%)	100	84	80	80	80.5	81	81	81	84
	OT (C)	28	29.1	29.2	29.2	29.2	29.15	29.15	29.15	29.3
	RH (%)	100	84	80	80	80	80.5	80.5	80.5	84
East Elevation	OT (C)	27.4	28.6	28.7	28.9	28.9	28.9	28.9	28.9	29
	RH (%)	100	82	79.7	79.8	79.9	79.96	80	80	81.5
	OT (C)	27.5	28.7	28.9	28.95	28.96	28.95	28.98	28.98	29
	RH (%)	100	82	79	79	79.5	79.5	79.7	79.9	81
North Elevation	OT (C)	27.5	28.5	28.6	28.7	28.6	28.7	28.8	28.5	28.9
	RH (%)	100	85	81	80.5	81.5	82	82.5	83	85
	OT (C)	27.4	28.5	28.6	28.6	28.7	28.7	28.6	28.6	28.85
	RH (%)	100	85	81	81	81.5	82	82	81.5	85
South Elevation	OT (C)	27.6	29	29.05	29.2	29.1	29.2	29,05	29.1	29.2
	RH (%)	100	84	82	82	82	82	82	82	84
	OT (C)	27.8	29	29.2	29.15	29.1	29.1	29.1	29.1	29.1
	RH (%)	100	83	82	82	82	83	82	82.6	81

Source Author, 2022

and lastly the western facades. The results have also shown that, as the floor level increases, the mean value of operative temperature sharply increases between first and second floors and then gentle increases from 3rd to 6th floors (to 7th floors for offices in southern facades) and then gently reduces on the subsequent floors, while that of the relative humidity sharply decreases from 1st to 2nd floors and gently reduces from 3rd to 6th floors and then increases on the subsequent floors as the floor level increases as shown in Figs. 2, 3, 4, 5, 6, 7, 8 and 9.

The difference in relative humidity between the offices on the first and third floors was found to be 20.7%, 19%, 18%, and 20% in the eastern, northern, southern, and western facades respectively.

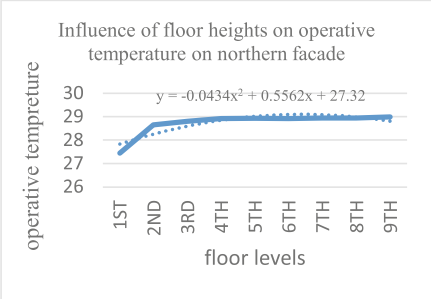

Fig. 2. Influence of operative temperature on the northern facade. *Source* Author, 2022

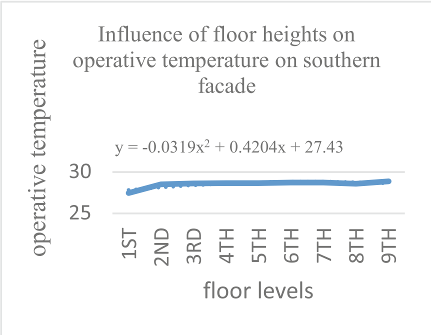

Fig. 3. Influence of operative temperature on southern. *Source* Author, 2022

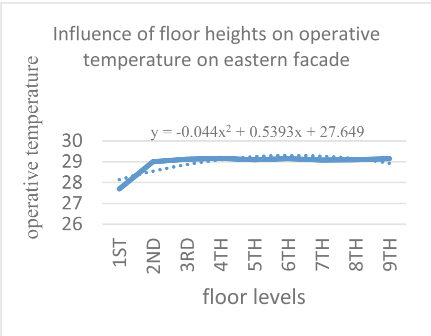

Fig. 4. Influence of operative temperature on eastern facade. *Source* Author, 2022

4.1 Hypothesis Testing

H_{01}: No significant difference of thermal comfort among the different floor levels of multi-storey structures in the temperate-dry climate of Nigeria.

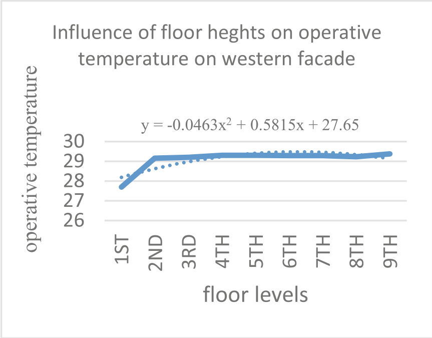

Fig. 5. Influence of operative temperature on the western facade. *Source* Author, 2022

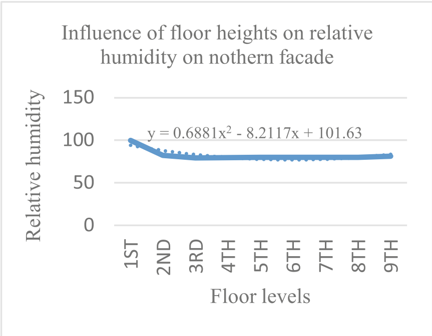

Fig. 6. Influence of relative humidity on the northern facade. *Source* Author, 2022

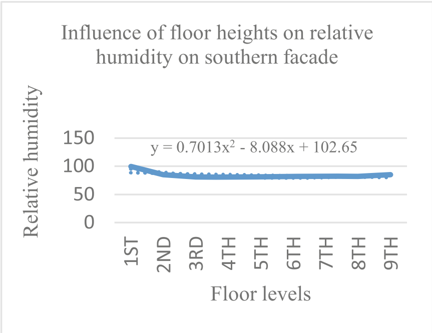

Fig. 7. Influence of relative humidity on the southern facade. *Source* Author, 2022

The data were tested for skewness and kurtosis and found to be within the acceptable range of values as specified by George and Mallery [25]. One-way **MANOVA** was then applied to test if the floor levels differed from one another significantly in one or more thermal comfort variables. The MANOVA was then conducted to test the combined effect

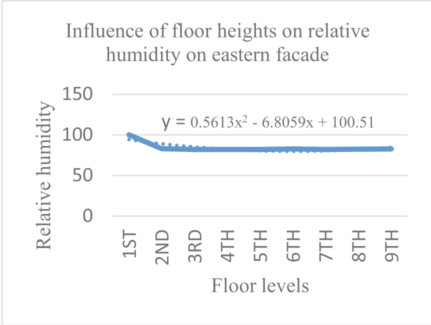

Fig. 8. Influence of relative humidity on eastern facade. *Source* Author, 2022

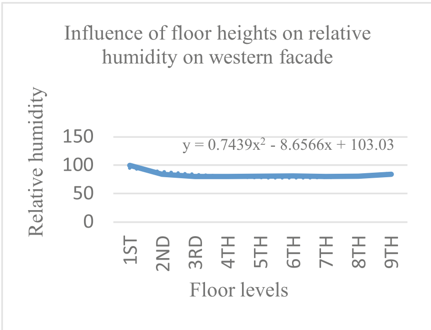

Fig. 9. Influence of relative humidity on the western facade. *Source* Author, 2022

of facades and floor levels, and a statistically significant difference was obtained, F (48, 72) = 1.892, p = .007; Pillai's Λ = 1.115, partial η2 = 0 .595. Hence the need for post-hoc was necessary since there were more than two (2) levels of the independent variable, to determine where the differences truly came from. The MANOVA was also used to test the effect of façade elevation along on the building, and a statistically significant difference was obtained, F (5, 72) = 96.318, p < .0000; Pillai's Λ = 1.778, partial η2 = 0.889. The effect of floor levels was also tested, and a statistically significant difference was obtained, F (16, 72) = 20.469, p < .0000; Pillai's Λ = 1.640, partial η2 = 0 .820.

For each of the variables a sequence of one-way ANOVA was conducted in addition to MANOVA. The results turned out to be statistically significant in all the thermal comfort variables for the effect of floor levels: Relative humidity *(F (8, 0.236) = 1322.512; p < .000; partial η2 = .997), and* Operative temperature (*F* (8, 0.008) = 218.373; *p* < .000; partial η^2 = .980). Whereas that of the effects of façade: Relative humidity *(F (3, 0.236) = 70.196; p < .000; partial η2 = .854), and* Operative temperature (*F* (3, 0.008) = 157.230; *p* < .000; partial η^2 = .929). These tests, therefore, showed that the thermal comfort of a midrise office building is affected by floor levels as well as façade elevations.

A sequence of post-hoc investigation using Fisher's LSD was conducted to examine distinct mean differences comparison through all the nine different levels of floors and thermal comfort constructs. It should be noted that the height between two (2) consecutive floors in this experiment was 3.08m. The results revealed that 1st, 2nd, and 9th floors are significantly different in thermal comfort from all other floors but others are not significantly different in operative temperature among themselves, even though are significantly different in relative humidity. When the floor levels (heights) and the comparable connotation values of operative temperature and relative humidity were correlated for the offices of the northern, southern, eastern, and western porticos, the resulting equations were correspondingly gotten: $y = -15.484x + 11.77$; $y = -6.3399x + 11.001$; $y = -16.79x + 12.832$; and $y = -11.771x + 12.546$ for the operative temperature, and $y = -18.261x + 11.101$; $y = 0.2363x + 10.034$; $y = -21.495x + 12.483$; and $y = -17.58x + 11.337$ for the relative humidity. Where y signifies the floor height in metres, and x symbolises significance values. The results of operative temperature are statistically significant with Eta Coefficient of association for northern, southern, eastern, and western façades are: ($\eta = 0.886$, $\eta 2 = 0.785$, $p = 0.017$); ($\eta = 0.772$, $\eta 2 = 0.596$, $p = 0.146$); ($\eta = 0.960$, $\eta 2 = 0.921$, $p = 0.000$); and ($\eta = 0.970$, $\eta 2 = 0.942$, $p = 0.000$) respectively. Whereas that of relative humidity are: ($\eta = 0.774$, $\eta 2 = 0.599$, $p = 0.010$); ($\eta = 0.731$, $\eta 2 = 0.534$, $p = 0.04$); ($\eta = 0.665$, $\eta 2 = 0.442$, $p = 0.045$); and ($\eta = 0.563$, $\eta 2 = 0.317$, $p = 0.163$) respectively. These show that two (2) floors in the northern, southern, eastern, and western façades are significantly different in operative temperature when they are 11m; 11m; 12m; and 12m apart, respectively, and 10m; 10m; 11.4m; and 10.5m for relative humidity respectively.

5 Conclusion

From the above results, the null hypothesis was rejected and concluded that passive thermal comfort in a single-baked midrise office building in the temperate dry climate of Nigeria is influenced by its floor levels. It has also been deduced that, two (2) floors in the northern, southern, eastern, and western façades are significantly different in operative temperature when they are 11m; 11m; 12m; and 12m apart, respectively, and for relative humidity 10m; 10m; 11.4m; and 10.5m respectively.

5.1 Recommendations

The study recommends that to achieve adequate passive thermal comfort in single-banked midrise office buildings, WWR, building materials, external shadings, and floor orientation should be based on floor levels and façade elevations.

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Improving Safety on Building Project Sites: The Role of Sensor-Based Technology

Andrew Ebekozien[1(✉)], Clinton Aigbavboa[1], John Aliu[1], Wellington Didibhuku Thwala[2], and Faith Ebekozien Emuchay[3]

[1] Department of Construction Management and Quantity Surveying, University of Johannesburg, Johannesburg, South Africa
ebekoandy45@yahoo.com

[2] Department of Civil Engineering, College of Science, Engineering and Technology, University of South Africa, Pretoria, South Africa

[3] Department of Design Engineering and Mathematics, Middlesex University-Hendon Campus, London, UK

Abstract. Sensor-based technology (SBT) is a new method of advancing construction safety management. The technology may abate the scourge of accidents on sites and improve workplace safety performance in construction. Research about Nigerian construction contractors/property developers' use of SBT is yet to receive in-depth studies. Thus, the study investigated the perceived encumbrances facing the implementation and recommended possible measures to improve safety by promoting SBT in Nigerian building project sites. The study adopted an interview type of qualitative research design and was complemented with eight construction sites observation to achieve the aim. The researchers engaged twenty-four participants (selected safety experts, property developers/building companies, and construction consultants). The paper adopted a thematic approach to analyse the collected data. Findings show that SBT usage is low across the eight construction sites studied. Three sub-themes (management, technical, and financial encumbrances) emerged from SBT usage issues. The study recommended feasible measures to improve SBT across high-rise Nigerian construction sites. Results from the study will strengthen and offer an insight into SBT on building sites. It would enlighten major industry practitioners (property developers and construction contracting firms) and policymakers to create an enabling platform for SBT improvement on construction sites.

Keywords: Construction site · Fourth industrial revolution technologies · Safety Technology · Site accident · Smart construction

1 Introduction

Globally, records have shown that the construction sector has had several casualties and property losses. Melzner et al. [20], Mwangi [22], Park et al. [25], and Boateng [5] revealed that the sector is among the leading in cases of accidents. This is one industry that influences economic development yet faces safety issues. It has cost the

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sector billions each year because of lax safety [19]. The latter authors highlighted some countries' literature regarding safety issues linked with the industry. For example, in the United States of America, the industry is rated fourth highest regarding fatality [6]. In Korea, the industry occupied the highest percentage of fatalities [37]. In China, 2538 fatalities were recorded in 2007 [39]. Guo et al. [14] opined that serious accident and death rates in the built environment during construction activities had been an issue in research and practice. Attempts to reduce the hazard created site safety management. Ahmed [1] identified 77 causes of accidents on Bangladeshi construction sites.

Over the past few decades, scholars and practitioners have been engrossed with site safety management mechanisms to mitigate the number of wounds and losses on construction sites. Perlman et al. [27] worked on improving hazard recognition, Rozenfeld et al. [31] worked on job hazard analysis, Jeelanie et al. [17] worked on training methods, and Shiau et al. [33] worked on health and safety within the construction environment, among others. Yet, the issue of safety is critical, especially in developing countries' construction sites. Nigeria is not exempted [10]. With the advancement in digitalisation in the 21st century, studies [2, 4, 7, 13, 14, 23, 24, 28, 30, 33, 38] have been advocating innovative approaches such as the use of advanced digital to improve construction site safety. It has gained momentum because of its potential to improve workplace safety conditions. The outcome would prevent or mitigate injuries and losses [15]. Park et al. [25] opined that sensing technologies might focus on detecting and warning about construction safety issues by relying on the detection capabilities of these technologies.

Different technologies are in use to improve construction site safety performance. One of them is sensor-based technology (SBT). It has been proved as a new approach for advancing construction safety management [23]. The technology could abate the scourge of accidents on sites and improve workplace safety performance in construction. Smart Market Report (2017) reported that not more than 25% of construction firms use emerging digital technologies for safety management. It was a study carried out by the Centre for Construction Research and Training (CPWR). This is a for many stakeholders because the diffusion rates of these digital technologies are not encouraging. Proffering measures to improve the usage cannot be over-emphasised. Among the possible measures to improve safety via promoting the use of SBT on Nigerian building project sites include capital investments into construction automation [32], misalignment from the end-users should be identified by manufacturers of these safety technologies for future improvement [12]. Developers should focus on improving safety technology effectiveness [23]. Others are choosing an optimal database model that best suits the application's data needs [30] and companies' motivation to adopt it via government support and funding programmes [24]. Also, safety on-site and off-site training via visualisation technology [14] and a combination of BIM and sensor-driven systems to improve safety management in construction [4]. Whether Nigeria's building sector has engaged these measures to improve the safety of building project sites via the usage of sensor-based technology (SBT) is uncertain. Thus, it is worth investigating to mitigate fatalities and loss of properties of stakeholders in the industry.

The construction industry is becoming digitised, and advanced smart city technologies possibly will present prospects for monitoring environmental construction conditions [26, 30]. However, there are limitations in the use of emerging technologies such as sensor-based technology (SBT) to improve the safety of workers on construction sites [23], especially in developing countries [11]. Global Position Systems (GPS), Ultra-wide Band (UWB), and Radio Frequency Identification (RFID) are the three commonly used SBT [14]. Thus, the paper investigated the perceived encumbrances facing the implementation of SBT. Also, the paper recommended feasible measures to improve safety via promoting the use of SBT in Nigerian building project sites. The study's aim was accomplished via the following:

i. To identify the relevance of SBT in advancing construction safety management.
ii. To investigate the perceived factors that could hinder SBT implementation on building project sites.
iii. To suggest feasible measures to improve safety via promoting SBT on Nigerian building project sites.

2 Sensor-Based Technology in the Building Industry

Several studies, such as [23], have shown that emerging digital technology could improve the safety of workers on construction sites. Riaz et al. [30] affirmed that the digital construction sector would promote the potential to monitor environmental and hazardous conditions continuously. It mitigates hazards within construction activities. Sensor-based technology (SBT) includes GPS, UWB, and RFID [14]. Choset et al. [7] and Razavi and Moselhi [29] asserted that GPS offers 3D coordinates continually and is not sensitive to weather and hindrances. It can be used to track staff, equipment, and materials. Aryan [3] and Zhang et al. [38] affirmed that UWB, in addition to GPS, it can operate in-door and out-door, respectively. By difference, RFID has a larger signal cover but feebler penetration ability than UWB. It can be used for in-door and out-door activities where few hindrances are present [21, 38]. Asadzadeh et al. [4] affirmed that sensor-based safety management systems could improve safety risk management processes on construction sites.

In Iran, lack of guidance and government supports, inadequate social infrastructure such as the constant supply of electricity, high cost of software, professionals attitude, low demand from clients, and inadequately trained personnel were identified as the factors that mitigated the use of digital technology to promote construction safety [19]. The authors recommended that the government should lead while the educational institutions upgrade their curricula to reflect the trend of construction digitalisation. Nnaji et al. [23] identified influencing factors affecting the decision to adopt safety technology usage on construction sites. This includes technology reliability, durability, proven technology effectiveness, level of training required for optimum performance, and company size. Others are capital cost, technology budget, potential cost savings, user experience, client demand, and teamwork (safety manager verse construction manager). Asadzadeh et al. [4] identified changing nature of construction sites and their complexity as possible challenging facing the use of RFID. Oesterreich and Teuteberg [24] identified general challenges facing the adoption of Industry 4.0 in the construction industry. And SBT is one of the components of Industry 4.0. This includes unwillingness to adopt, huge implementation cost, inadequate skills, lack of standards, higher requirements for computing equipment, and regulatory compliance issues.

3 Research Method

The research adopted phenomenology, a type of qualitative research design. Creswell and Creswell [9] affirmed that phenomenology focuses on participants' proficiency and experience during the interview. It aligned with [10], that adopted the same approach in investigating construction firms' compliance with safety equipment for Nigerian workers. The study data were collected by observing eight construction sites and conducting face-to-face interviews. The interviewees and selected sites were from Abuja and Lagos, as presented in Table 1. The two locations are known for large construction activities [11]. The interviewees' locations, years of experience, ranks, and the number of employees were reported. The study obscured the interviewees' identities for confidentiality reasons and aligned with [16]. Twenty-four interviews from eight property/construction firms (A-H), consultant experts (I), and safety experts (J) were involved. The study achieved saturation. The collected data were analysed through a thematic analysis.

The researchers adopted the snowball sampling technique to achieve good saturation and representation [35]. The virtual interviews lasted 50 min on average and took place between August 2021 to November 2021. The participants were engaged with questions within the stated objectives. Concerning the construction firms, three medium and five large firms were engaged. The researchers coded the collated data [8, 16]. Fifty codes emerged from the coding and categorised into six categories. From the six categories, three themes emerged.

4 Findings and Discussion

The section presents results and discussion that emerged from the participants.

4.1 Theme 1: Relevance of SBT

The relevance of SBT in advancing construction safety management in the 21st-century industry cannot be over-emphasised. Findings across the board agree that SBT can improve the safety of construction sites if the operators (construction firms/property developers) are well enforced and implemented. Participant P23 says, "…*apart from RFID, UWB, among others, SBT used to prevent collision accidents of heavy construction machinery equipment, they can be used for routine prediction and planning for machinery equipment and workers*…" Participants P5, P11, P23, and P24 opine that SBT can be used as a preventive-safety device. Findings show that workers can mitigate unsafe behaviour, and safety management can be made easy via SBT devices such as GPS, RFID, and UWB. Results agree with Zhang et al. (2017). The authors avowed that SBT offers real-time construction safety management accuracy to facilitate modernisation

Table 1. Description of the participants' background

ID	Company	Firm code	Location	Employees	Years of experience	Participant rank
P1	Large	A	Abuja	340	21	Safety Manager
P2	Large	A	Abuja	340	19	Management staff
P3	Medium	B	Abuja	65	28	Project Coordinator
P4	Medium	B	Abuja	65	17	Director
P5	Medium	B	Abuja	65	24	Software Engineer
P6	Large	C	Abuja	370	23	Operation Director
P7	Large	D	Abuja	300	20	Site Manager
P8	Large	D	Abuja	300	17	Head, Engineering
P9	Medium	E	Lagos	60	29	Managing Director
P10	Medium	E	Lagos	60	23	Quality Controller
P11	Large	F	Lagos	300	20	Site Safety Officer
P12	Medium	G	Lagos	60	34	Maintenance Engineer
P13	Medium	G	Lagos	60	35	Contract Manager
P14	Large	H	Lagos	320	22	Safety Officer
P15	Large	H	Lagos	320	18	Site Engineer
P16	Large	H	Lagos	320	29	Logistic Manager
P17	Engineering firm	I	Lagos	5	30	Partner
P18	Architecture Firm	I	Lagos	5	23	Chief Resident Architect
P19	Engineering firm	I	Abuja	7	34	Managing Director
P20	Quantity Survey. Firm	I	Abuja	6	35	Managing Partner
P21	Safety Consultant	I	Lagos	4	32	Principal Partner/Academia
P22	Safety Consultant	I	Abuja	5	27	Partner/Academia
P23	Mechanical Eng. Firm	J	Abuja	15	27	Heavy Duty Equipment Expert
P24	Software Consultant	J	Lagos	8	25	Software Expert in Cons. Equipment

and informatisation in the 21st-century construction industry. Regarding safety training and education, vision-based sensing, one of SBT can be used to provide a platform for staffers' safety training and learning (P11 and P24). Results agree with [25], and it was asserted that apart from detecting and warning about safety issues, they can be used for training construction safety-related matters. Findings from the observation of the eight sites show that only sites A and F attempted to use SBT in their safe operation but were faced with challenges.

4.2 Theme 2: Perceived Factors

Several papers have been published from developed countries concerning the advantages of SBT in improving building site safety. Findings show that few Nigerian building sites that attempted using SBT in their safe operation are faced with diverse encumbrances. Thus, the sub-section offers the interviewees a platform to identify the encumbrances affecting SBT usage on construction sites. Nine factors hindering SBT implementation on building project sites emerged. This includes technology budget, inadequate potential cost savings awareness, technology reliability issues, and user experience of the technology effectiveness. Others are hesitation to implement, implementation cost, inadequate skills for sustainability, higher requirements for computing equipment, and regulatory compliance issue. From the nine emerged factors, inadequate potential cost savings awareness, initial implementation cost, hesitation to implement, and higher requirements for computing equipment were common among the interviewees as possible factors influencing SBT usage in Nigeria.

Participant P11 says, "…*we attempted to use an automated safety monitoring system to identify possible site hazards on this site, but the running cost is higher compared to engaging safety officers. We are more concerned with accuracy and mitigating hazards. If not, perhaps would have switched to a manual approach….*" This is one of the concerns of many medium construction firms that indicates interest in SBT, knowing the efficiency and accuracy regarding mitigating construction site hazards (P5, P9, P10, and P13). Findings agree with [24]. The authors discovered that new technologies' high implementation costs and investment costs are among the possible hindrances of digital technology usage in the built environment sector. Findings reveal that Nigeria's built environment is not prepared for a high safety mechanism. The observation worsens this by awareness and absence of basic infrastructures such as a stable electricity supply and a good road network across the eight selected construction sites. Findings agree with [18]. The authors discovered the absence of basic infrastructure and technological barriers as components of developing countries' hindrances.

4.3 Theme 3: Proposed Measures

The sub-section presents feasible measures to improve safety by promoting SBT on Nigerian building project sites. One pertinent point that emerged is that the government needs to play the leading role so that more construction firms will embrace SBT. The reviewed literature articulated the benefits to the industry. Unfortunately, the level of awareness among major Nigerian stakeholders is appalling. Participant P12 says, "….*our government needs to create an enabling environment via institutional policies that promote awareness and improve SBT implementation on construction sites….*" Findings reveal that the campaign for SBT implementation should be encouraged by the government via policy promoting the usage. Examples of such policies are engaging non-governmental organisations in bringing awareness and campaigning for the benefits of SBT via various safety-related agencies (P3, P12, P22, and P23). Also, providing 'soft loans' to construction firms through one financial instrument reduces the initial high implementation cost (majority). Findings agree with Weerakkody et al. [36], and it was recommended that for developing countries, including Nigeria, government policies should be driven towards developing basic infrastructure and sensitisation concerning ICT infrastructure.

"*….reskilling and upskilling of our safety and operational officers on construction sites is pertinent if we want to succeed in SBT implementation. The digitalisation level involved is high. Thus, training and re-training to operate the devices cannot be over-emphasised.…..*" said Participant P21. Findings from the observation show that many safety officers are far behind digitally and should be available to reskill and upskill. Participant P1 suggests that major stakeholders can provide training to the safety officers and operators of the construction firms as part of their corporate social responsibility about the benefits of SBT. Participant P18 says, "*….it is not out of place if government set-up free training programmes for firms that indicate interests for SBT implementation. When it comes to digitalisation of the construction industry, many developed countries give various forms of incentives to attract construction firms to embrace the deal….*" Findings agree with Smart Nation and Digital Government Office [34]. It was reported that the Singaporean Government supported the thriving of digitalisation via scholarships and fellowships. SkillsFuture Singapore created the platform for lifelong learning TechSkills Accelerator, among others.

5 Conclusion and Recommendations

This paper investigated the perceived encumbrances facing the implementation and recommended possible measures to improve safety by promoting SBT in Nigerian building project sites. Data were collected from observation of eight construction sites and supplemented with face-to-face interviews with experts. The perceived factors that could hinder SBT implementation on building project sites were identified. The paper suggested potential measures to improve safety by promoting the use of SBT. Thus, the paper recommended the following measures to improve safety via promoting the use of SBT on Nigerian building project sites.

i. The study recommends that the government need to play a leading role so that more construction firms will embrace SBT. This can be achieved by developing an institutional framework that will promote the use of SBT within the built environment stakeholders. Government needs to support this approach with a tactical and holistic awareness programme.
ii. Developers/construction firms that indicate interest in using SBT should have access to 'free interest loans.' This will act as one of the motivations and promote the use of SBT in the built environment. This can be achieved via pro-active government policy tailored towards infrastructural safety during construction.
iii. The paper further recommends that the built environment personnel be trained because SBT is a highly digitalised mechanism. Thus, reskilling and upskilling of key staff in the operation and safety department cannot be over-emphasised.

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Assessment of Architects Adoption of Green Smart Design Strategies in High-Rise Office Building in Lagos Nigeria

Michael Gboyega Adeogun(✉)

Department of Architecture, College of Post Graduate Studies, Caleb University, Lagos, Nigeria
mikeadeogun20@gmail.com

Abstract. With 200 million people, Nigeria has limited access to adequate urban infrastructure and power supply. The global threat of urban explosions and climate change has compelled developed cities to prioritize renewable energy and CO2 emission reduction. This research aimed to investigate architects' adoption of GSB design strategies in view to improve energy usage in high-rise office buildings. The objectives are to identify the different GSB design strategies available, the architect's knowledge, and the extent of their adoption in practice. A review of relevant literature with a simple descriptive statistical survey was conducted with 174 structured questionnaires using a Likert scale ranking. 143 of these were returned for analysis using the SPSS statistical tool. The results revealed that GSB is at a developing stage due to a lack of adequate architect participation. There is general knowledge of GSB design strategies and their major benefits, but there is a low level of adoption in practice due to inadequate training and programs. Passive energy design should be encouraged among professionals while prioritizing affordable eco-friendly materials that will help to optimize energy consumption in high-rise office buildings. Professional groups and the government should make people aware of GSB. GB certification of Nigeria should be set up to help more new and existing buildings get certified.

Keywords: Green smart building · Design · Adoption · Architects · Energy

1 Introduction

Human daily activities for survival exacerbate environmental negative impacts [1]. Climate change is caused by the use of fossil fuels, which emit greenhouse gases and increase the earth's temperature by 1 °C [2]. The construction sector is known for excessive energy use, waste, environmental pollution, and degradation [3]. The global urban population explosion is disconcerting, as African cities are projected to have 61.8% of the 3.95 billion world population in cities. With over 200 million people, Nigeria has limited access to adequate urban infrastructure and power supply, forcing people to buy portable generators. Buildings at a global level utilize about 40% of energy, 25% of water, and 40% of resources, and emit about 33% of greenhouse gases. These threats have compelled developed cities to prioritize sustainable building development [4]. To

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achieve this, environmentalists introduced 17 sustainable development goals (SDGs) to deal with energy, CO2, and other environmental problems in cities by separating economic growth from climate change, poverty, and inequality [5]. Furthermore, SDG goals 3, 7, 8, 9, 11, 12, 15, and 17 were identified as the benefits of G.B features in designs [6]. These encouraged the integration of the life cycle into green methods in practice [7]. In design planning, three sustainable objectives such as earth, people, and supply chain profits must be adopted [8]. Green building (GB), also known as sustainable building, uses building structures and environmentally resource-efficient processes throughout a building's life cycle, from planning to design, construction, operation, maintenance, and renovation. [7] and calls for cooperation among the construction team and the client [9] which helps traditional building design goals of cost, service, life cycle, and users' comfort [10]. Green smart buildings (GSB) promote technological optimization in GB. [6] list several GSB design strategies, including site potential and energy; building space and material use; improved indoor environmental quality; operational maintenance; waste reduction; recycling; sustainable design; active sustainable design; and smart technologies [11]. Nigerian cities are growing rapidly due to urbanization and lack revolutionary tools to improve the construction industry [12–14], and effort should be taken to explore solar energy services so that developers can operate low-cost intelligent buildings [15]. The architecture industry consumes a lot of energy and releases waste, making it an environmentally unfriendly industry [16]. According to [17], nearly two and a half times as much energy is used per square meter of floor space in high-rise office buildings with 20 stories or more than in low-rise buildings with 6 stories or less. The amount of energy used in high-rise buildings has gone up from 38 to 61% of the total amount of energy used in commercial buildings [18]. Nigeria's per capita energy consumption is 120.5 kWh, which is more than 10 times below the global average [10]. The study focused mainly on architects' practice because architects' detailed designs are needed before other professional designs. In addition, Lagos, which is the study area, is a megacity with about 14.86 million people in 2021 [19]. Also known as the most economically viable state [20] with a total output of 136 billion dollars, accounts for more than a third of Nigeria's GDP [21], and would have been the fifth-largest economy in Africa if it were a country [22]. It has a greater concentration of architects than any other state, with about 60% of the country's commercial construction projects [23]. Lagos is home to the headquarters of most of the biggest architectural practices regulated by ARCON [24]. Thus, the study is important because of gaps identified in the literature on sustainable buildings such as cost, awareness, and adoption of GSB; skills; unavailability of power supply; security, and the need for Nigeria to catch up with technological innovations and sustainable development around the world [25]. GSB implementation must be done right from the pre-design to post-construction stages by an architect who is licensed in the art and science of building design and construction [26, 27]. The study aimed to investigate architects' adoption of GSB design strategies in Lagos to improve energy efficiency in the design of high-rise offices. The objectives are to identify different GSB design strategies available; assess the knowledge of architects on GSB, and examine architects' adoption of GSB design strategies in architects' practice in Lagos.

2 Literature Review

Commercial buildings consume more than 60% of total energy consumption. Therefore, architects need to strategize on the best practices to resolve these issues right from the design stage. The study identified different GSB design strategies available, assessed the knowledge of architects on GSB, and examined architects' adoption of GSB design strategies in architects' practice in Lagos.

2.1 GSB Design Strategies

According to [28], GSB is a new-generation building incorporating BIM, GIS, Internet of Things (IoT), cloud computing, and other technologies in GB. It saves resources and improves energy utilization while reducing environmental pollution and resource waste in the country. GSB helps to achieve maximum efficiency in the construction industry. It promises a better living environment and supports one of the sustainability principles by making the building less harmful to the environment. [25]., [6] identifies various GSB design strategies: optimized site potential; optimized energy; optimized building space; and material use; enhanced indoor environmental quality; optimized operational and maintenance practices; waste reduction and recycling; and passive sustainable design, active sustainable design, and smart technology) [11]. According to [29], the site should have good building orientation and adequate building cost and performance. Materials such as insulated roofs and walls have significant effects on the indoor users' indoor comfort [30, 31]. In addition, thermal comfort is achieved through the use of a double façade compared to a single façade on indoor air quality considering proper wall to window ratio, bright external wall painting, and the use of daylighting control devices, which reduce energy usage [32]. Building envelopes reduce air leaks in design; energy-saving devices and LEED-certified lighting aid energy usage in building operations [33]. According to [34], the life cycle of a building is dependent on proper operation and maintenance right from the design stage till post-occupancy. The value of GB became significantly high over time, which yielded more than ten times the return on investment, leading to increased property value and reduced maintenance costs [35]. Ultra-low flush toilets and low-flow showerheads result in improved water conservation [36]. The waste in landfills in construction and building operations should be reduced by providing waste collection bins, while liquid waste from the building can be recycled as greywater to generate electricity [37]. Passive energy-saving technology and proactive energy-saving adoption result in increased public perception of GSB awareness. Other alternative sources of energy include wind energy, inverters, biomass, and biogas [38]. Furthermore, in the [16] study, GB's use of advanced technology through IoT helps to achieve an effective design. Smart technologies include automatic doors, door face recognition systems, IP cloud home systems, wireless communication devices, and environmental monitoring control. Environmental monitoring control includes smart LED lighting; automatic temperature control; smart A.C; smart switches; gas leakage sensors; and health management, which includes body status sensors and homing devices. Entertainment sharing devices include mobile media and digital interaction sharing.

2.2 Knowledge and Adoption of GSB in Architects Practice

Architects' knowledge (awareness) of GSB, cost, skills gap in the implementation, epileptic power supply, and enabling policies have been identified as major limitations to the adoption of GSB [25] GSB promotes technological optimization, well-being, comfort, improved energy use, and eco-friendly materials. The government at all levels should initiate enabling policies and opportunities [39–42]. The implications for not adopting GB are continual conventional construction with maximal exploitation and resource depletion. Artificial Intelligent and GB features used in designs help to promote GSB [43–46]. Factors that promote GSB design strategies in Taiwan have been identified as timers for extractor fans, multi-split AC, automatic photovoltaic solar panels, and automatic indoor air control systems. Green structures and green facilities were the focus of GSB design; green structures include roof insulation, exterior wall insulation, roof overhangs, concrete floor, large windows, low emission glass, sunroof, green roof, and adequate ventilation designs and shading devices. Some of the green features are light designs that use less energy, photovoltaic or solar power panels, rainwater storage, and coatings with low levels of volatile organic compounds. [11] [47] emphasized the need for an architect to strategize on an effective approach to design by considering the environment, economy, and social rights in practice. The materials the architects specify in the design proposals are all derived from the physical environment, and the manipulation of the design space may affect the local ecology. However, with the low adoption level, if Nigeria is in a global survival race, a new approach to architectural practice has to be adopted. Furthermore, the government should create enabling conditions and policies that allow stakeholders to construct more green buildings in Nigeria. In design, the consideration of solar power or photovoltaic systems and ventilation, double-paned glass, low emissive glass, natural resources, and the geographical environment should be encouraged right from the design stage or phases during the execution of green buildings [48, 49]. According to [26], architects consider factors such as security, structure, and facilities; lighting, ventilation, interior, and exterior space planning, and natural resources in design.

3 Methodology

This study investigates architects' adoption of GSB design strategies in high-rise office buildings in Lagos. Mixed-method research was adopted where secondary data was collected via a review of relevant literature, which helped to get adequate information for the structured questionnaire on GSB design strategies and energy consumption in high-rise buildings, architect knowledge of GSB, and its adoption in practice. The questionnaire was administered to the architects in Lagos because Lagos is a megacity known as the most economically viable state and known as the nation's largest urban area [20], also identified as the most populous city and commercial capital in the country [22]. In addition, Lagos has a greater concentration of architects than any other state in Nigeria, having most of the headquarters of the biggest architectural practices regulated by the ARCON, and having over 60% of the country's construction projects [24]. All these are important to ensure adequate and accurate views of the respondents when investigating architects' adoption of GSB design strategies in high-rise office buildings in

Lagos. According to [50], the population of architects in practice in Lagos is 1470 in 2021. The raosoft sample size calculator adopted a confidence level of 95%, a margin of error of 7%, and a population proportion of 50%, which resulted in a sample size of one hundred and seventy-four (174). Section 1 was designed to collect brief respondents' information, while Section 2 gathered information on the existing GSB design strategies by adopting mixed questions with a 5-point Likert scale, with 5 being very significant, 4 being significant, 3 being average, 2 being low, and 1 being very low. Sections 3 and 4 were designed to gather data on the knowledge of architects on GSB and the extent of GSB adoption in architects' practice. They adopted mixed questions with a 5-point Likert scale, with 5 being very significant, 4 being significant, 3 being average, 2 being low, and 1. One hundred and seventy-four architects participated in the study. 147 out of the 174 questionnaires sent out were collected and returned for analysis, which is an 82.2% response rate and is believed adequate for the study. A simple descriptive frequency analysis was adopted using IBM SSPS statistics 26 for the analysis, while the results of the data analysis were presented with relatable works of literature.

4 Results and Discussions

4.1 Characteristics of Respondents that Participated in the Study

This section gives respondents information that examines variables such as educational qualification, architect's ARCON registration, and work experience. 17 respondents (11.9%) were technicians; 22 respondents (15.4%) were technologists; 35 respondents (24.5%) were provisional 1, 42 respondents (29.4%) were provisional 2, and 27 respondents (18.9%) were fully registered architects. 16 respondents (11.2%) have an OND, 14 respondents (9.8%) have an HND, 26 respondents (18.2%) have a B.Sc., 83 respondents (58%) have an M.Sc., and 4 respondents (28%) have a Ph.D. 31 respondents (21.7%) had less than 5 years of experience, 60 respondents (42%) were between 5–10 years, 33 respondents (23.1%) were between 11–15 years, 16 respondents (11.2%) were between 15–20 years, and 3 respondents (2.1%) were between 20 years and above. The results show that all the respondents were educated, while the majority were undergoing tutelage under the supervision of a fully registered member. Thus, they have some level of experience, which is the basis for knowledge of GSB in practice.

4.2 Green Smart Building (GSB) Design Strategies

This section addresses research objective one. Variables such as the different GSB design strategies and GSB energy-efficient features were examined. 97 respondents (67.8%) agree with the life cycle assessment as a GSB strategy. An on-site and structural design efficiency strategy was chosen by 79% of respondents. Energy efficiency was chosen by 130 of the respondents. Water efficiency was chosen by 115 of the respondents, and materials by 117 of the respondents were chosen by 81% of the respondents. 117 respondents (81.8%) agreed on indoor environmental quality enhancement as a GSB strategy, and 100 respondents (69.9%) agreed on operation and maintenance as a GSB strategy. 113 respondents (79%) agree on waste reduction as a GSB strategy; 106 respondents

(74.1%) agree on passive sustainable design as a GSB strategy; 115 respondents (80.4%) agree on active sustainable design, and 118 respondents (82.5%) agree on smart technology as a GSB strategy. 89 respondents (62.2%) agree that the adequate wall-to-window ratio will provide an energy-efficient feature in the design. 92 respondents (64.3%) agree that the heat reduction glass will provide an energy-efficient feature in the design. 73 respondents (51%) agree that the energy-saving meters will provide an energy-efficient feature in the design. 99 respondents (69.2%) agree that the external shading devices will provide an energy-efficient feature in the design. 77 respondents (53.8%) agree that the LEED lights will provide an energy-efficient feature in the design. 79 respondents (55.2%) agree that the automatic lights will provide an energy-efficient feature in the design. 93 respondents (65%) show that the solar panel will provide an energy-efficient feature in the design. 85 respondents (59.4%) agree that the automatic water closet will provide an energy-efficient feature in the design. 91 respondents (63.6%) agree that the automatic door will provide an energy-efficient feature in the design. 94 respondents (65.7%) indicated that the automatic gate would provide an energy-efficient feature in the design. 93 people (65%) stated that the automatic fire alarm system would be an energy-saving feature in the design. This result shows that respondents are familiar with GSB Design strategies and their components.

4.3 Knowledge of the Architect on GSB

This section addresses research objective 2, variables such as GB definition, GB participation, GB efficiency, green products, GB environmental benefit, green building economic benefit, and green building social and health benefit. 3 respondents (2.1%) indicated that GSB is a building painted green; 73 respondents (51%) stated that GSB is a modern building; 77 respondents (53.8%) show that GSB keeps the environment's air clean; 82 respondents (57.3%) show that GSB improves health and social life, and 71 respondents (49.7%) indicated that GSB reduces maintenance costs. 11 respondents (7.7%) said they have been involved in GSB, 63 respondents (44.1%) said they have never been involved in GSB design, and 69 respondents (48.3%) indicated that they have never participated in GSB. 5 respondents (3.5%) strongly disagree that green products help to optimize energy; 4 respondents (2.8%) disagree that green products help to optimize energy, and 9 respondents (6.3%) were undecided on whether or not green products help to optimize energy. 83 respondents (58%) agree that green products help optimize energy use, and 42 respondents (29.4%) strongly agree that green products help optimize energy use. 2 respondents (2.1%) strongly disagreed that eco-friendly materials help to optimize energy. 98 respondents (68.5%) indicated the environmental benefits of GSB reduce water consumption. 86 respondents (60.1%) showed that the environmental benefits of GSB help to lower energy consumption, and 87 respondents (60.8%) said that the environmental benefits of GSB increase biodiversity. 74 respondents (51.7%) agree that the environmental benefits of GSB include reducing greenhouse emissions. 116 respondents (81.1%) agree that the economic benefits of GSB are increased property values and occupancy rates, and 101 respondents (70.6%) agree that the economic benefits of GSB are job creation. 103 respondents (72%) agree that the economic benefit of GSB boosts human social performance; 100 respondents (69.9%) indicate that the economic benefit of GSB improves people's health and well-being, and 100 respondents

(69.9%) agree that GSB increases property values and occupancy rates. The result shows the architect's participation is low, although they have vast knowledge of GSB and its benefits to users.

4.4 Adoption of GSB Design Strategies in Practice

This section addresses research objective 3 where variables such as GSB pre-design strategies adoption in practice, GSB design, and construction stage strategies adoption in practice 15 respondents (10.5%) strongly disagreed that GSB is only for new designs; 82 respondents (57.3%) disagreed that GSB is only for new designs; 12 respondents (8.4%) were undecided that GSB is only for new designs; 31 respondents (21.7%) agreed that GSB is only for new designs, and 3 respondents (2.1%) strongly agreed that GSB is only for new designs. 15 respondents (10.5%) are not sure whether GSB strategies can be used in all building types. 87 respondents (60.8%) agreed that GSB strategies could be used in all building types, and 41 respondents (28.7%) disagreed that they could be used in all building types. 133 respondents (93%) agree that GSB design strategies are adopted in practice at the pre-design stage; 121 respondents (84.6%) agree that GSB design strategies are adopted in practice at the design stage; 71 respondents (49.7%) agree that GSB design strategies are adopted in practice at the construction stage, and 62 respondents (43.4%) agree that GSB design strategies are adopted in practice at the post-construction stage. 131 respondents (91.6%) agree that site selection and planning should be used in GSB design. 89 respondents (62.2%) agree that building form/envelope and orientation should be used in GSB design. 107 respondents (74.8%) agree that energy-efficient materials should be used in GSB design. 91 respondents (63.6%) agree that space allocation for renewable roof solar control should be used in GSB design. 31 respondents (21.7%) agree that a wall-to-window ratio should be used in GSB design. 55 respondents (38.5%) agree that solar heating mechanisms should be used in GSB design, and 125 respondents (87.4%) agree that well-designed landscapes should be considered in GSB design and construction stage strategies. The wall-to-window ratio should be considered in GSB design and construction stage strategies. 58 respondents (40.6%) agree that double-skin façades should be considered in GSB design and construction stage strategies. 102 respondents (71.3%) agree that façade shading devices should be considered in GSB design and construction stage strategies. 52 respondents (36.4%) agree that façades in vibrant colors should be considered in GSB design and construction stage strategies. 74 respondents (51.7%) agree that alternative energy should be considered in GSB design adoption. 65 respondents (45.5%) agree that green roofs should be considered in GSB design adoption. 84 respondents (58.7%) agree that these are energy-efficient materials, and 4 respondents (2.8%) agree that the wall-to-window ratio should be considered in GSB design adoption. 113 respondents (79%) agree that designs for future retrofitting should be considered in GSB post-construction design. 57 respondents (39.9%) agree that a CO_2 sensor monitor should be considered in the GSB post-construction design. 83 respondents (58%) agree that a daylight control mechanism should be considered in the GSB post-construction design, and 67 respondents (46.9%) agree that an energy use data collection system should be considered in the GSB post-construction design. This result shows that GSB adoption in practice is very low.

4.5 Result Summary

The study shows that a higher percentage of the respondents exhibit knowledge of GSB strategies and energy efficiency features. However, there is less participation in GSB, which has a significant impact on architect adoption in practice (48.3%). It further shows that respondents know the environmental, economic, and social benefits of GSB. (54.5%) agree that smart technology helps in green building feature optimization. 58% agree that green products increase energy efficiency in buildings. 3% disagree that GSB can only be used in new buildings, while 60.8% agree that GSB strategies can be used in all building types. All the respondents indicated that GSBs should be adopted in all 4 stages of design. More GSB implementation is needed in Nigeria in earnest.

5 Conclusion and Recommendations

The architects know the GSB design strategies available due to their educational background and years of work experience. Furthermore, the findings indicate that the level of GSB design strategy adoption in practice is still in its developing phase due to the low participation of Nigerian architects. Although they are aware of the economic, environmental, social, and health benefits of GSB adoption in practice, it is also believed that prioritizing eco-friendly materials such as green products will help the adoption of GSB practices by optimizing energy consumption in high-rise office buildings. Unfortunately, the majority of the features adopted in designs are at the design and approval stages with the building permit authorities. On this note, it is recommended that ARCON should encourage them to incorporate GSB strategies into their construction design and project implementation**.** ARCON should focus more on training and educating its members on GSB to achieve maximum knowledge and adoption in practice through seminars, training, conferences, etc. on GSB practice. The government should give stakeholders in the construction industry and investors a playing field for more implementation of GSB projects. The developmental policy review will create a more enabling environment for more individuals and corporate developers to invest in the real estate market. In addition, the Edge building certification in Lagos should be a prompt certification process to encourage individuals and investors to participate in registering their building for certification as there are fewer green-certified buildings in Lagos. This study suggests that the Green Building Council of Nigeria (GBCN) be fully set up for increased green building practices that will be used in future projects and in retrofitting existing buildings.

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Evaluation of Alternative Materials for Building Construction in Nigeria

Akintayo Opawole[1](✉), Kahilu Kajimo-Shakantu[1], and Joy Olabimpe Olapade[2]

[1] Department of Quantity Surveying and Construction Management, University of the Free State, Bloemfontein, South Africa
tayoappmail@gmail.com, kajimo-shakantuk@ufs.ac.za

[2] Department of Quantity Surveying, Obafemi Awolowo University, Ile-Ife, Nigeria

Abstract. Building materials incur up to 65% of the total construction cost, which implies that the incorporation of sustainable material into the delivery process could result in significant cost saving. This study therefore examines the level of awareness of alternative construction material and their extent of usage. The study adopted a quantitative approach though a questionnaire survey. Quantitative data were obtained using a structured questionnaire which were self-administered to 9 architects, 31 quantity surveyors, 22 engineers, 4 builders and 1 project manager, who are active construction industry players. The respondents were selected using a random sampling method. Data analysis was achieved using both descriptive and inferential statistics method, including percentage, mean score and Mann-Whitney test. Aluminum, low emissivity glass window and door, structural insulated panels and thatch are the five highest ranked materials as regards the frequency of usage while the five least ranked materials include plastic bottle waste, straw-bales, faswel, rice husk and ferro-cement. The practical implication indicated is that more awareness will boost market demand for alternative construction material. In addition, it will enable appropriate policy response that will support use of alternative construction materials.

Keywords: Building materials · Sustainability · Alternative construction material · Construction

1 Introduction

Construction material is described as any substance used for construction purposes. These include wood, cement, aggregates, metal, bricks, etc. Construction materials can either be naturally occurring or man-made. The naturally occurring materials available include clay, rock, sand and wooden twigs and leaves, etc. Man-made materials include fired-brick and clay blocks, cement, concrete, glass, plastic, metal, ceramics, among others [1]. Johnson, Natalia and Maren [2] described alternative construction materials as substitutes to conventional ones in the form of total or partial substitutions. Alternative construction materials have come under numerous nomenclatures such as traditional, unconventional, and sustainable construction materials. The use of alternative

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construction material defines sustainability in construction process to a greater extent due to characteristics such as; recyclability, pollution prevention, energy reduction, cost effectiveness and availability.

The significance of materials costs component in total construction cost and demand for effective cost control have attracted several researches on construction materials. Study such as [2] focuses on the development of nomenclature of terminology and definition as well as the benefits of the concept. Mpakati-Gama, Wamuziri and Sloan [3] and Gbadebo [4] had considered the strategies to promote the use of alternative building materials and Ali and Mansour [5] was a study specific to the use of waste plastic bottle as an alternative and substitute to concrete block.

The impact of material cost on the total cost and cost optimization objective in building projects have made it imperative to identify the various alternative materials that can be utilized in solving the problem of high cost of construction. However, previous studies appeared not to have generalized the awareness of various alternative materials available as well as their extent of usage. Also, previous studies appeared to have focused on the promotion of alternative materials, whereas the awareness level of the alternative materials appeared not to have been adequately documented in the study area. This study therefore aims to identify the alternative materials and the extent of their usage. The research will help to improve the adoption of locally available materials, which will foster sustainable and economical construction.

2 Literature Review

Alternative construction materials can be defined as materials other than cement blocks or clay bricks that can perform similar or even give a more excellent quality to products [6]. These include locally available materials as well as industrial and agricultural products that can be used instead of the conventional construction materials [1, 7]. Also, they are materials for construction purpose which can be used to replace the conventional ones. These materials are either naturally available or made from end products with potential for improving environmental friendliness. Examples include aluminum, bitumen materials, soil conditioning agents, tempered glass, crumb rubber, fiber reinforced polymer, glass fiber reinforced plastics, bamboo, reinforced plastics, ferro-cement and polyester fibers [8]. Chandlers [9] defined alternative construction materials as products that have been discovered with environmental issues in mind which can help to drastically reduce the large amount of carbon dioxide (CO_2) gases that are produced by the construction processes.

Alternative construction material is a generic term. It encompasses construction materials that are referred to by different names. Most definitions in literature connote alternative construction materials as sustainable since they are characterized by variables of sustainability concept; economic, social, and health benefits. Alternative materials are so defined if they possess characteristics such as cost effectiveness [10], local availability [1, 11] and relevant in climate change mitigation to foster a green construction [12], among others.

Some identified alternative construction materials are aluminum, bamboo, bamboo, earth, rammed earth, compressed earth block, non-erodible mud plaster, straw or straw bale, thatch, plastic bottle waster, fibre cement composites, fly ash, palm oil fly ash, fly ash brick, bottom sediment, lime, ferro-cement, cement concrete hollow block, rice husk, quarry sand, basalt rebar, shipping containers; and expanded polystyrene concrete [1, 13]. The level of usage of alternative materials is a sub-set of objective of this research work hence, implementation or adoption of any kind of product has to be effectively and efficiently marketed which is a form of ensuring that the public are aware about the existence and benefits of the materials. The adoption of alternative construction material in building projects would be defined by the extent of the awareness and benefits of the materials. Evaluation of this concept is imperative to provide empirical evidence which could be used to guide appropriate policy response and acceptability among the construction industry stakeholders.

3 Research Methodology

Quantitative research approach was adopted with the use of a structured questionnaire which was designed to capture the respondents' opinions. The respondents were selected using a random sampling approach. The respondents include 9 architects, 31 quantity surveyors, 22 engineers, 4 builders and 1 project manager. The respondents were considered qualified enough to give information as touching alternative materials in building projects as their mean years of experience in the construction shows 10 years while the numbers of the projects they have executed is 12 on average.

A structured questionnaire was adopted to ensure a simple and quick evaluation of the concept [13]. The first part of the questionnaire was designed to collect respondent's profiles such as the numbers of project they have executed, years of experience in the construction industry and if they are aware about alternative materials and how often they make use of them in building projects. The second part of the questionnaire assessed the specific objective of the study. This part was structured in 5-points Likert scale, where 1 and 5 represents the least and highest ranking, respectively. The alternative materials identified from literature were listed out. The second part assessed the frequency of usage of the identified alternative materials.

Data analysis was achieved using mean, standard deviation and Kruskal Wallis H test. Kruskal Wallis H test was conducted in order to understand if there is any statistical difference in the respondents' opinion concerning the issues assessed [14]. This explores the variation in the opinions of the groups of the respondents at p-value of ≤ 0.05, from the extracted variables.

4 Results and Discussions

4.1 Profile of respondents

The profiles of the respondents showed the nature of organization, type of respondents, highest academic qualifications, and professional affiliations of the respondents among others. Analysis of the respondents' organizations shows that about 56.7% of them work in contracting firm while 43.3% of the respondents work in a consulting firms. Majority of the participants were quantity surveyors, which is about 46.3%. About 13.45% of the respondents were architects, about 32.8% of them were engineers, 6.0% of them were builders while only 1.5% of them were from other professions.

An evaluation of the respondents' highest academic qualifications showed that 67.2% of the respondents were First Degree holders, about 14.9% were Diploma holders, while 17.9% held Masters Degree. Professionally, 13.4% of the respondents were affiliated to Nigerian Institute of Architects (NIA), 44.8% were affiliated to Nigerian Institute of Quantity Surveyors (NIQS), 34.3% were affiliated to The Nigerian Society of Engineers (NSE), 4.5% were affiliated to The Nigerian Institute of Building (NIOB), and 3.0% were affiliated to other professional bodies. On the respondents' years of professional experience in the construction industry, the average is 10 years. An analysis of the number of projects executed by the respondents indicated 12. These criteria support a credible data for the study.

4.2 Evaluation of the Use of Alternative Construction Materials

The assessment commenced by drawing up a list of alternative construction materials from literature. This list was given to the respondents and they were asked to rate their level of awareness on the identified alternative materials. The retrieved data were analyzed using frequency distribution, mean score, standard deviation, and Mann-Whitney's test. The result is presented in Table 1. The respondents' general levels of awareness on the materials were assessed. The results under concrete work, showed Portland Pozzolan Cement (PPC) had the highest mean of 4.15. This indicates that majority of the respondents are aware of this material. Furthermore, cellular lightweight concrete had a mean score of 3.70, which also indicates popular awareness of this material. However, the least ranked material was 'bottom sediments' with a mean score of 3.21. This implies that the respondents are moderately aware of bottom sediments as an alternative construction material.

For the masonry group, ceramics topped the group as the alternative construction material with the highest level of awareness. It ranked first with a mean score of 4.61. This implies that the respondents are highly aware of ceramics. Followed closely was particle board which ranked second with a mean score of 4.46. On the other hand, the lowest ranked material was earth bag, with a mean score of 3.64. However, earth bag being the lowest ranked does not mean that the respondents are not aware of the materia. The mean score of 3.64 shows that the respondents have moderate awareness of the material.

Under the frames section, wood has the highest level of awareness with a mean score of 4.42. The least ranked material was ferro-cement with mean score of 3.30. Ceramics (MS = 4.73) ranked first as the floor finish alternative material with the highest level of awareness. An evaluation of the overall means of all the identified alternative construction materials showed that those with the highest level of awareness were ceramics for floor finish and aluminum for windows and doors with mean score of 4.73. The respondents from both the contracting and consulting organizations jointly ranked this first. The mean score of 4.73 suggests that the respondents are mostly aware of these two alternative construction materials.

The top ten ranked alternative construction materials with high level of awareness were ceramics with mean sore (MS = 4.73), aluminum (MS = 4.73), terrazzo (MS =

4.72), bamboo for (MS = 4.66), ceramics for masonry (MS = 4.61), bamboo for upper floors (MS = 4.58), low emissivity glass windows or doors (MS = 4.52), medium density fiberboard (MS = 4.52), fiberboard (MS = 4.51), and particle board (MS = 4.46). These ten alternative construction materials and components have high level of awareness. The least five ranked were; rice husk (MS = 3.39), strawbales (MS = 3.37), palm kernel fly ash (MS = 3.33), ferro-cement (MS = 3.30), and bottom sediments (MS = 3.21).

Ceramics ranked first as the material which the respondents were most aware of because of its frequency of application in the construction industry. Ceramics is produced from clay which makes it an alternative construction material. The ranking of ceramics this way could have been influenced by its aesthetic characteristics both on masonry and in floor finishes. Aluminum ranked the second component presumably because it is currently the most specified opening component by designers (architects). Also, Terrazzo ranked third most aware of material because it is an ancient flooring finishes which most people have seen in buildings either while growing up or construction professionals must have come in contact during most renovation works. Terrazzo was famous until some decades ago when the use of tiles became famous in building projects.

Bamboo as the fourth ranked most aware of component is also ranked high due to its popularity in the construction industry. Aside the recent implementation of bamboo (frames, fittings and fixtures), bamboo is one of the oldest and famous scaffold materials that are known by all and sundry. The popularity of bamboo might have triggered its high level of awareness, availability and use amongst the respondents.

Generally, the rationale behind the high rankings of the 5 top materials is not far-fetched. Peoples' awareness about things are usually because they have seen the material first-hand; they have made use of it or they have read about it from literature. Besides, these top rated materials satisfy local availability and some other sustainable requirements of alternative materials as indicated in [1, 10, 11]. The 5 least ranked material/components are identified to be rice husk, straw bales, palm kernel fly ash, ferro-cement and bottom sediment.

The rationale behind this result is that the least rated materials are rare to come by and they are not so popular to come by in market and their implementations are not well advocated for. They are low in usage hence, low awareness about them.

Significant difference exists only in the ranking of few among the materials when the views of the respondents from contracting and consulting organizations were evaluated using Mann-Whitney test**.** These were limited to; palm oil fly ash, rice husk, rammed earth, earth bag, fly ash brick, wood, straw bales, thatch, bamboo board, faswell at p value ≤ 0.005.

4.3 Evaluation of the Use of Alternative Construction Materials

The extent of usage of the identified alternative materials is evaluated in Table 2. The respondents were asked to rate the frequency of use of these materials as well indicate the average number of building projects involving them where the materials have been used. The results show that for concrete components, Portland Pozzolan Cement (PPC) had the highest mean of 3.10 in average four numbers of projects. This indicates that some respondents have used PPC more frequently compared to others materials.

Table 1. Awareness of alternative construction materials

Material	Overall Mean			MW- **
	Mean	SD	R	
Concrete work				
Portland Pozzolana Cement (PPC) e.g., Fly Ash	4.15	0.99	18	.291
Cellular Lightweight Concrete	3.70	1.23	27	.031
Sulfo Aluminate Cement	3.42	1.32	32	.030
Palm oil fly ash	3.43	1.32	31	.009*
Bottom sediments	3.21	1.38	38	.013
Rice husk	3.39	1.31	33	.001*
Palm kernel fly ash	3.33	1.24	36	.035
Masonry				
Adobe Block	3.96	1.22	22	0.854
Fired Bricks	4.25	0.86	15	0.110
Fly ash brick	3.87	1.24	25	0.010*
Earthbag	3.64	1.29	28	0.005*
Rammed Earth	3.93	1.16	23	0.021*
Mud and clay	4.31	0.84	14	0.095
Ceramics	4.61	0.65	5	0.278
Particle Board	4.46	0.82	10	0.145
Frames				
Autoclave Aerated Concrete	3.63	1.03	29	0.318
Structural Insulated Panels	3.90	1.05	24	0.691
Wood	4.42	0.68	11	0.039*
Plastic bottle waste	3.39	1.10	33	0.246
Ferro-cement	3.30	1.18	37	0.213
Strawbales	3.37	1.28	35	0.008*
Upper floor				
Bamboo	4.58	0.68	6	0.730
Shipping container	4.33	0.86	13	0.129
Windows and doors				
Low emissivity glass windows or doors	4.52	0.68	7	0.900
Aluminum	4.73	0.59	1	0.221
Roof				

(*continued*)

Table 1. (*continued*)

Material	Overall Mean			MW- **
	Mean	SD	R	
Thatch	4.24	0.95	16	0.003*
Structural Insulated Panels	4.40	0.85	12	0.264
Bamboo board	4.18	0.87	17	0.004*
Wall finishes				
Low volatile compound paint	4.06	1.11	20	0.132
Grass cloth wall paper	3.52	1.09	30	0.054
Floor finishes				
Terrazzo	4.72	0.57	3	0.814
Eco Surfaces	4.01	1.08	21	0.111
Medium density fiberboard	4.52	0.77	7	0.850
Ceramic	4.73	0.62	1	0.818
Fittings and finishes				
Bamboo	4.66	0.81	4	0.787
Fiberboard	4.51	0.84	9	0.362
Drainage work				
Grass Pavers	4.09	1.11	19	0.747
Faswell	3.79	1.19	26	0.012*

MW- ** = Mann-Whitney test, SD = Standard Deviation, R = Rank

Moreover, cellular lightweight concrete had a mean score of 2.57, which implies that good number of the respondents use this material frequently, at least in four projects on average. However, the least used alternative construction material was rice husk with a mean score of 2.09. This implies that rice husk is used less frequently for building projects. For the masonry group, particle board topped the group as the most used alternative construction material. It ranked first with a mean score of 3.79. This was followed by ceramics which ranked second with a mean score of 3.70. Conversely, the least used alternative masonry material was earth bag, with a mean score of 2.40, which implies that earth bag is used less frequently. Under the frames section, wood had the highest level of awareness with a mean score of 4.06. The least ranked material was plastic bottle waste with mean score of 1.87. Ceramics (MS = 4.34) ranked first as the most used floor finish alternative material.

An evaluation of the overall means of all the identified alternative construction materials showed that the most used alternative construction material is aluminum for windows and doors with mean score of 4.73. The ten top ranked alternative construction materials with the high level of awareness were aluminum (MS = 4.73), low emissivity glass windows or doors (MS = 4.52), structural insulated panels (MS = 4.40), ceramic for floor finish (MS = 4.34), thatch (MS = 4.24), bamboo board (MS = 4.18), wood (MS = 4.06), bamboo for upper floors (MS = 3.90), bamboo for fittings and doors (MS = 3.88), and particle board (MS = 3.79). On the other hand, the five least ranked materials were; ferro-cement (MS = 2.12), rice husk (MS = 2.09), strawbales (MS = 1.96), faswell (MS = 1.96), and plastic bottle waste (MS = 1.87).

Aluminum is ranked most frequently used component by the respondents. Aluminum is widely used in buildings because of its intrinsic properties of lightness and corrosion resistance. Unlike wood or louvre blades in openings, aluminum is said to be more durable, has low maintenance cost, non-combustible and eco-friendly.

Aluminum has been famous in buildings especially for openings in the last few decades. Low emissivity window and door ranked the second most frequently used component by the respondents. Low emissivity glass is designed to limit the amount of solar heat that passes into a building for the purpose of keeping buildings cooler. Low emissivity window and doors is currently used in building because it is aesthetically attractive and it makes the building cooler. It is probably popularly in the study area because of its unique nature.

Structural insulated panel is ranked the third most frequently used component by the respondents. Structural insulated panel are used for commercial buildings that can have higher temperature levels due to the presence of machines and equipment. Structural insulated panel is mostly used in the study area because of high-concentration of commercial buildings in it.

Ceramics is ranked frequently used by the respondent because of its intrinsic properties of been durable, low maintenance cost and attractiveness. It is also readily available in the market and it is generally accepted by construction industry's stakeholders. The high ranking of thatch is also because it is a roofing material that is readily available [10] and has been in existence for centuries in many locations around the world. It was not so common until recently when it is now been used for aesthetic reasons in recreation centres. It is also a roofing material that provides warmth for its users. The five least frequently used materials were identified to be ferro-cement, rice husk, straw bales, faswel and plastic bottle waste. The materials are least used because of the risk of implementing new practices, fear of failure of such materials and also because they are not readily available in the market [1].

5 Conclusion

The various alternative construction material and components used in building project have been identified from literature review and the opinions of respondent from both consultancy and contracting firm were sought as regards the awareness of the alternative construction materials in the study area. Findings indicated a general awareness of the alternative construction materials. However, the results indicate that the respondents have applied them at different rate. Based on findings, the awareness about alternative construction materials is profound and the level of usage indicated an increasing trend as the study revealed the respondents that chose 'always, 'more often' and 'often, to reveal how frequent alternative construction materials are used accounts for 65.7%. Comparing cost implication of alternative construction materials with conventional ones would bring the study to a much broader scope.

Table 2. Alternative construction materials available and used

Material	Mean	SD	R	OR	KW*	**
Concrete work						
Portland Pozzolana Cement	3.10	1.42	1	15	.189	4
Cellular Lightweight Concrete	2.57	1.27	2	24	.069	4
Sulfo Aluminate Cement	2.36	1.33	4	29	.122	1
Palm oil fly ash	2.42	1.18	3	26	.124	2
Bottom sediments	2.31	1.28	5	30	.101	2
Rice husk	2.09	1.19	7	35	.002*	3
Palm kernel fly ash	2.22	1.08	6	32	.139	2
Masonry						
Adobe Block	2.64	1.29	5	22	.030	6
Fired Bricks	3.09	1.04	3	16	.324	10
Fly ash brick	2.55	1.13	6	25	.243	3
Earthbag	2.40	1.19	7	27	.146	3
Rammed Earth	2.64	1.14	5	22	.489	5
Mud and clay	2.76	1.17	4	20	.054	4
Ceramics	3.70	1.03	2	12	.459	0
Particle Board	3.79	0.81	1	10	.046*	0
Frames						
Autoclave Aerated Concrete	2.28	0.97	3	31	.144	4
Structural Insulated Panels	2.90	1.17	2	18	.094	4
Wood	4.06	0.85	1	7	.191	8
Plastic bottle waste	1.87	0.4	6	38	.002*	1
Ferro-cement	2.12	1.1	4	34	.143	0
Strawbales	1.96	0.93	5	36	.004*	1
Upper floors						
Bamboo	3.90	1.18	1	8	.761	8
Shipping container	3.64	1.23	2	13	.106	6
Windows and doors						
Low emissivity glass windows or doors	4.52	0.68	2	2	.652	5
Aluminum	4.73	0.59	1	1	.367	16
Roof						
Thatch	4.24	0.95	2	5	.018*	5

(*continued*)

Table 2. (*continued*)

Material	Mean	SD	R	OR	KW*	**
Structural Insulated Panels	4.40	0.85	1	3	.649	3
Bamboo board	4.18	0.87	33	6	.087	3
Wall finishes						
Low volatile compound paint	3.01	1.16	1	17	.693	2
Grass cloth wall paper	2.37	1.04	2	28	.374	4
Floor finishes						
Terrazzo	2.85	1.10	3	19	.715	16
Eco Surfaces	2.22	0.98	2	32	.812	3
Medium density fiberboard	3.49	1.09	2	14	.291	6
Ceramic	4.34	0.86	1	4	.465	16
Fittings and finishes						
Bamboo	3.88	1.16	1	9	.962	6
Fiberboard	3.73	1.14	2	11	.236	6
Drainage works						
Grass Pavers	2.75	1.24	1	21	.519	4
Faswel	1.96	0.94	2	36	.747	0

** Number of projects where used, KW* Kruskal Wallis H Test, IR = Interphase ranking, OR = Overall Ranking, SD = Standard Deviation, M = Mean

5.1 Implications of the Findings

The findings provide implication for formulating appropriate policies and regulation that will encourage the use of alternative construction materials in building projects. This will improve a higher market demand and end users support.

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Investigation of Indoor Environmental Quality of Lecture Rooms on Students' Comfort in Selected Polytechnics, Lagos, Nigeria

Opeyemi Asaju[1](✉), Oluwole Alagbe[1], and Olugbenga Adetona[2]

[1] Department of Architecture, Caleb University, Imota, Lagos State, Nigeria
aj.ope.oa@gmail.com, oluwolealagbe@calebuniversity.edu.ng
[2] Department of Architecture, Federal Polytechnic, Ilaro, Ogun State, Nigeria
gbengaadetona@federalpolyilaro.edu

Abstract. Indoor environmental quality (IEQ) has an impact on the academic performance of students irrespective of the type of institution. The recent challenge with both global warming and climate change alongside the consequent depletion of the ozone layer is affecting general comfort in an enclosed environment. An increase in heat transfer through materials used for construction has called for a closer look into lecture rooms. Students spend a large proportion of their days acquiring knowledge in them. The paper aims to investigate the impact of IEQ on students' comfort in selected polytechnics in Lagos State, Nigeria. The objectives are primarily to identify factors that contribute to comfort in the lecture rooms, the ones with high impact, and possible recommendations. A stratified random sampling method was used to select three polytechnics from the Federal, State to privately owned. Total of 151 respondents comprising 115 public and 36 private completed the structured survey questionnaires. A descriptive data analysis was used to represent the data gathered. The results showed strong associations between the environmental parameters of IEQ with thermal comfort ranking highest. The population of students and furniture types was followed respectively as significantly impacting students' comfort in the lecture rooms. Since the study identified that the population of students contributes to the overall IEQ in the lecture room, it is recommended that bigger and more spacious rooms be provided to reduce the impact of thermal discomfort. The number of students per lecture room can also be reduced for better transfer of passive air within the space with the provision of comfortable furniture.

Keywords: Academic performance · Indoor environmental quality · Lecture rooms · Polytechnics · Students' comfort

1 Introduction

The higher education sector represents a unique environment that acts as a work environment for faculty, a learning environment, and frequently, a home environment for students. The World Bank's report outlined the positive effects of raising an informed

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populace [1]. This is based on the idea that education is a critical component of accomplishing growth and development [2]. In pursuance of this, students spend about 87% of their time indoors, where they are exposed to environmental effects as indoor air may be more contaminated than outdoor air [3]. A comfortable and healthy lecture room is significant to the eventual output of the student as the indoor environment plays an important role in the health, performance, and behavior of occupants, and this is determined by the quality of the indoor environmental quality [4]. Issa et al. [5] expressed Indoor Environmental Quality (IEQ) to be the "quality of the interior environment concerning its inhabitants' health and well-being. It involves aspects of design, analysis, and operation that result in energy efficiency, healthy, and pleasant buildings". Research has shown that adequate Indoor Environmental Quality (IEQ) decreases the frequency and severity of illness, and reduces absenteeism, and loss of time for students [6].

Recently, urbanization and modernization have resulted in making people spend an essential part of their life in indoor spaces [7] as compared to past decades. Millions of citizens within the World Health Organisation (WHO) European Region now spend approximately 90% of their time indoors. This includes homes (2/3 of this time), workplaces, schools, and public spaces [8]. Indoor environmental quality (IEQ) is one of the features of green buildings and a sustainable environment that is drawing attention due to its high impact on the behavior of the building users [9]. IEQ is a key determinant of comfort experienced within any enclosed space as the acceptable levels of thermal, visual, and acoustic (sound) comfort in addition to Indoor Air Quality (IAQ) among others is dependent on it [10, 11]. However, Wong et al. [12] inferred that an environment can be said to achieve 'reasonable comfort' when at least 80% of its occupants are thermally comfortable. Furthermore, Health and Safety Executive [13] expressed environmental factors as being in direct proportion to the comfort experienced by the human in any given space which in turn translates to its productivity. Finishing materials emitting Volatile Organic Compounds (VOC) also affect occupants' comfort and this is connected to the Indoor Air Quality (IAQ) [14] as IAQ is a function of the Outdoor air quality, human activity in buildings and the building and construction materials. Van et al. [15] expressed that "the overall comfort is an umbrella variable which covers peoples' perception of heating, cooling, lighting alongside noise". It is against this background that this study sought to investigate the indoor environmental quality of lecture rooms in selected polytechnics in Lagos State, Nigeria. The specific objectives of this study are to:

i. Identify the factors that have an impact on the students' comfort in their lecture rooms.
ii. Ascertain which of the factors contributes most to the students' comfort in the lecture rooms.
iii. Recommend ways of improving students' comfort within their lecture rooms.

2 Research Background

Although there is a growing assemblage of indoor environmental quality (IEQ) studies [16, 17] argued that less attention has been given to its impact on student learning comfort in classrooms. Studies on students and Indoor environmental quality have expressed different results and connections. WHO [6] presented that student, teacher, and staff absenteeism improved by 2–7.5% and student performance by 8–19% in green Canadian schools compared with conventional schools. Heschong [18] indicated good views as enhancing better student learning compared to glare, direct sun penetration, poor ventilation, and poor indoor air quality which worsen it. Another study by Hathaway et al. [19] described how studying in classrooms with natural daylight can reduce absenteeism by 3.5 days per year.

Thermal comfort (TC), Indoor Air Quality (IAQ), Acoustic Comfort (AC), and Visual Comfort (VC) are listed as four essential parameters for assessing satisfactory Indoor Environmental Quality [15], making IEQ = TC + IAQ + AC + VC. OSHA [20] outlined the need for control of thermal and atmospheric conditions of an enclosed space to ensure the health and comfort of the occupants as thermal comfort is ranked more important compared with visual, acoustic, and respiratory comfort.

ASHRAE Standard [20] refers to indoor air quality (IAQ) as the temperature conditions that can have an impact on the health and well-being of inhabitants. Health risks such as headaches, weariness, respiratory issues, and irritations or allergies of the nose, eyes, and throat may occur when pollutants such as mold, radon, carbon monoxide, and formaldehyde are present in the air [21]. Many interior pollutants, like allergies, particulates, volatile chemical substances, and so on, might cause both long-term and short-term health issues for students and faculty in their lecture halls, and also contribute to decreased productivity [22].

Visual comfort is more than just giving an adequate amount of light. Illuminance, brightness distributions, and other factors like light color characteristics, and glare also influence the quality of lighting. Precious studies show lecture halls with natural lighting to have a 21% boost in students' performance than the ones without [23]. The visual connection to exterior space has been demonstrated to have a positive effect. This includes the restoration of attention, stress reduction, and overall health and well-being of people [24] as windows serve as a primary connector to the outdoors [25] Acoustic or sound quality is related to a variety of physical elements, including both the physical qualities of sound and space [26]. "Overall physical indoor environmental parameters are all interrelated, and the feeling of comfort is a composite state involving an occupant's sensations of all these factors" [27].

Temperature, humidity, and air movement are all considered when determining the thermal comfort level in a certain zone [28]. It was discovered that when 80% of the building inhabitants were comfortable with the surrounding thermal conditions, the thermal environment is in good shape [29]. However, satisfaction with the thermal environment is a complex, subjective response with many interacting variables and was found to have an impact on the perception of other IEQ factors [30]. Lee and Guerin [31] indicated that the quality of office furnishing contributes to both occupants' satisfaction and performance whereas indoor air quality affects only the occupants' performance.

3 Materials and Methods

a. **Study site**

Lagos State has a total of six polytechnics comprising two government-owned and four private in different locations.

- Yaba College of Technology, Yaba, Lagos State.
- Grace Polytechnic, Surulere, Lagos State.
- Lagos State Polytechnic, Ikorodu, Lagos State.
- Kalac Christal Polytechnic, Sangoted, Lekki, Lagos State.
- Lagos City Polytechnic, Ikeja, Lagos State.
- Ronik Polytechnic, Ejigbo, Lagos State.

A stratified random sampling method was used to select three polytechnics for the study as they are the representation of categories of polytechnics in the State (Federal, State and private-owned). They are all located on the mainland which is the heart of the state. The academic buildings housing the lecture rooms are representative of the many existing polytechnic buildings with multiple faculties. Key information concerning these buildings is summarized in Table 1.

Table 1. General overview of selected polytechnic buildings

Name	Ownership/type	Building type monitored	Illumination type	No. of responses
Yaba College of Technology, Yaba	Federal Government /public	Lecture room -Storey building	Natural	62
Grace Polytechnic, Surulere	Private	Lecture room-Storey building	Natural/artificial	36
Lagos State Polytechnic (Open distance flexible learning center), Surulere	State Goverment/public	Lecture room-Bungalow	Natural	53

b. **Data collection**

This research was conducted employing the use of primary data which was obtained through the instrumentality of a structured closed-ended questionnaire to obtain responses from students who have utilized the various lecture rooms for a minimum of

6 months. The questionnaire comprises of multiple-choice, close-ended, and Likert-type questions. It was divided into different sections ranging from the background information to the four aspects of comfort highlighted by Lee and Guerin [31] as those with a high impact on users. They include thermal comfort, acoustic (sound), lighting, and indoor air quality. 151 students in the selected polytechnics who showed interest in the research filled out the questionnaire on their indoor environmental quality. It was administered to students through the support of their lecturers and staff in the institutions representing 41% YABATECH, 24% GRACE POLY and 35% LAGOSPOLY.

4 Results and Discussions

4.1 Acoustic (Sound) Quality

The chart below indicated the responses of participants on Acoustic (sound) quality. Students in the selected polytechnics get distracted more as a result of noise from vehicles because of the location of the lecture rooms close to the road. Adjoining lecture rooms also contribute to sound discomfort with Grace polytechnic having the highest distraction level due to noise from other lecture rooms because of their location and closeness (Fig. 1).

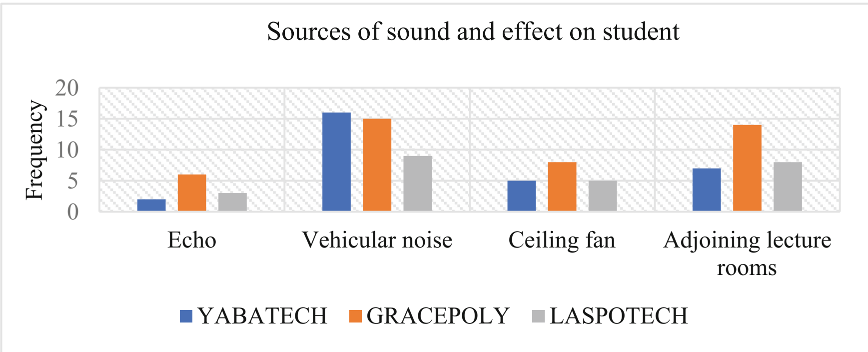

Fig. 1. General responses to acoustic (sound) quality

4.2 Visual Comfort

The visual comfort enjoyed by students in each of the selected institutions differs. The percentage of lecture rooms that have electronic smart boards is approximately 17% which made the use of marker boards prevalent in their spaces. The placement concerning the sitting position of the students influenced their responses to their visual comfort. Generally, most students admitted to good visual comfort with less or no need for visual aids to reading from their boards, however, the rating does not give an accurate percentage of the comfort as they are forced to adjust to the available state. 47.3% of the participants affirmed that they didn't need artificial light in their lecture rooms, 39.0% needed while 12.0% were undecided (Plate 1).

Plate 1. Images of Yabatech, Gracepoly, and Laspotech visual comfort of lecture spaces

4.3 Lighting Quality

Natural lighting played an important role in all the institutions. About 46.7% of the participants affirmed that natural lighting gives the best illumination to the lecture rooms, 38.5% affirmed that a combination of artificial and natural lighting gives the best illumination to the lecture rooms and 13.1% responded that artificial lighting gives the best illumination to the lecture rooms. The time of the day and season of the year also played a role in the prevalent lighting type in the lecture rooms. Furthermore, 46.0% responded that the penetration of natural lighting concerning the shape of the building was good, 26.9% rated the penetration as fair, 16.9% rated the penetration of natural lighting as excellent, 6.3% rated it as very poor and 6.3% rated it as very poor. 55.8% of the participants affirmed that the orientation of the building contributes to the penetration of light, 23.3% responded with maybe and 20.2% affirmed that the orientation of the building does not contribute to the penetration of light respectively (Fig. 2).

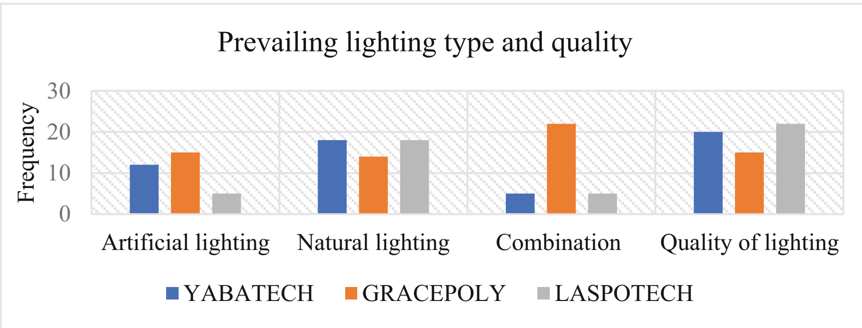

Fig. 2. Lighting types and quality

Generally, the lighting quality was approved by the majority of the students to be excellent. However, the quality of this is dependent on the institution. A combination of natural and artificial lighting is more acceptable to be of better quality in Grace polytechnic when compared to the other selected schools (Plates 2 and 3).

4.4 Thermal Comfort

Thermal comfort is a function of many variables as reflected in [23]. This has made the exact position of users of the spaces a bit complex to conclude. The overall thermal

Plate 2. Grace Polytechnic, Surulere, Lagos

Plate 3. Lagos State Polytechnic, Surulere

comfort was generally accepted as good to the highest population of students. Each school's thermal comfort varies which is subject to both the heat balance approach and adaptive thermal comfort.

4.5 IEQ in the Selected Polytechnics

In an attempt to compare the IEQ factors contributing to comfort in lecture rooms among the selected schools, it was discovered that the population of the students influenced the IEQ factors. YABATECH with the highest number of respondents had a higher response in thermal discomfort compared to LASPOTECH and GRACEPOLY. The result supported the importance of furniture as opined by Alfa and Öztürk [9] as that which plays a crucial role in their studies of the healthcare facility and further established the importance of thermal comfort in the indoor environment (Fig. 3).

Table 2. Selected polytechnics and their IEQ parameters results

Parameters measured	Institutions		
	YABATECH	GRACEPOLY	LASPOTECH
Indoor air quality	Good	Fair	Good
Sound/acoustic quality	Good	Poor	Fair
Thermal comfort	Good	Fair	Good
Lighting quality	Very good	Good	Excellent
Visual comfort	Excellent	Good	Excellent
Furniture	Good	Fair	Fair

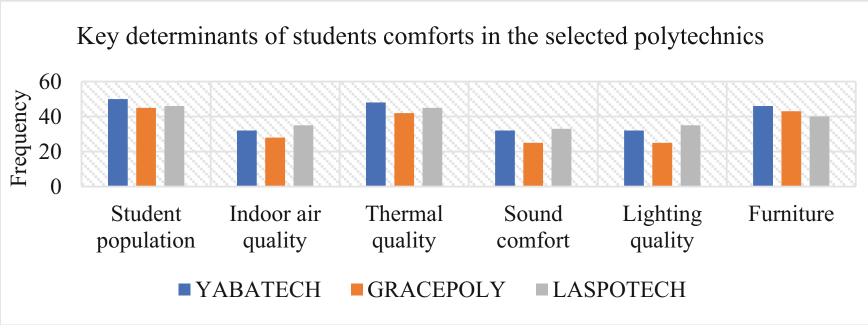

Fig. 3. Responses on students' comfort determinants

5 Conclusion and Recommendation

Many factors have been discovered to contribute to students' comfort. This can be seen in Table 2 differentiating each parameter from the other in each of the selected polytechnics. Comfort level cannot be said to be attained without all the factors being in a proportion to complement one another. A good IAQ with a good tolerance level of sound coupled with proper lighting will boost the comfort of students making the room conducive to learning. Alongside a sizeable number of students per room with the availability of good furniture. The population of students in each of the lecture rooms in the selected public polytechnics is high to the available space. It is therefore recommended that there is the need for the provision of bigger and more spacious lecture rooms in public polytechnics to accommodate the population of students. The number of students can also be reduced per room to achieve good perceived comfort. This will help in the circulation of air and increase thermal comfort. Better furniture designs should be provided to enhance maximum comfort.

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Evaluation of Low-Cost Housing Estate Readiness to Green Environment Creation

Desmond Eseoghene Ighravwe(✉) and Daniel Mashao

Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa
ighravwedesmond@gmail.com, dmashao@uj.ac.za

Abstract. There are growing concerns about the built environment's sustainability because of climate change. This issue has made stakeholders suggest different approaches to green environments; energy and water management are some suggested approaches. Despite the availability of the approaches, several communities are yet to implement them. Hence, analysis of a community's readiness for green environment creation needs to be addressed. This article presents a balanced scorecard (BSC) model for investigating the continent's readiness for green environment creation to answer this question. The BSC allowed the model to relate different concepts to EGC. This study used the model to establish the weights of indicators offered in the GECBSC by distributing questionnaires to specialists in the Lagos building sector. The experts' judgments were analysed using a fuzzy-based technique. This study allowed for the identification of specific performance gaps. Gaps in GEC were discovered throughout the review process – the gap was 3.24% from a benchmark value of 80%. The article's findings provide a more profound knowledge of establishing a green environment in an African community by first identifying customer-related performance gaps in a target community and then offering strategic suggestions for the gaps discovered. The framework could be used in other areas of construction management, although it would need redefining ideas.

Keywords: Balanced scorecard · Green environment creation · Fuzzy logic · Decision-making · Low-cost housing estate

1 Introduction

Becoming green is at the centre of various governmental and non-governmental efforts because of the intrinsic benefits it brings to our environment. These advantages can be divided into three categories: economic, health, and environmental [1]. Going green has several economic benefits that directly impact a community's gross domestic product. For example, it can assist a community in lowering its energy use, which is a cost-cutting action. Purchases of energy-saving appliances, water-saving appliances, and recyclable products could help achieve a green environment [2]. Going green has numerous health benefits. For example, there is a direct link between clean air and a healthy lifestyle.

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Communities encourage the purchase of eco-friendly products such as electric automobiles and cosmetics to encourage clean air [3]. These products help reduce air pollution and chemicals in the environment that can harm the human immune system. One of the environmental advantages of going green is the reduction of waste. Organic farming is also good for the environment because it reduces greenhouse gas emissions [4]. With these advantages in mind, going green is no longer a thing of the past; it is now a way of life.

While these advantages are clear to stakeholders in the built environment, the international community is concerned about their willingness to implement green environmental policies. On the other hand, scholars and practitioners are mute on how to assess a community's readiness to create a green environment. This knowledge gap must be filled to provide empirical models to stakeholders, particularly those in the built environment, which will benefit our environment. However, new research on environmental sustainability has been reported by several academics. Most of the works concentrate on specific aspects of environmental sustainability, such as energy, waste, and water [5]. Energy management is a topic that has piqued the interest of academics; works in this area focus on cleaner production [6]. Because of its impact on clean air, waste management is regarded as a pillar of the green environment; work in this area stimulates the use of recyclable materials. Another pillar of the green environment is water management, which focuses on water quality and quantity [7].

The scientific publications cited above focus less on assessing families' willingness to green environmental creation, particularly from the standpoint of low-cost housing estates (LHE). This assessment is significant due to the numerous advantages of being green, particularly climate change mitigation. To solve this issue, benchmarks for key performance metrics required for green environment adoption must be set. There is a need for a framework for one-to-one key performance indicators (KPI) mapping as a benchmark. A structure like this should be able to give information about LHE finances, learning and growth, clients, and internal processes. These metrics could be used to identify performance gaps in LHE's green environment preparation. It will also include an inter-state debate on LHE's readiness to implement green environmental policies.

Tleuken et al. [8] presented a report on residential buildings' readiness for green environments, but their study did not consider it from a balanced scorecard perspective. Fuzzy balanced scorecards (FBSC) are used to address this knowledge gap. It presents an instrument for evaluating LHE readiness to build a green environment by combining KPI. The built FBSC creates a platform for showing the interrelationships among specified KPIs for the current study challenge. In addition, the results of a performance gap for estates in Lagos, Nigeria, are presented in this study.

2 Methodology

This FBSC method uses a purposive sampling approach to provide information about a decision-making problem. It is used to assess the performance of a system using four (KPIs). The KPIs are financial, customer, internal process, and learning and growth. They serve as a foundation for making system-wide strategic decisions. It is based on internal or external comparison of criteria to the performance of a system. As a result, it provides policymakers with empirical data on internal characteristics that impede their performance. The following are the technical stages for implementing it:

Step 1: Definition of Terms

This step entails establishing an agreement with the organisation's major stakeholders. Furthermore, stakeholders agree on the inclusion of a balancing scorecard. Because there are various factors for evaluating performance in an organisation, this process is frequently iterative. For the current article, this study conducted a review exercise with selected stakeholders in the Nigerian built environment and presented Table 1 as the proposed BSC for evaluating a low-cost housing estate readiness for green environment creation.

Table 1. Proposed BSC

Dimension	Criteria	References
Financial	Energy and water savings	[9]
	Reduced health costs	
Customer	Utility expenses reduction	[10]
	Willingness to pay for a green environment	[11]
	Customers' attraction to a green environment	[12]
	Green facility per customer	[13]
	Green facility increase rate	[9]
Internal process	Resources and capability	[14]
	Energy and water efficiency	[15]
	Waste management technology	[16]
	Green construction	[17]
	Green facility management	[18]
Learning and growth	Responsibility ascription	[19]
	Green environment competence	[20]
	Research and development	[12]
	Green construction response	[21]

Step 2: Understanding the Expected Outcomes

The desired consequences of a balanced scorecard implementation can be defined in various ways. Numerical figures are typically difficult for this step since several criteria in a balanced scorecard are challenging to explain numerically; instead, verbal terms offer such criteria more significance. As a result, academics rely on fuzzy mathematics to define expected results. This article uses the linguistic variables in Table 2 for its analysis.

Table 2. Linguistic variables for the criteria importance and scoring

Criteria importance		Criteria scoring	
Linguistic variable	Fuzzy variables	Linguistic variable	Fuzzy variables
Extremely important (EI)	(0.7,0.9,1.0)	Extremely high (EH)	(7,9,10)
Highly important (HI)	(0.5,0.7,0.9)	Very high (VH)	(5,7,9)
Important (I)	(0.3,0.5,0.7)	High (H)	(3,5,7)
Somewhat important (SI)	(0.1,0.3,0.5)	Somewhat high (SH)	(1,3,5)
Unimportant (U)	(0.0,0.1,0.3)	Low (L)	(0,1,3)

Based on the explanation in Stage 2, this study used a fuzzy BSC in the current study. This article based its analysis on the information in Table 1.

Scholars use Eq. (1) to aggregate their linguistic responses for multi-evaluators.

$$a_i, b_i, c_i = \frac{1}{K}\left(\sum_{k=1}^{K} a_i^k, \sum_{k=1}^{K} b_i^k, \sum_{k=1}^{K} c_i^k\right) \tag{1}$$

$$d_i = \frac{a_i + 4b_i + c_i}{6} \tag{2}$$

Step 3: Strategy Discussion

Because an organisation needs to achieve strategic alignment, strategic discussions about BSC results, the vision and mission of an organisation can be used to achieve this alignment. Additionally, an organisation's obstacles can be used to explain strategic decisions related to BSC performance. This article identifies a built environment readiness to create a green environment from two phases. First, it reports an estate readiness from financial, customer, internal process, and learning and growth perspectives. Second, it aggregated these perspectives.

Step 4: KPIs and Action Plans

This stage uses the outcome from BSC to define action plans that will enable organisations to close identified performance gaps. Information about action plans for the subject matter is discussed using a case study. This article used information obtained about an estate in Lagos, Nigeria, to evaluate the applicability of BSC for the current research problem. The study areas' locations are as follows: Iba Housing is located in the Lagos local government regions of Ojo and Unity Housing Estate in Alimosho. Ojo LGA, located at 6° 28' N 3° 11' E, is the study area. To the south, Ojo is Iyagbe and Ikum-Ibese. Agbara and Badagry are located to the west. Satellite and Festac towns lie to the east, and Igando and Ejigbo are to the north. The area benefits from coastal weather conditions due to its proximity to the water [22].

Step 5: Cultural Transformations

Organisations make cultural transformations depending on areas where performance gaps exist. Personnel changes, operational methods, and new technology investments may be part of such adjustments. Information about the cultural transformations for creating a green environment in a low-cost housing estate is presented in the next section.

3 Case Study

This study used a low-income housing estate as its case study because most households in the estate have different families that could be classified as low-class and middle-class families. Hence, its readiness could demonstrate the attributes of typical society. Studying their readiness for a green environment will provide information on this issue more than those of higher and lower households in a community. Information about the case study is presented in [22]. Since a purposive sampling method is used, four LGA secretariat employees were consulted to offer information on the estates' readiness to create a green environment. The first expert (E1) has an estate management degree, whereas the second expert (E2) has an architecture degree. The fourth (E4) and third (E3) have civil engineering and urban planning degrees. The minimum working experience of an expert in ten years.

A questionnaire was utilised to get information from these experts; the questionnaire includes information on the importance of the criteria and a scoring system (Table 3).

Table 3. Linguistic ratings for the FBSC parameters

	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
C1	EI	I	VI	I	EH	VH	EH	H	SH	EH	SH	EH
C2	EI	EI	EI	I	VH	H	H	EH	H	VH	EH	SH
C3	EI	VI	VI	I	EH	H	EH	EH	H	H	EH	VH
C4	I	I	VI	VI	EH	VH	H	H	EH	H	SH	VH
C5	VI	I	I	EI	VH	EH	H	H	H	H	EH	EH
C6	EI	VI	EI	VI	H	H	VH	EH	H	EH	H	VH
C7	VI	VI	I	I	H	VH	VH	EH	EH	VH	SH	H
C8	I	EI	I	VI	VH	EH	EH	EH	SH	EH	H	EH
C9	I	EI	EI	EI	EH	H	VH	VH	EH	H	VH	EH
C10	EI	VI	VI	VI	H	VH	H	H	H	VH	VH	H
C11	VI	VI	I	I	VH	VH	EH	VH	H	H	SH	VH
C12	EI	I	I	VI	VH	VH	VH	VH	VH	EH	VH	EH
C13	VI	VI	EI	VI	VH	VH	H	EH	SH	H	EH	H
C14	EI	I	EI	VI	EH	EH	VH	VH	H	H	EH	VH
C15	VI	EI	EI	EI	EH	VH	H	VH	VH	H	H	SH
C16	I	VI	I	VI	EH	VH	EH	EH	VH	VH	EH	EH

Using Eqs. (1) and (2) and interpolative modelling, this study converted the information in Table 3 to crisp values. This process considers a benchmark of 80% as the minimum target for each criterion.

Table 4. Summarised performance of the criteria.

Criteria	Target rating (%)	Actual rating (%)	Weight (%)	Actual performance (%)	Weighted performance (%)
C1	67.01	83.99	45.06	76.72	34.57
C2	67.48	73.14	54.94	96.19	52.85
C3	73.14	89.18	20.88	81.51	17.02
C4	67.48	73.14	18.00	96.19	17.32
C5	78.33	73.14	19.38	57.46	11.13
C6	73.14	78.80	23.75	96.86	23.00
C7	67.48	78.80	18.00	81.84	14.73
C8	72.67	94.85	18.86	78.83	14.86
C9	83.99	78.80	22.99	68.58	15.77
C10	67.95	62.29	21.78	39.65	8.63
C11	56.63	84.47	17.52	64.41	11.28
C12	89.66	79.28	18.86	84.67	15.97
C13	61.82	78.80	25.50	73.05	18.63
C14	73.14	89.66	25.36	81.27	20.61
C15	56.63	78.80	28.63	66.40	19.01
C16	89.66	94.85	20.51	99.62	20.43

According to the findings, waste management technologies (C10) had the lowest performance among internal process requirements and other criteria (see Table 4). On the other hand, green construction response (C16) had the best performance in the learning and growth perspective. This fact likewise holds for its performance compared to that of other perspectives. The financial perspective had the lowest weighted performance (11.27%), whereas the customer perspective had the highest weighted performance (24.95%). For internal process and learning and growth perspectives, respectively, their weighted performances are 20.49 and 20.70%. The overall readiness of the case study for green environment creation is 77.41%, which is lower than the benchmark value.

4 Conclusions

The FBSC method has been demonstrated to be influential in determining whether low-cost housing estates are ready to generate green environments. Four performance indicators for green settings were examined using FBSC, each with its own set of criteria. An example of a real-life case study demonstrated that the FBSC generated helpful information about creating green environments. For example, in the low-cost housing estate, it was discovered that waste management technology adoption is a serious concern. In addition, it was discovered that the response to green construction was not a significant concern. The information supplied by the FBSC framework revealed that more must be done in terms of green environment creation for the case study because there is a performance gap of 3.24%. One of the limitations of this article is that it did not employ a standard approach to determine the importance of the criteria; instead, it relied on a direct link between the criteria scores and their linguistic significance. This constraint represents a knowledge gap that needs to be investigated further. Finally, it will be interesting to see if machining learning algorithms can be used to assess low-cost housing estate readiness for green environment creation in the future.

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Towards the Adoption of Modular Construction in Residential Projects in Egypt: Benefits, Barriers, and Enablers

Ali Hassan Ali[1](✉), Ghada Mohamed El-Mahdy[1], Ahmed Hussein Ibrahim[2], and Ahmed Osama Daoud[1]

[1] Civil Engineering Department, Faculty of Engineering, The British University in Egypt (BUE), Cairo-Suez Desert Road, Al-Shorouk, Cairo 11837, Egypt
{ali.hassan,ghada.elmahdy,ahmed.daoud}@bue.edu.eg

[2] Construction Management Engineering Department, Faculty of Engineering, Zagazig University, Zagazig 44519, Ash Sharqia, Egypt
mekky@zu.edu.eg

Abstract. The construction sector is one of the largest sectors globally as it has a positive impact on the countries' economies. In the past few years, buyers and investors have shown interest in the prefabricated homes industry. Modular construction (MC) is a technique of manufacturing volumetric three-dimensional (3D) fully finished modules at offsite facilities and then transporting them to the construction site for installation. MC in Egypt is currently implemented only in infrastructure projects; however, it is still not widely implemented in residential projects. According to different researchers, MC's application in construction projects has significant benefits regarding sustainability, time, cost, and quality assurance. Unfortunately, the introduction of MC in the construction industry has multiple barriers that face its implementation, such as attitudinal barriers, knowledge barriers, technical barriers, and financial barriers. Fortunately, those barriers can be tackled through enablers that facilitate the accomplishment of the adoption of MC in residential projects in Egypt. Therefore, this paper, through a comprehensive review of recent research papers and technical and governmental reports, aims to: (1) identify the current scale of MC implementation in residential projects in Egypt; (2) explore the main benefits and barriers of implementing MC in residential projects in Egypt to promote its adoption in favour of Egypt's vision 2030; and (3) investigate the enablers that can overcome the barriers and facilitate MC adoption in residential projects in Egypt. Findings from this study are expected to be beneficial to local and central governments, academics, construction industry practitioners, and policymakers contending with a sustainable Egyptian construction sector.

Keywords: Modular construction · Sustainable construction · Benefits · Barriers · Egypt · Offsite construction

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1 Introduction

As the population increases worldwide, the development of civil infrastructures and buildings is needed to fulfil society's housing needs. The construction sector makes up approximately 13% of the world's gross domestic product (GDP), which is rapidly increasing and may become 14.7% by 2030. Notwithstanding the economic advantages, the construction sector is placing a severe burden on the environment by overconsuming natural resources, increasing carbon dioxide emissions (CO_2), and increasing the amount of waste in landfills [1].

Modular construction (MC) is regarded as a sustainable offsite construction method. It is a significant breakthrough worldwide in improving and increasing the level of productivity in the construction sector, therefore, decreasing the subsequent social and environmental negative impacts due to conventional construction methods' activities [2].

MC is a construction method that is implemented by constructing a building utilising three-dimensional (3D) or modular units, which are then produced and assembled in a factory [3]. Also, MC is a technique of manufacturing 3D-volumetric fully finished modules at offsite facilities and then transporting them to the construction site for installation. This technology is part of the offsite construction (OSC) techniques [4].

The implementations of modular construction are multipurpose. It has the exact implementation as conventional construction; however, it has extra values like quality, flexibility, and movability. It can be implemented in construction projects that are multi-storey and high-rise. In addition, single-storey and low-rise construction can also benefit from modular construction. Moreover, modular construction can be utilised for the following applications like office and administration, residential, education, retail and commercial, infrastructure, and healthcare and hospital [3].

This paper's findings are presumed to be advantageous to academics, professionals in the construction sector, local and central governments, and policymakers taking on a sustainable construction sector. This is achieved through the aims of this paper, which are discovering how MC has been adopted and applied in residential projects in Egypt. In addition, identifying the barriers and the benefits of adopting and applying MC in Egyptian residential projects. Moreover, determining the enablers that aid in overcoming the barriers and therefore ease the implementation of MC in Egypt's residential projects.

2 Research Methodology

The research methodology adopted in this paper depended mainly on reviewing several research papers related to the MC over the past decades to extract MC's benefits, barriers, and enablers in order to facilitate the adoption of MC in residential projects in Egypt. The research plan and approaches mainly depended on exploring several internet databases, such as Web of Science (WOS), Google Scholar, Scopus, ProQuest, and JSTOR, which were utilised to perform a systemic search to review the theses and research papers regarding the topic. According to Daoud et al. [5] these databases are considered reliable to serve the purpose of extensive research [5]. Certain keywords, or a combination of those keywords, were used to aid in the search, such as 'Modular Construction', 'Modular Integrated Construction', 'Egypt', 'Construction Building

Industry', 'Sustainability', 'Offsite Construction', 'Barriers of MC', Benefits of MC', and 'Enablers of MC'. Accordingly, 26 references were retrieved from this extensive search covering the last ten years. It was made sure to categorise these papers into three main themes: benefits, barriers, and enablers. The retrieved references include journal papers, conference papers, theses, and books. In order to avoid duplication, the different investigated themes were filtered to avoid repetition of components, in which the components mentioned in one reference are not mentioned in the other. Despite that, these references focus on developing and developed countries, not mainly on Egypt; however, the retrieved information (i.e. components) is planned to be used in a future study focusing mainly on the Egyptian construction industry. The paper structure is based on the following: it starts by exploring the nature of the Egyptian construction industry. Afterwards, it investigates the current methods of project execution in Egypt. Then, it discusses the characteristics of modular construction. In addition, it sheds light on the benefits of mc. Furthermore, it focuses on the barriers to applying modular construction. Moreover, it determines the enablers of modular construction that facilitate the adoption of MC and overcome the barriers. Finally, the conclusion and recommendations for future research are defined.

3 Results and Discussion

3.1 Nature of the Egyptian Construction Industry

The construction sector holds a prominent position in the economy of Egypt and, by its supply of physical facilities, has a significant effect on the overall economic and social development and growth of the nation. The latest changes in Egypt have impacted the industry's environment, especially the project's nature, the resource markets and the established technologies [6]. Nowadays, the government of Egypt is carrying out a large number of mega projects following Egypt's vision 2030's political agenda [7].

Since 2019, Egypt has hurriedly constructed mega-projects, including roads, new cities, tunnels, and bridges. The Ministry of Housing, along with the New Urban Communities Authority, have been working on constructing 14 different new cities termed "Fourth Generation Cities". The New Administrative Capital, New Ismailia city, New Alamein, New Mansoura, and East Port Said are all among those projects. These new 14 cities make up a total area of 380,000 acres [8].

3.2 Current Methods of Projects Execution in Egypt

Mokhtar [9] investigated the execution method of construction projects in Egypt. It was indicated that there are three primary stages of building construction as follows: (1) pre-construction phase; (2) construction phase; and (3) post-construction phase [9]. The pre-construction phase is the job of the civil engineers and the architects to select the project working on the project's design. This stage involves surveying, land rehabilitation, testing the soil, and preparing the site to begin the next construction stage. The second stage, which is the construction stage, is the main stage of the construction industry. It includes the works on site, laying the foundations, framing the structures, and installing the utility systems. Therefore, this stage involves utilising heavy machinery (e.g., concrete mixers, loaders, cranes, equipment, devices for measuring and levelling, fixtures, and others). This stage also consumes a large quantity and variety of raw materials. The materials used are mainly steel in multiple forms, shapes, and grades, concrete with different types according to the onsite environment type and the construction type, mining and mineral materials, wood, and composites. The third and final stage, which is the post-construction phase, entails installing utility systems, such as air conditioning, communication, water piping and fittings, gas, electricity, and plumbing and sewage [9]. Therefore, it is concluded that residential projects in Egypt use the traditional construction method and have not yet adopted the MC method.

After investigating the adoption of MC in Egypt through reviewing the current projects executed by the largest construction firms in Egypt, it has been indicated that MC has only been adopted in infrastructure projects like bridges [8–10]. The system of MC started to be utilised only in specific items in the bridge; however, it does not include all of the project's elements [10]. The MC system in bridges is used in constructing and manufacturing the superstructure elements like the precast concrete girders, prefabricated steel girders, and slab decks. These elements are manufactured offsite and then transported to the construction site to be directly installed [11]. Even though MC is utilised in several parts of bridge projects, but it is not utilised widely in all the project items, such as the piers and the abutments [12]. It is worth mentioning that whenever MC is adopted in the construction phase of a project, the efficiency and sustainability aspects are enhanced, as demonstrated in the following subsections.

3.3 Characteristics of Modular Construction

MC has multiple powerful and essential characteristics. First, high quality identical modular since modular construction's main feature is the identical or standardised modules [13]. They are mass-produced in a manufacturing facility or a controlled factory that produces high-quality modules. The manufacturing facilities have strict programs for quality assurance/quality control (QA/QC) with independent protocols for inspection and testing. Second, sustainable and greener construction since building in a controlled environment decreases the production of waste, and it creates less noise and less disturbance [13]. Moreover, it has greater flexibility and reuse because it can be disassembled. The modules can be relocated or even refurbished for new use, which reduces the demand for raw materials and helps promote sustainability. Third, it speeds up the project schedule since the factory processes are more efficient and faster, replacing the site activities that are unproductive and slow. Also, the construction of modular buildings takes place simultaneously, which enables the projects to be finished in half of the time required for the conventional construction method [13].

3.4 Benefits of Modular Construction

According to different researchers, implementing MC has several benefits in regards to sustainability, time, environmental effect quality, safety, and productivity. Table 1 demonstrates the benefits according to the research conducted in the last decade.

Table 1. The benefits of modular construction

Benefits of modular construction	References
• Production of fewer amounts of waste by accurate purchasing planning and cutting of the materials • Process logistics also benefit the environment, like the shortened production times causing a less energy requirement • Automobile trips by suppliers, subcontractors, and contractors to the construction site are decreased or even replaced by fewer trips by the suppliers of the factory workers that deliver in bulk to the manufacturing facility	[14]
• The utilisation of less material that is lightweight, as well as less production of waste in comparison to the conventional construction • Higher quality because of the factory-based construction process where QA/QC are implemented • A decrease in the requirement for onsite labour gives rise to safer construction regarding the site and factory activities • During construction, there is less production of noise pollution in the neighbourhood • Modular building has the capability of disassembling and reusing the modules somewhere else	[15]
• Extensive utilisation of recycled materials (such as aluminium, steel, and timber) • A reduction of up to 80% of waste materials during the works occurring onsite • A reduction of up to 60% of emissions of CO_2 and the annual energy consumption throughout the building life cycle	[16]
• The ability to decrease the construction schedule significantly by dodging the unavoidable delays in conventional construction methods • An increase in the productivity of the labour • The chances of theft of equipment and materials on site are significantly reduced since the construction's costly elements are finished in the factory and then assembled on site	[17]

3.5 The Barriers to Applying Modular Construction

The introduction of MC in the construction industry is disruptive and commands major changes to some established practices. Seeing as how the construction sector is slow in adopting innovation, the introduction of MC is fighting a confrontational welcome among a complex host of barriers [18]. There are multiple barriers that face the implementation of modular construction worldwide in the construction sector.

Those barriers are classified into the following categories: (1) attitudinal barriers; (2) knowledge barriers; (3) technical barriers; and (4) financial barriers [18]. The different types of barriers are investigated in detail in Table 2.

3.6 Enablers of Modular Construction

Table 3 includes the enablers, which is an additional step that can overcome the barriers and facilitate the accomplishment of the adoption of MC in residential projects in Egypt.

Table 2. The barriers to modular construction

Categories	Barriers to modular construction	References
Attitudinal barriers	• Scepticism and resistance of clients to innovation and change • The dissatisfaction of current end users • Lack of confidence in the MC industry • Claims that MC is expensive • Claims that there is a low market value for modular homes	[19–21]
Knowledge barriers	• Inexperience of suppliers, manufacturers, and designers with the components of MC • Lack of suppliers and manufacturers providing products for MC • Unskilled and untrained operatives • Insufficient understanding of the approach of MC • Lack of experience in the design of modules and their installation • Limited understanding of the stakeholders' roles	[18, 22–24]
Technical barriers	• Insufficient technology and testing modules institutes • Inability to modify the design during the construction stage when required • Restraints to the design because of transportation restrictions • Insufficient educational programs regarding structural and architectural aspects • Limited chances for the repeatability of a component on the same project or future projects • Inadequate capacity to manufacture as well as supply products for MC • Insufficient research and development centres for MC	[21, 24–27]
Financial barriers	• Difficulty in accomplishing returns on a high initial investment • Difficulty in achieving the finances needed for the MC projects • Excessive fixed overheads and significant capital are needed in executing the factories • Higher cost of capital • A longer period of capital possession • Excessive costs of rectification and rework • Expensive logistics • Contractors asking for high bidding prices • Need labours that are skilled with higher wages • Extra project planning, design and procurement cost	[24, 25, 28–31]

Table 3. The enablers of modular construction

Barrier's categories	Enablers that solve the barriers	References
Attitudinal barriers	• The stakeholders of construction projects need to be made aware of MC through marketing campaigns, seminars, and exhibitions • The benefits from early completion need to be identified by the owners, which are early product sales, less costs for owner site supervision, less site-safety and site-productivity risks (downtime and costs) and several more. Those benefits are usually ignored, or their effects are underestimated	[32, 33]
Knowledge barriers	• Engineers and labours (practitioners) need to enhance their MC skills and knowledge through workshops and training • The owner and contractors should perform early screening studies during the selection phase for choosing from different fabrication factories to guarantee fulfilling the project requirements • Hiring foreign experts to benefit from their expertise in the field of MC • The project stakeholders and teams have sufficient experience and knowledge	[32–34]
Technical barriers	• Early design completion and freezing • Steer clear of situations where the size of the OFE is substandard or wrong for the modular approach (e.g., aspect ratio) as it could restrict the options for transportation • The presence of a sample pilot project with full MC adoption to benefit from early studies regarding equipment selection, technology selection, and the scope of modular work • The owner should be willing to invest in early studies into modularisation opportunities in order to capture the full benefit	[32–34]
Financial barriers	• Contractors and owners should use past modular projects in order to gather cost-saving benchmarking data • MC reduces the cost and makes savings from the following aspects: differences in labour wage rates and decrease supervision cost of labour and material • MC eliminated or reduced some additional costs such as the cost of scaffolding, cost of material storage, and cost of safety management	[33]

4 Conclusion and Recommendations

Nowadays, the government of Egypt is carrying out a large number of mega projects, following Egypt vision 2030's political agenda, such as the establishment of new cities, the national projects for the development of Upper Egypt, national projects for roads and bridges. The literature illustrated that there is a lack of adoption of MC in Egypt and the current scale of implementation of MC in residential projects in Egypt is too low. According to the portfolio of the largest construction firms in Egypt, it is concluded that MC has only been adopted in infrastructure projects like bridges. The system of MC started to be utilised only in specific items in the bridge; however, it does not include all of the project's elements. This paper reviewed the various characteristics and features of MC, such as (1) the high quality; (2) the sustainable and greener construction; (3) the flexibility and reuse; and (4) the low project time. Furthermore, it reviewed the significant benefits regarding productivity, time, safety, quality and sustainability that will positively affect the Egyptian construction industry if MC is applied and adopted in residential projects. Moreover, it investigated the different types of barriers that may face MC adoption in residential projects in Egypt. Those barriers are (1) attitudinal barriers such as scepticism and resistance of clients to innovation and change; (2) knowledge barriers such as lack of experience in the design of modules and their installation; (3) technical barriers such as Inability to modify the design during the construction stage when required; and (4) financial barriers such as higher cost of capital. In addition, this paper highlighted the enablers that may help in mitigating the barriers and facilitating MC adoption in residential projects in Egypt. Due to the previously mentioned problem, future research is recommended to develop and introduce a conceptual framework that can guide the practitioners and professional organisations in the Egyptian construction industry on adopting key enablers towards promoting the adoption of MC in residential projects in Egypt. Moreover, the MC method must be spread widely in Egypt by including it in the universities' curriculum and promoting it as a topic of interest in academic research. Furthermore, the Egyptian Syndicate of Engineers must make an awareness campaign to spread the importance of implementing MC in residential projects in Egypt. Besides, the Egyptian government must offer incentives to encourage construction companies and developers to apply MC in any of their new residential projects to meet Egypt Vision 2030 regarding sustainable development.

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Retrofitting and Maintaining Existing South African Government Buildings for Improving Safety from Fire: A Comprehensive Review of Literature

Evans Magaisa, Kathy Michell(✉), and Alireza Moghayedi(✉)

Sustainability Oriented + Cyber Research Unit for Built Environment (S⊕CUBE), Department of Construction Economics and Management, University of Cape Town, Cape Town, South Africa
{kathy.michell,alireza.moghayedi}@uct.ac.za

Abstract. Fire is wrecking Government and other buildings in South Africa at a cost of hundreds of millions to billions of Rand plus an incalculable loss of human and other life. The factors that compromise the safety of South African government buildings to fire inarguably emanate from poor maintenance of the building stock that also comprises many old buildings with resultantly obsolete building services. This trend prompted this study to investigate how to utilize technological innovation in retrofitting and maintaining the existing South African government buildings in order to improve their safety from fire. Harnessing technology into government buildings will help avoid fire outbreaks, reduce the spread of fire and minimize the response period in the case of an outbreak. The purpose of this paper was to document a critical review of scholarly sources in order to understand the different, carefully selected, latest technologies that can be incorporated into the building fabric and around the government premises to improve reactive and proactive firefighting capacity. The internet of things, automatic robots, automatic sprinklers, water mist suppression systems, artificial intelligence, building information modelling, drones, smart cameras and smart fire alarms were identified and interrogated to understand how they can improve buildings' fire fighting capacity as well as understand their strengths and weaknesses. The technologies were recommended for South African Government buildings. The study will potentially benefit the Government of South Africa by recommending how to retrofit and maintain the existing stock of government buildings in a bid to improve their resistance to, and reduce damage from, fire outbreaks. Ultimately, the result will be safer public workplaces and a huge saving from the ongoing loss through fire wreckage of government buildings.

Keywords: Existing buildings · Fire · Government buildings · Maintaining buildings · Retrofitting buildings · South Africa

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1 Introduction

While fire is an essential element of technological advancement, it, however, continues to cause serious damage to buildings and unfathomable loss through fatalities and injuries to employees, loss of production time and goodwill [9]. Grant et al. [10] concur that fire losses remain too high and firefighting too hazardous throughout the world, causing massive losses. This trend, coupled with the fact that fire protection measures in buildings generally do not account for all contemporary fire hazard issues, has made buildings' fire safety a growing concern [15]. In the context of the South African Government, the problem is exacerbated by the existence of a large stock of old buildings which are at the same time poorly maintained [8]. As a result, South African Government buildings house obsolete building services, among them firefighting systems, which compromises their resistance to fire outbreaks as well as their firefighting capacity. South African government buildings are therefore at a big risk of fire, which poses a big risk of loss at a cost of millions of Rand and risk to the life of building occupants. The most important of the recently affected buildings is the Parliament Precinct in Cape Town, where the first fire outbreak was reported on 16 March 2021 in the old assembly building at the Parliament as a result of an electrical fault. A second fire outbreak followed on 2 January 2022 that devastated the parliamentary buildings and their contents and assets, including Parliament's historical treasures of heritage [24]. This is despite the fact that government buildings are important touchpoints that define the image of the government for the communities they serve, and colour the interactions between citizens and public servants.

Since developments in building technologies impact significantly on fire safety in buildings, it is necessary to review the manner in which fire safety systems were provided in South African buildings in the past [19]. Retrofitting and maintaining South African Government buildings are therefore necessary, as they are critical functions of the operation phase of the life cycle of buildings, that help counter the effects of deterioration, which all buildings face over time, thereby keeping buildings in a good operational state safer from accidents and injuries [31]. De Lille [8] concurs to the need for refurbishing existing South African Government buildings so as to reduce risk of occupancy. Fire safety in buildings can be significantly increased by exploiting the abundance of new technologies and cyber information systems to improve performance, safety, prediction and resilience in firefighting in buildings [10]. concur that rapid developments in information technology, data analytics and other detection monitoring systems have provided the basis for fire safety researchers to rethink and improve fire safety strategies in the built environment primarily for the protection of the lives of building occupants. The need for such new technologies is of greater importance when it comes to existing buildings, which face a greater challenge in retrofitting for fire safety as compared to new buildings [34]. The goal of this paper was therefore to critique how incorporation of latest innovation technologies in the building fabric of existing South African Government buildings can reduce their chances of catching fire and increase effectiveness in their response in case of a fire outbreak.

2 Retrofitting and Maintaining South African Government Buildings

Government buildings refer to physical building structures owned by the Central and Local Governments of South Africa. The role of government buildings is to support core functions of the Government in fulfilling its mandate of delivering public services such as education, health, justice and social welfare. It is the goal of the Government to effectively manage the operation of its buildings and spearhead a positive transformation of the built environment [20]. Government buildings are pivots that support the pillars of public service delivery as well as benchmarks for the standards of the facilities management of the country's buildings. The Government of South Africa has a central role in providing leadership in the facilities management of buildings, and should lead by example and ensure provision of buildings that are highly efficient in operation and encourage other sectors to follow [21]. The South African Government building stock consists of many, very old, dilapidated buildings that need face-lifting and upgrading of obsolete components in order to improve sustainability and operational efficiency [22]. This is, however, common in many countries where the public sector buildings are characterised by a huge backlog in proactive maintenance programmes, mainly due to shortage of resources [26].

Retrofitting Government buildings using the latest firefighting technologies is therefore necessary so as to replace the obsolete firefighting systems with new technologies that revive the buildings' firefighting capacity. Firefighting systems are assemblies of interrelated or interdependent parts forming a more complex and unified whole and serving the same purpose of detecting and extinguishing fire [6]. The need for retrofitting existing buildings emanates from the need to capture evolving technologies that were not existent when the buildings were designed, and improve the firefighting capacity of the buildings. The design, installation and maintenance of a firefighting systems should be done in accordance with regulations of the National Building Regulations Part T: Fire Protection (SANS 10400-T) of 2011), Republic of South Africa as guided by the National Building Regulations and Building Standards Act (1977) (Act Number 103 of 1977). Prior to retrofitting a building, fire performance tests must be carried out to determine the effectiveness of the fire fighting system. After installation, a rigorous and proactive approach to maintenance of the fire fighting system is necessary in order to ensure that it will be efficiently working by the time of a fire outbreak and reduce the problems of slow response time, false alarms. In order to remain effective, firefighting systems should be maintained according to the manufacturer's recommendations and the relevant technical standards [32].

3 Methodology

In this study, the literature review was used as an end in itself, to inform practice and provide a comprehensive understanding about firefighting in buildings [17]. While year of publication, language and type of article are among the criteria that was used to determine the relevance of the primary, secondary and tertiary sources for inclusion and exclusion in the study, more emphasis was put on logical and valid motives to answer the research question (Snyder, 2019). A problem centered approach was used to carefully select primary and secondary data sources that are most suitable in proffering a solution to the problem of fire in South African Government buildings [17]. In the event of a fire, the safety of the building occupants, the first responders and the protection of property is guaranteed through a combination of passive and active means. Passive fire refers to the integral part of the building layout and materials of construction that help in firefighting, such as firewalls to confine the fire, stairways to assist in rapid evacuation. Active fire protection systems are designed to come into play when a fire breaks out. Fire protection in buildings is achieved through a combination of both passive and active fire protection and management systems [4]. While passive fire protection systems are surely reliable once installed, it is the active fire protection systems, it is active fire protection systems that should have a quick response capacity in extinguishing or controlling the development of a fire in its initial stage. However, active fire protection systems usually have low functional reliability and unsatisfactory operational results [4]. A constructivist orientation was adopted, in which the researchers sought to accommodate new trends and insights from what is known, in a bid to improve active firefighting in buildings.

4 Discussion

The carefully selected, latest active firefighting technologies for buildings are discussed as follows:

The internet of things. The internet of things is a network of physical devices and objects embedded with electronics, software, sensors, and network connectivity which enable these objects to collect and exchange data and communicate with one another, in order to determine the health and status of things [13]. It offers facilities management the opportunity to understand in real time what is happening throughout every aspect and every component of a building and its operation and maintenance. The internet of things is crucial in facilities management as it enables having a building management system under computer monitoring and control for fire detection and suppression, tackling small fires, evacuation and major firefighting and integration of such systems with the architecture of the building [5]. The idea is to collect a wide range of information from a wide range of databases and sensor networks and the use of computational tools to analyze that information in order to make predictions of fire growth, building performance, occupant evacuation and fire suppression [10]. The internet of things uses heat and smoke-sensing terminals that have electronic chips responsible for collecting data on the room temperature and the level of smoke, before relaying the data to cloud platforms through a wireless network [29]. A fire can be detected much faster than when using traditional smoke detectors, before it can even emit smoke, therefore allowing quicker response. The data is then processed and relayed back to relevant department users and to the activation of other firefighting technologies. At a first fire incident, for planning purposes, the fire fighting authorities utilize information collected from the building on the causes of fire, from the community about the traffic, weather, police, hospitals and from the building occupants about the statistics of occupation on the building. The internet of things platform provides capabilities for device access, management and data analysis and storage. Shi and Shonglin [29] note that the internet of things systems have low power dissipation and high data accuracy. However, they are expensive to install. After detection of data, the terminals send the data to the central unit for processing, which will activate response of other technologies in order to combat the fire, which include automatic robots, automatic water mist suppression systems and fire alarms discussed below, though these technologies can still be efficiently utilized without the internet of things.

Automatic fire sprinklers and water mist suppression systems. Water has favourable fire extinguishing capacity because of its high heat capacity and high latent heat of vaporization than enables it to effectively absorb heat from the fire and provide a cooling effect, coupled with high expansion rate that enables the steam to effectively displace oxygen and fuel vapors [18]. Among firefighting technologies in buildings that use water as an extinguishing medium, automatic water sprinklers have been in use for a long time. Water sprinklers provide an automatic spray dedicated to the area of fire outbreak through the utilization of temperature sensitive elements in sprinkler heads that respond immediately to heat, hereby discharging the contents of the water main to which they are attached [12]. Another author the wet system is the simplest and most widely used application, in which the pipework is permanently charged with water [12]. Sprinklers are a quick solution to reduce and isolate fire damage, that uses less water to control a fire than the firefighting service, thereby preventing further damage from excess water [12]. However, automatic sprinklers discharge large amounts of water, and resultantly most of the water does not evaporate, but descends to the floor. This results in damage of the surfaces to which they are exposed, resulting in property damage. Further, water is wasted and more labour is required in cleaning.

By contrast, an automatic water mist sprinkler system is a spontaneous detection and actuation, water distribution system connected to a water supply, fitted with one or more water mist nozzles that discharge micro-water droplets intended to control, suppress or extinguish fire [32] Automatic water mist suppression systems function in almost the same way as water sprinklers. However, the water mist suppression system is designed to generate, distribute and maintain a concentration of very small droplets for sufficient time to control and suppress a fire. An automatic fire pump is required to pump water from the storage tank or the municipal mains, at a pressure that will be determined by a risk assessment on the building [32]. A very high percentage of the small water droplets rapidly evaporates as they enter the fire, thereby reducing the temperature and extinguishing the fire. Further, the rapid expansion of the tiny water droplets as they evaporate into steam reduces the oxygen concentration, which will also extinguish the fire [18]. The automatic nozzles contain a heat-sensitive device that is usually a fluid filled gas bulb, that holds a nozzle-sealing assembly against the water standby pressure [32]. When a fire occurs, the heat from the fire gasses will cause the liquid in the glass bulb to expand due to rises in temperature, and eventually cause the glass to shutter and release the valve-sealing assembly [32]. The nozzles are either installed below the ceiling (pendant nozzles), recessed into the ceiling (concealed nozzles) or mounted on to the walls close to the ceiling (sidewall nozzles) [32]. Regular maintenance of the water mist systems should be implemented in order to ensure effective performance in the event of a fire. The orifices of the nozzles of water mist suppression systems are very small and more prone to blockage, therefore strainers are used to filter out any dirt particles from the water [32]. The water mist fire suppression therefore provides economy in the use of water, thereby minimizing water-damage, using only one quarter of the water used by sprinklers [18]. It therefore reduces water wastage and does not affect the surface exposed to it and does not cause an electrocution, and therefore is useful in locations that house important properties and documents ([18]: 17898).

Automatic robots. While robots can work effectively using their technology, improved management can be gained through the use of internet of things-based mobile robots. It is very important to contain the spread of a fire after it has started, therefore the need to always make the necessary assumption that the fire will start. Fire causes severe damage to buildings and firefighting, saving lives and stopping a fire disaster present major risks, hence a technological breakthrough is necessary in order to replace people from the dangerous situation that automatically detects, navigate and suppress a fire before it rages out of control ([25]: 2437). it automatically detects a fire, a water spraying mechanism is triggered to extinguish the fire. Robots use ultraviolet sensors that detect fires, and automatically sound an alarm and activate an electronic valve that sprinkles water on the flame [14]. Robots are important in firefighting as they reduce exposure to dangerous, unfriendly, unhealthy and life threatening environments characterized by long working hours, high temperatures, dust, low humidity and collapsing buildings [14]. Robots help reduce the load of firefighters in huge disasters and can be used to effectively rescue more victims, making human life safer and firefighting more economic [14].

Artificial intelligence. Artificial intelligence is an umbrella term that refers to the wide range of technologies and applications that display intelligent behaviour by analyzing their environment and taking action with some degree of autonomy, in order to achieve specific goals [3]. Artificial intelligence techniques are capable of recognising the fire before the alarm system can [2]. Artificial intelligence helps firefighters to diagnose cardiac arrests faster and autonomous vehicles move emergency responders and equipment [30]. Artificial intelligence also helps to identify potential fire hazards and ensure a proactive approach to avoid them [30].

Building information modelling. Salamonowicz et al. [28] notes that smoke in a building presents the greatest threat to life of building occupants and firefighters. Ghalaenoi et al. [11] assert that it is important to have means of evacuation in an emergency in order to save lives. Sabbaghzadeh et al. [27] notes that a proactive approach during the design stage is necessary to provide occupants with safe evacuation and cut down on the number of fatalities and injuries, through studying smoke propagation in conjunction with other factors that affect evacuation such as familiarity with the building and congestion. Building information modelling can be updated during the renovation of the facility to create an as-built record of construction conditions and ultimately create a complete and living record to support facilities management.

Smart fire alarm systems. Fire alarm systems should provide audible sound in the case of a fire outbreak, alarming concerned individuals to call the fire department and occupants to evacuate from the building or help in fighting the fire. A slow emergency response time is detrimental and is one of the contributing factors why fires can consume the whole building or people's lives. This was the case on the fire outbreak on the Parliament Precinct in Cape Town. Another challenge is false alarms, which are caused by false positive readings of the fire alarm systems, resulting in panic and consumption of firefighters resources. The internet of things is effective in monitoring fire alarm systems to the nearest fire department and the users know about a fire incident as soon as fire is detected [23].

Smart cameras. While fire alarms detect smoke, carbon monoxide or flames, these technologies only work out when fire has already broken out. Thermal cameras create an image from infrared radiation that corresponds to the temperature distribution field on the surface of the object, thereby determining the temperature change rate [16]. There is therefore a necessity to predict a potential fire accident when the temperature rises rapidly using remote and wide ranged thermal cameras. Smart cameras are unique, non-contact fire detectors capable of detecting a fire from a distance based on flame data or shape of the smoke [2]. Smart cameras are capable of fire detection in both daytime and night-time [2]. Smart cameras are also useful in detecting trapped in buildings and ensuring timely rescue [33].

Drones. Drones are also useful, in conjunction with smart cameras, in detecting and rescuing occupants trapped in burning buildings [33]. Drones can perform difficult or more dangerous tasks outside the building, for example, the use of camera equipped drones to carry out roof inspections. Drones provide an immediate, more efficient, less risky and more affordable inspection of structures to ensure appropriate serviceability and structural integrity, as compared to conventional methods [7]. In order to function effectively, a drone system should be used in conjunction with a platform that manages and changes their batteries and refills the fire extinguishing liquid [1]. While fire alarms detect smoke, carbon monoxide or flames, these technologies only work out when fire has already broken out. Thermal cameras create an image from infrared radiation that corresponds to the temperature distribution field on the surface of the object, thereby determining the temperature change rate [16].

Summary. The technologies discussed in this study can improve firefighting in different ways. However, it is acknowledged that inasmuch as they can all be useful, they vary in terms of the strengths and weaknesses as summarized in Table 1.

5 Conclusions and Recommendations

The firefighting technologies that were selected from the literature are effective in avoiding fire outbreaks as well as fighting fire outbreaks. The internet of things, artificial intelligence, and building information modelling are important in preventing the outbreak and spread of fires. The combination of smart cameras and drones is especially essential in rescuing trapped occupants and saving lives. Retrofitting all government buildings with the latest firefighting technologies is recommended in order to protect them and avoid further losses from fire. Replacing fire sprinklers with water mist suppression systems is recommended especially in rooms that house important documents that can be damaged by water. Proper facilities management practice in order to ensure proactive maintenance of the fire technologies is recommended so as to keep them up to good

Table 1. Firefighting technologies for buildings.

Technology	Levels of skills required to use the technology	Availability in the market	Effectiveness of technology in firefighting	Maintenance cost
Internet of things	8	3	10	8
Fire mist suppression systems	3	5	3	2
Automatic robots	9	1	7	9
Artificial intelligence	9	1	6	8
Building information modelling	7	3	7	6
Smart fire alarm systems	2	4	8	3
Smart cameras	4	6	6	5
Drones	10	1	8	10

Key 0–10 represents the extent of the positivity in the extent of the parameter

standard. An empirical inquiry is recommended for further study, to unpack a real life experience of the effectiveness of the firefighting technologies in the context of South African Government buildings.

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Assessment of the Perception and Practices of Sustainable Construction in the University of Nigeria

Nzoputa Blessed Madueme[1(✉)] and Chidozie Charles Nnaji[1,2]

[1] Department of Civil Engineering, University of Nigeria, Nsukka, Nigeria
{nzoputa.madueme,chidozie.nnaji}@unn.edu.ng
[2] Faculty of Engineering and Built Environment, University of Johannesburg, Johannesburg, South Africa

Abstract. Sustainable construction is becoming a more prominent issue in construction research. It is a multi-faceted issue encompassing the reduction of construction projects' social, economic, and environmental footprints. Government laws in industrialized nations such as the United States of America, the United Kingdom, and China already promote and accomplish environmentally friendly construction projects. However, emerging economies such as Nigeria appear to be lagging behind in both research and implementation of sustainable construction practices. This is due to a number of obstacles unique to these countries, including the economics, a lack of public knowledge, and, as a result, a lack of demand for sustainable constructions in these developing countries. This article makes an assessment of the perception and practices of sustainable construction in the University of Nigeria. In addition, the study looks into the impact of sustainable constructions on end users' perceptions of health in metropolitan environments in the post-coronavirus age. A multiple-choice questionnaire was designed in line with the existing and relevant literature in the subject area. These questionnaires were administered to residents in the university community. The University of Nigeria campus was chosen as a case study because it provided an urban, educated community with which to assure high-quality replies. This study will assist communities in developing countries such as Nigeria in achieving a sustainable and eco-friendly construction environment by utilizing simple, and cost-effective strategies.

Keywords: Coronavirus · Green construction · Perceived health · Sustainability · Sustainable construction

1 Introduction

The construction sector is one of the fastest-growing industries on the planet. At the same time, it has significant societal economic, environmental, and social consequences [1]. As a result of rising urbanization, construction has become a large energy user,

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accounting for 39% of worldwide energy expenditure [2]. The construction sector is also responsible for a significant amount of pollution created globally [3]. In recent years, sustainable construction has gotten a lot of attention as an alternate approach. Sustainable construction, also known as green construction, low-energy construction, and eco-construction, is designed to reduce the strain on natural resources while also restraining negative health effects by maximizing resource efficiency, reducing waste, and ensuring residents' well-being through improved living conditions [4]. Whereas sustainable construction is also referred to as green construction, it is worth noting that green construction focuses solely on the environmental aspect of sustainability while sustainable construction rests on all social, economic, and environmental pillars. Hence, sustainable or green construction gives rise to sustainable or green buildings. Governments all around the globe have recognized green construction as a critical step toward a more sustainable construction industry [5].

According to Kotkar and Salunkhe [1], the concept of green construction is based on four main points: lowering a structure's environmental impact, or rather its side effects, improving and increasing the health of structure occupants, saving and returns on investments to investors and the community, and life cycle considerations during the design and development process. Similarly, Raynsford [6] defines sustainable construction as a collection of procedures through which a successful and competitive industry produces physical assets (buildings, structures, supporting infrastructure, and their immediate environments) that (i) enhance living quality and provide consumer happiness, (ii) provide adaptability and the ability to accommodate future user changes, (iii) offer and foster aesthetically pleasing natural and social settings, and (iv) maximize resource efficiency.

As a result, the primary purpose of implementing long-term solutions is to improve people's quality of life. People in the construction business are starting to pay attention to sustainability in design and construction. Their objective is to reduce greenhouse gas emissions overall in order to promote human and environmental health [7]. Sustainable construction, as a result, has an impact on society's health. When it comes to human health, there is a contrast between perceived and real human health. Actual health is an individual's clinically measured entire health condition, whereas perceived health is a subjective evaluation of an individual's overall health status [8]. Despite the fact that people's perceptions of their health condition may differ from reality, authors [9, 10] have said that perceived health is often regarded as a trustworthy and legitimate indicator of an individual's health status. In the face of a worldwide health danger presented by the coronavirus, this is becoming increasingly relevant, particularly for poor nations. As a result, the purpose of this study is; (i) to assess sustainable construction techniques and infrastructure at Nigerian institutions utilizing the University of Nigeria as a case study, (ii) to investigate the adoption of sustainable construction practices by residents in the university community, and (iii) to investigate the influence of sustainable construction practices on the perceived health of residents in the post-coronavirus era.

2 Literature Review

2.1 Green Construction in the Global View

Green construction requirements have been included in construction rules in a number of nations worldwide. In southwest China, the Natural Resources Defense Council (NRDC) assisted the Ministry of Construction in developing an energy efficiency standard for both residential and public buildings [11]. China's Eleventh Five-Year Plan approved the standard, which required a 50% reduction in a building's overall operational load [11]. The government also enacted various supporting systems, such as revising design regulations for heating, ventilation, and air conditioning (HVAC) systems and establishing an energy-saving review mechanism to enhance the built environment [11]. Technical Guidelines for Green Buildings were published in 2005 by the Ministry of Development and the Ministry of Science and Technology, encouraging the construction of green buildings [12]. The State Council announced the "Green Building Action Plan" at the beginning of 2013, and governments at all levels have continued to provide incentives to encourage the development of green buildings [13].

In the United States, the establishment of the United States Green Building Council (USGBC), a non-profit organization, in 1993 signified that green construction was about to take off. Green building energy efficiency was emphasized heavily in the Energy Policy Act of 2005, which resulted in green construction publications. Early in 2010, the ASHRAE 189.1 Standard for the Design of High-Performance Green Buildings was published. This standard outlines mandatory standards in all topic areas (site construction, materials, energy, indoor environmental quality, and water) and provides two options for compliance. California created its own state-wide green building code, known as CAL Green, in 2010, and a revised version was produced in 2013 that went into effect in January 2014" [14].

The UK Green Building Council (UKGBC) was established in 2007 in response to the 2004 Sustainable Building Task Group Report: Better Buildings, Better Lives, with the purpose of "radically altering" all areas of the UK's existing and future built environment. The UKGBC's establishment is anticipated to encourage green construction research. Based on China's, the United States, and the United Kingdom's experiences, it is believed that the creation of a UK council or special government programs will encourage study in this field.

According to Mao et al. [15], the United States was the most productive country in green construction research, accounting for 14.98% of all publications published. With 13.29% and 8.27%, respectively, China (including Hong Kong and Taiwan) and the United Kingdom finished second and third. European countries such as Italy, Spain, and Germany have likewise prioritized green construction.

The South African National Energy Development Institute (SANEDI) played a key role in influencing the energy efficiency of South African buildings under the National Energy Efficiency Strategy. SANS10400XA, which aided in the implementation of National Building Regulations such as Part X, which implements environmental sustainability, and Part XA, which entails energy usage within buildings; SANS1544, which regulates the allowance for energy efficient savings, under which building owners would be entitled to claim a deduction for proved energy efficiency savings in their facility; aids in the certification of energy performance for structures [16].

2.2 Green Construction in Nigeria

A few efforts have been undertaken in Nigeria to maintain a balance between all areas of sustainable development activities in the framework of developing a green construction environment. However, due to a lack of focus, the impact of these efforts has been limited. It's worth noting that in 2011, the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) hosted a workshop titled "Promoting Energy Efficiency in Residential and Public Sector in Nigeria" [17]. The purpose of the workshop was to examine the growing importance of green construction in Nigeria. However, the four-year project's results (2011–2015) showed that it failed to make a meaningful difference in Nigeria's awareness of green constructions [17]. According to a board member of the Nigerian Green Building Council, a project called "Small but Mighty" housing initiative, modular green housing was initiated to help address the country's affordable housing, power, water, and sanitation challenges, and was set to increase the relevance of green construction in the country [18]. Unfortunately, the workshop fell short of its goal of igniting politicians and the general public's interest in energy-efficient construction efforts. Nigeria has a population of about 170 million people, with the majority (60%) of the population living in a degraded environment [19]. As a result, the Nigerian built environment, both urban and rural, is beset by problems such as slum and squatter development, urban sprawl, pollution (land, air, and water), and urban flooding and erosion [20–22]. These issues provide major environmental, social, and economic obstacles to the country's long-term growth. This illustrates the country's incapacity to regulate environmental degradation and its consequences on the built environment.

2.3 Barriers and Contradicts of Green Construction Implementation

The largest important hindrance to global green construction expansion is frequently seen as higher prices [23]. Green construction adoption is also hampered by a lack of market demand and knowledge. Occupant satisfaction is crucial in terms of market demand. Paul and Taylor [24] polled employees on their work environment in terms of ambiance, calm, lighting, sound, ventilation, heat, humidity, and general satisfaction. Despite the lack of clarity, Khoshbakht [25] identified two global contexts: users in the west (primarily the United States and the United Kingdom) reported no significant differences in satisfaction between green and traditional buildings, whereas users in the east (primarily China and South Korea) reported significantly higher satisfaction than traditional building users.

3 Methodology

A quantitative research technique was used to attain the study's goal. Quantitative research, according to Bryman [26], is a research approach that emphasizes quantification in data collection, interpretation, and analysis. Thus, a quantitative research technique is defined as a method for counting and analyzing data statistically and estimating outcomes in numerical formats [27]. The study focused on the University of Nigeria community, hence the target population was university staff living on campus grounds. Based on a literature search, a questionnaire was created using a 5-point Likert scale, with 1 indicating strongly disagree, 2 indicating disagree, 3 indicating neutral, 4 indicating agree, and 5 indicating strongly agree. Respondents were asked to rate their extent of agreement to the presence of the various sustainable construction practices gleaned from literature in the University of Nigeria. Respondents were also required to provide a yes/no answer (yes = 2 and no = 1) to show their level of adoption of the various sustainable construction practices enumerated in their places of residence in the University of Nigeria.

3.1 Distribution of Questionnaire and Response Rate

The questionnaires were delivered to the respondents by hand through the convenience sampling approach. It should be highlighted that the survey participants received a total of 100 questionnaires, whereas 63 questionnaires were returned. The number of questionnaires distributed was obtained from Yamane's formula [28]:

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

where N is the population size (1000), and e is the margin of error (10%). The response rate, also known as the completion rate or return rate, is calculated by dividing the number of survey respondents by the total number of persons in the sample. It is most commonly stated as a percentage. As a result, the response rate is 63%.

3.2 Data Analysis

Descriptive statistical approaches were used in the data analysis. The process of explaining or summarizing quantitative data acquired in research in a clear and intelligible style (for example, tables and charts) is known as descriptive statistics [29]. It also gives a high-level overview of a vast quantity of data, as well as a logical and understandable representation of the data. The quantitative data received in the survey were analyzed using mean, percentage, and standard deviation in this study. The variables in the research are stated in broad terms with mean values and sorted in a hierarchical way. An internal reliability test utilizing Cronbach's coefficient alpha was used to assess the scale questions' reliability. Gallais et al. [30] argues that Cronbach's alpha coefficient must be more than 0.7 or at least 0.6 in order to be considered dependable. Table 1 shows that the alpha value for the 19 variables was 0.929, suggesting that the assessment using the five-point Likert scale was reliable. The Statistical Program for the social sciences (SPSS) 25.0 statistical software was deployed for data analysis.

4 Presentation and Discussion of Findings

4.1 Background Information

The result of the background information of the respondents revealed that 7.3% of the respondents had at least an ordinary national diploma (OND), 73.1% had at least a

Table 1. Reliability statistics for perception of sustainable practices in UNN.

Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items
0.929	0.928	19

bachelor's degree (BSc), while 19.7% had obtained a master's degree (MSc). In terms of age, 31% were between the ages of 16–20, 48% were between the ages of 21–25, 12% were between the ages of 26–30, 5% were between the ages of 31–35, while 4% were 36 years and above. The average age of respondents was between 21–25 years, reflecting that most of the respondents were the children of the campus staff who were at home. The result also shows that the majority of the respondents (92.7%) had at least a bachelor's degree, which shows that they were academically equipped to constructively interpret the questions asked and give a significant response to the questions of the study.

4.2 Perception and Adoption of Sustainable Construction Practices in UNN

This presents the results obtained, the impressions of the respondents were measured using a Likert scale with a range of 1–5, spanning from least agreement to most agreement.

4.3 Discussion and Implications of the Perception and Adoption of Sustainable Construction Practices in UNN

This study investigated the perception and adoption of sustainable construction practices in the University of Nigeria. The significant findings have been highlighted for further discussion. First, the results indicated that respondents' perceptions of sustainable construction practices in the University of Nigeria were mostly favorable, with an average of 60%, indicating that the university's level of awareness and presence of sustainability elements are somewhat above average. With a mean of 3.89 and 78%, the greatest percentage of respondents strongly identified the "Presence of vegetation around buildings", hence it is ranked first. The second-ranked sustainable practice was "Presence of timber structures or flooring" with a mean of 3.55 and 71%. "Use of inverters systems for electricity" was ranked third with a mean of 3.18 and 64%. The other variables identified all received an above-average ranking with the exception of "Presence of electric car and bicycle charging points" and "Presence of black water recycling system" which had means of 2.5 and 2.32 respectively. This result appears to be consistent with findings from previous studies in other developing countries such as South Africa [31], which based on the mean ranking analysis, found kitchen and water-closet (WC) water-efficient fittings, megawatt photovoltaic solar plants, and water metering for monitoring and leak detection to be the top three most important sustainable construction features in the Western Cape Province of South Africa. Also, in Turkey, Korkmaz et al. [32] reported that houses employ a range of solar technologies, including direct-heated ventilation air, solar flat-plate collectors, photovoltaic cells, and passive solar heating systems.

Table 2. Perception on sustainable construction practices in the University of Nigeria.

	Mean	Std. Deviation	Variance	Percentage	Rank
P-12 Presence of vegetation around buildings	3.89	1.161	1.348	78	1
P-13 Presence of timber structures or flooring	3.55	1.263	1.596	71	2
P-11 Use of inverters systems for electricity	3.18	1.373	1.886	64	3
P-19 Use of wind energy (e.g. wind turbines and wind power plants)	3.16	1.581	2.498	63	4
P-4 Use of photovoltaic solar panel system on building roofs	3.10	1.376	1.892	62	5
P-6 Presence of electrical sub-metering used for individual billing purposes	3.10	1.165	1.357	62	5
P-14 Renewable materials such as bamboo and rubber	3.08	1.320	1.743	62	5
P-7 Presence of borehole water and reverse osmosis plant cyclist and shower facilities	3.05	1.146	1.314	61	6
P-1 Use of kitchen and WC water-efficient fittings (e.g. censored taps and greywater collector)	3.00	1.414	2.000	60	7
P-10 Use of roof light and skylight (e.g. tear drops or atrium roof lights)	2.98	1.017	1.034	60	7
P-2 Presence of megawatt photovoltaic solar plant	2.94	1.329	1.766	59	8
P-9 Recycled glass and steel	2.88	1.595	2.545	58	9
P-5 Presence of economy cycle water recycling systems (e.g. rainwater harvesting)	2.87	1.271	1.616	58	9
P-17 Use of carpets made from 100% recycled material	2.82	1.349	1.820	56	10
P-3 Use of water metering for monitoring and leak detection	2.81	1.278	1.634	56	10
P-8 Heating and cooling provided by a three-pipe VRF system	2.69	1.148	1.318	54	11
P-15 Presence of biometric reader system (BRM)	2.56	1.263	1.594	51	12
P-18 Presence of electric car and bicycle charging points	2.50	1.364	1.861	50	13
P-16 Presence of black water recycling system	2.32	1.037	1.075	46	14
Total average				60	

Second, the findings of the adoption of sustainable construction practices show that inhabitants in the university community have been sluggish to integrate these practices. With an aggregate average of 39%, a larger percentage of the responses demonstrated inadequate adaptability. “Presence of vegetation around buildings” is the most often adopted practice, with 69% of respondents reporting that they had it in their residence. With 59%, “presence of timber buildings or floors” came in second, while “presence of electrical sub-metering utilized for individual billing reasons” came in third with 58%. As a result, while the University of Nigeria’s perspective of construction practices is mostly favorable, with an above-average value of 60%, the level of adoption of sustainable

Table 3. Adoption of sustainable construction practices in the University of Nigeria.

	Mean	Std. Deviation	Variance	% Yes	% No	Rank
AP-12 Presence of vegetation around buildings	1.69	0.464	0.216	69	31	1
AP-13 Presence of timber structures or flooring	1.59	0.495	0.245	59	41	2
AP-6 Presence of electrical sub-metering used for individual billing purposes	1.58	0.498	0.248	58	42	3
AP-7 Presence of borehole water and reverse osmosis plant cyclist and shower facilities	1.54	0.502	0.252	54	46	4
AP-11 Use of inverters systems for electricity	1.51	0.504	0.254	51	49	5
AP-4 Use of photovoltaic solar panel system on building roofs	1.44	0.501	0.251	44	56	6
AP-5 Presence of economy cycle water recycling systems (e.g. rain water harvesting)	1.44	0.501	0.251	44	56	7
AP-1 Use of kitchen and WC water-efficient fittings (e.g. censored taps and grey water collector)	1.42	0.498	0.248	42	58	8
AP-14 Renewable materials such as bamboo and rubber	1.42	0.498	0.248	42	58	8
AP-19 Use of wind energy (e.g. wind turbines and wind power plant)	1.39	0.492	0.242	39	61	9
AP-8 Heating and cooling provided by a three-pipe VRF system	1.34	0.477	0.228	34	66	10
AP-17 Use of carpets made from 100% recycled material	1.34	0.477	0.228	34	66	10
AP-10 Use of roof light and skylight (e.g. tear drops or atrium roof lights)	1.31	0.464	0.216	31	69	11
AP-2 Presence of megawatt photovoltaic solar plant	1.27	0.448	0.201	27	73	12
AP-15 Presence of biometric reader system (BRM)	1.27	0.448	0.201	27	73	12
AP-18 Presence of electric car and bicycle charging points	1.19	0.393	0.154	19	81	13
AP-3 Use of water metering for monitoring and leak detection	1.17	0.378	0.143	17	83	14
AP-16 Presence of black water recycling system	1.14	0.345	0.119	14	86	15
Total average				39	61	

Table 4. Influence of sustainable construction practices on the perceived health of residents in the post-coronavirus era.

	% Yes	% No	% Unsure
Sustainable buildings give me a perceived sense of improved health	74	22	4

construction practices is still low, with an average adaption value of 39% (see Tables 2 and 3).

Third, it can be concluded that sustainable construction practices lead to perceived improved health by residents According to the study's findings, 74% of respondents indicated that living in sustainably constructed buildings enhanced their health (see Table 4). This is in line with the results of Dipeolu et al. [33], Nalewaik and Venters [34] who described the benefits of increased health as having self-confidence and a sense of relief from stress and despair, as well as getting enough sleep despite their anxieties. According to Alcock and White [35], these are crucial mental health topics that are becoming more vital and relevant in the post-corona virus era.

5 Conclusion

Through a survey of residents presently staying at the University of Nigeria in Enugu State, this study analyzed the perception and implementation of sustainable practices in Nigerian institutions. The study indicates that there is adequate awareness of the issue of sustainable construction in the institution and that the general impression of the subject is positive. The study also supports the link between sustainable construction practices and perceived health, with the majority of residents agreeing that living in sustainably constructed buildings improves their feeling of well-being. Residents' adaptability to sustainable construction principles, on the other hand, was found to be minimal. As a result, the biggest impediments to the advancement of sustainable construction practices in developing countries are likely to be related to the economics, policies, and the availability of materials, rather than to the awareness of sustainable construction.

The findings of this study add to the body of knowledge by highlighting the state of sustainable construction practices, perceptions, and adoption in Nigeria using an urbanized university campus setting; an area that has received little attention in terms of research location in the country's discussion of sustainable construction practices. However, because of some limitations, caution should be exercised when extrapolating the conclusions of the study. The first is the possibility of selection bias in the study's sample. Further research with a broader population can be undertaken by spreading to additional campuses across the country rather than using only one campus as in this present study.

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Barriers to the Successful Adoption of Innovative Building Materials for Sustainable Construction: A Review

Modupe Cecilia Mewomo[1(✉)], Iseoluwa Joanna Mogaji[1], Anugwo Iruka[1], and Sina Abayomi Makanjuola[2]

[1] Department of Construction Management and Quantity Surveying, Durban University of Technology, Durban, South Africa
modupem@dut.ac.za

[2] Department of Building, Federal University of Technology, Akure, Ondo State, Nigeria

Abstract. The use of sustainable or innovative building materials (IBM) for sustainable construction has brought about many significant advantages to the construction industry. These advantages include increased productivity, environmental protection, efficient use of materials, etc. Despite these advantages, there are still numerous barriers affecting the successful adoption of IBM. However, this paper aims to outline and discuss the barriers influencing IBM and also recommend better ways for IBM adoption. To explore the present issues of barriers to IBM adoption, the study considered published academic journals and thesis to get the most valuable sources of information. Thus, the research findings identified 25 barriers but the 6 (six) most reported barriers were discussed in this paper; and they include lack of awareness and knowledge; lack of local authority and government involvement; poor funding for research and developments, training, and education; lack of clear benefits; lack of qualified staff or practitioners; and lack of building codes and, regulations on innovation. Therefore, identifying these barriers and providing recommendations might help to overcome the barriers to IBM adoption for sustainable construction.

Keywords: Innovative building materials · Sustainable construction · Construction industry · Barriers · Adoption

1 Introduction

According to [1], construction materials can account for up to 40% of the total cost of building projects; and [2] between 50–60% of the project cost. Even as construction activities improve peoples' lives, they also have a significant environmental impact. Construction materials have a huge direct and indirect impact on the global environment, not only because of large energy usage but also for the massive greenhouse gas emissions [3]. The building industry has a substantial environmental influence on the overall environment [4]. They are responsible for a large number of harmful pollutants, accounting for 30% of greenhouse gas emissions induced by their operation, including an additional 18% contributed by material extraction and transportation [5, 6].

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Sustainable construction is achieved when the construction industry employs more recycled, revitalized, and reused materials for construction while utilizing less energy and other natural resources. One of the main objectives of sustainable construction is to create a better-built environment for human lives. To achieve this objective, there is a need to focus more on sustainability techniques. Sustainable or innovative building material is an aspect of sustainable construction. Aside from technology and trends, innovative construction materials contribute to the advancement of construction innovation. Materials used for construction should be selected based on the project's specifications and suitability. According to [7] the latest advanced materials have the potential to change the way we create and retrofit buildings and they provide value by enhancing the performance and functionality of the building.

This paper focuses on the barriers affecting the successful adoption of IBM. This was achieved through the following questions:

1. What are the barriers that affect the successful adoption of IBM in construction?
2. What are the recommendations to the top barriers affecting IBM adoption?

Studying the concept and benefits of IBM and how they can act as barriers to IBM adoption, addresses a specific research gap through:

1. Collecting barriers of IBM by literature review from academic journals.
2. Identifying and discussing how the top barriers significantly influence the adoption of IBM by using a qualitative approach.
3. Providing recommendations to the top barriers.

The paper is structured as follows; The concepts of Sustainable Construction (SC) and Innovative Building Materials (IBM) are briefly described in the next section, followed by the research methodology. The section after the methodology covers research findings and discussion. Finally, conclusions and recommendations are presented.

In light of environmental impact, global warming, high usage of resources, waste generation, and pollution, technologies designed to promote sustainability are receiving special attention due to their importance in achieving 17 United Nations Sustainable Development Goals [8] with special emphasis on Goal 11 (sustainable cities and communities) and Goal 9 (fostering innovation). Therefore, the way the building sector could contribute to the creation of sustainable cities and communities is by the successful implementation of innovative building materials to ensure sustainable construction and safety for all.

2 Literature Review

2.1 Understanding Sustainable Construction

Langston and Ding [9] regarded sustainable construction as part of sustainable development that encompasses design, tendering process, site planning and organization, selection of materials, material recycling, and waste reduction. Sustainable construction is the process of creating a structure that is environmentally friendly and resource-efficient throughout its life. To improve performance, reduce the project's environmental problems, waste minimization, and be more environmentally friendly, sustainability in construction entails following appropriate practices in terms of selecting and sourcing material, construction methodologies, and design principles [10]. The goal of sustainability is to prevent depletion of energy, raw materials, and water, as well as deterioration of the environment caused during the life cycle of the facilities and infrastructure [11] (Fig. 1).

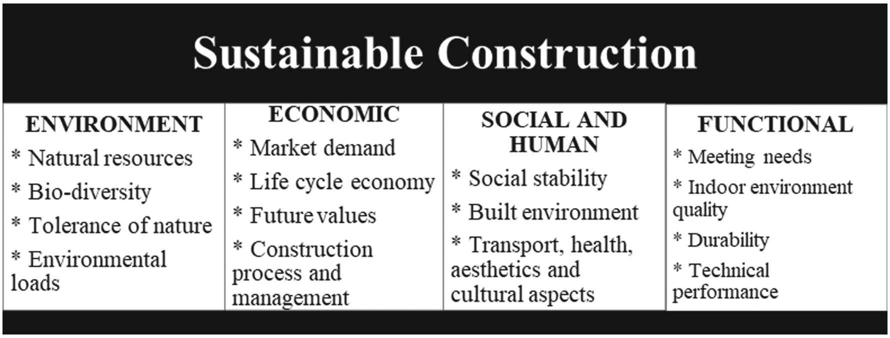

Fig. 1. Four components of sustainable construction [12]

2.2 Understanding Innovative Building Materials (IBM)

IBM is one of the aspects of the modern method of construction, others include innovative building technology and innovative project finance, and these construction methods are connected to sustainability. Innovative building materials are also known as sustainable building materials. Sustainable materials according to [13] are materials that are economically and thermally sustainable, and environmentally friendly, thereby requiring lesser energy than conventional materials and also low harmful emissions such as Carbon (iv) oxide emissions and renewable resources are used. According to [14] based on the material life cycle, three distinct groups of criteria are used to assess the sustainability of building materials. Also, the presence of one or more of these characteristics in building materials is guaranteed to be environmentally friendly.

(1) **In Pre-Building Phase** (Manufacture): Pollution prevention, waste reduction, recycled content, embodied energy of a material, natural materials
(2) **In Building Phase** (Use): Construction waste minimization, locally produced building materials, energy efficiency, water conservation, non or less-toxic materials, renewable energy systems, and longer life materials
(3) **In Post-Building Phase** (Disposal): Reusability, recyclability, and biodegradability

Also, according to the study carried out by [16] about 150 innovative building materials were analysed from various design considerations which include physical properties, physical performance, environmental properties, installation, and maintenance factors (Fig. 2).

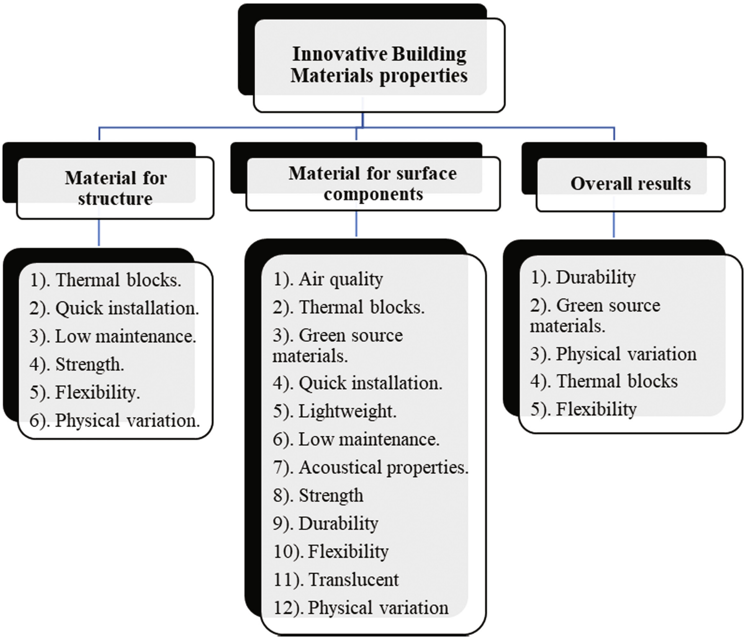

Fig. 2. The properties of innovative building materials [15]

Examples of IBM include 3D printed ceramics, 3D printing, aluminum foam, laminated wood, pollution-absorbing concrete, bio-receptive concrete, bamboo reinforced concrete, bricks made from pollutants, superplasticizers, and plaited microbial cellulose [16].

The benefits of IBM however go beyond cost savings, they should include reusing materials, lower environmental effects, thermally effective, adoption of renewable resources, economically sustainable, and low harmful emissions. The fundamental aims of sustainable or green construction according to [17] are to reduce environmental impact, improve end-user health and wellbeing, and provide a corresponding return on client investment. This study adds to [18] conclusions that the most essential benefits of IBM-designed buildings are low lifecycle costs, lower energy consumption, improved occupant health and comfort, overall productivity increase, and environmental protection. One of the primary benefits of using IBM in construction, according to [19] is a reduction in operating expenses, a rise in asset value and profitability, an improvement in occupant health and comfort, and an increase in staff productivity and satisfaction. The selection of IBM according to [20] is encouraged by toxic emissions reduction, carbon emissions reduction, employment creation, and, skill improvement opportunities for people. [21] affirms that the improvement in the quality of construction products, efficiency, and safety of the construction process is one of the most important ways towards achieving sustainable construction.

3 Research Methodology

The study adopted an exploratory approach using literature as its primary technique. To explore the present issues of barriers or challenges to IBM adoption, the study considered published academic journals and thesis to get the most valuable sources of information. To retrieve relevant papers for this study, a systematic literature search was conducted using the Scopus and web of science search engines. The search keywords used include 'barriers', 'innovative building materials', 'sustainable building materials', 'sustainable construction' 'construction innovation', and 'sustainable development'. The initial search was limited to articles published from 2000 to 2022. The IBM barriers reported in the relevant articles were critically reviewed, presented, and discussed in the next section of the paper and finally recommendations and conclusions were made.

4 Research Findings and Discussions

Through the review of the related papers considered in this study, a total of 25 barriers were identified as shown in table 1 along with their codes. In addition, the IBM barriers identified from the literature were ranked according to the number of times the barrier was reported by the papers. Therefore, Table 1 shows the several barriers that affect the successful adoption of IBM, but the six most reported barriers are B1, B2, B3, B4, B5, and B6. Showing that these are the major barriers hindering IBM adoption for sustainable construction.

This paper discusses only the top six barriers to IBM adoption.

B1: **Lack of awareness and knowledge**: It is vital to raise public awareness by providing adequate information and prioritizing education first since this promotes long-term behavior and this can also serve as a driver of IBM. Lack of information as a result of poor education and inaccurate research on IBM not only makes attaining good IBM knowledge difficult but also reduces the public awareness of IBM. Based on previous studies, lack of awareness and knowledge of IBM has become the top global barrier to the implementation of IBM. According to research conducted by [25, 28, 29], lack of awareness and understanding among people and developers influences the adoption of innovative construction materials. Most design and construction professionals lack awareness and education on the potential benefits of building innovative building technologies as the most significant barriers to the growth of green construction in Malaysia [32] and in Burkina Faso [28].

B2: Lack of local authority and government involvement: From this review, lack of local authority and government involvement has shown to be the second-ranked barrier to IBM adoption in this paper. This government-related barrier was identified in various

Table 1. IBM barriers identified from previous research

Code	Barriers	References
B1	Lack of awareness and knowledge	[22, 24–26, 28–31]
B2	Lack of local authority and government involvement	[22, 26–31]
B3	Poor funding for research and developments, training, and education	[24–26, 28–31]
B4	Lack of clear benefits	[24, 26–28, 30, 31]
B5	Lack of qualified staff or practitioners	[25, 26, 28–31]
B6	Lack of building codes and, regulations on innovation	[26–28, 30, 31]
B7	Inappropriate regulations/standards	[22, 24, 26, 27, 29]
B8	Cost & economic viability	[22, 24, 28, 29]
B9	Lack of public interest and buyers' demand	[22, 29–31]
B10	Lack of availability of green/ sustainable building materials on the market	[22, 23, 28, 29]
B11	Lack of end-user involvement and knowledge	[24–26, 28]
B12	Poor technical knowhow	[24, 25, 27, 28]
B13	Fragmented nature of construction	[24–27]
B14	Poor coordination and communication among project participants	[25, 27, 30, 31]
B15	Lack of top management commitment	[22, 25, 29]
B16	Unwillingness to change	[25–27]
B17	Learning/training period	[22, 28, 29]
B18	Temporary nature of construction (one-off construction industry)	[24, 25, 27]
B19	The perception that the industry is doing well without it	[24, 26]
B20	Lack of green/innovative building databases and access to information venues	[28, 32]
B21	Project delivery method	[27, 28]
B22	Lack of exemplar demonstration projects	[23]
B23	Poor innovation motivators in an organization	[25]
B24	Lack of sustainability measurement tools	[23]
B25	Associating sustainable concepts with luxury living	[22]

literature considered for this study [22, 26–28, 30–32]. The study conducted by [29] also noted a lack of implementation and enforcement of the law by local authorities and the government as a barrier that affects the practice of sustainability in the building industry in Nigeria.

B3: Poor funding for research and developments, training, and education: Inadequate funding for research and developments, training, and education (from the government) is ranked third among the top six IBM barriers identified in the literature. There is lack of a long-term financing foundation for the national research and development (R&D) center. Adequate funding for training and education from the government is important for promoting IBM adoption. In essence, adequate training serves as a driver that makes people adopt and incorporate IBM for their building projects. Despite the importance of research and developments in encouraging IBM adoption among the public and stakeholders, studies have shown that they are still lacking in many countries thereby affecting IBM adoption [24–26, 28, 30] and [31]. Active research activities foster innovation but require adequate funding. Therefore, inadequate research funding is a barrier to innovation.

B4: Lack of clear benefits: One of the commonly perceived barriers is people's lack of awareness of the need for IBM as well as their lack of understanding of its numerous benefits and also lack of database and available information on IBM [26, 28, 30, 31]. The results indicate that the lack of clear benefits hinders the widespread adoption of IBM. However, this finding has several implications for both governments, the public, and other stakeholders.

B5: Lack of qualified staff or practitioners: The lack of qualified workers with the appropriate technical experience needed to properly handle or install innovative building materials is a rank fifth among the top 6 IBM barriers identified in the literature review. Innovation demands some level of expertise without which innovation may be hampered [24]. Highly qualified professionals are essential for the inception and management of innovation. However, this has an impact on the level of innovation of a team.

B6: Lack of building codes and regulations on innovation: From our review, lack of IBM codes and regulations has been identified as the sixth most reported barrier. These barriers were identified in various research papers [26–28, 30, 31]. Mandatory IBM codes and regulations are lacking, which hinders individuals from adopting IBM; thus, the development of codes and standards would be beneficial in facilitating IBM adoption.

5 Conclusion and Recommendations

A systematic review of literature on barriers to IBM adoption was conducted for this paper. Scopus and web of science search engines were used to collect relevant academic journal articles reviewed in this study.

From the first objective of reviewing the literature on IBM barriers, it was found that there are numerous barriers affecting IBM adoption but the top 6 barriers in the paper such as lack of awareness and knowledge; lack of local authority and government involvement; poor funding for research and developments, training and education; lack of clear benefits; lack of qualified staff or practitioners; and lack of building codes and, regulations on innovation; implying that these 6 (six) barriers are the major barriers hindering the adoption of IBM in the global construction community. The second objective was to recommend measures to overcome the barriers to IBM adoption for sustainable construction.

As a result, potential options derived from the literature are presented in this section to address each of the top six barriers outlined above.

The first recommendation is that the government, construction industry associations, and all the stakeholders involved in the development of innovative building materials and technologies should adopt a strong collaborative system. This is to facilitate the successful adoption of IBM in developing and developed countries.

The most frequently stated barrier to IBM adoption in the literature, according to this review, is a lack of awareness and knowledge (which is due to poor funding for research and developments, training, and education), which leads to lack of understanding and public awareness about IBM, demonstrating the importance of information in IBM implementation. [28] suggested that government should provide funds for research for innovative materials and technologies to gain a comprehensive understanding of their characteristics, benefits, and disadvantages, as well as where the IBM should be applied. Also, the government could incorporate innovative design in education and into existing education systems, as well as increase the amount of formal innovative design education programs. [28] That is, this also allows for the implementation of training in the use of green or innovative materials for all stakeholders (such as architects, engineers, technicians, and masons) by including this training in the educational curriculum of schools and vocational programs.

This study has contributed to the knowledge of barriers affecting IBM adoption by identifying the most reported barriers in this literature. The findings are essential because they provide information on primary barriers to IBM implementation, leading to the proper understanding of what hinders the successful adoption of IBM from a global perspective. This study has been able to contribute to the global construction community as it has revealed the top six barriers to IBM adoption and provided recommendations that improve sustainable construction. It is expected that when the barriers are tackled, stakeholders would be eager to increase the level of adoption of innovative or sustainable features instead of conventional features in future construction projects. Also, the checklist of IBM barriers and references provided in this study can be relevant to scholars for further empirical studies on IBM barriers in different locations.

Limitation of the study

The scope of the research was limited to academic journals and thesis to get valuable information on the barriers or challenges of IBM adoption for sustainable construction.

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Barriers to the Implementation of Industrialized Building System in South Africa

Mabiletja Rebone[1](✉), Sukdeo Nita[2], and Ohiomah Ifije[2]

[1] Department of Quantity Department and Construction Management, University of Johannesburg, Johannesburg, South Africa
215080791@uj.ac.za

[2] Department of Quality and Operation Management, University of Johannesburg, Johannesburg, South Africa
nsukdeo@uj.ac.za

Abstract. The aim of this study is to identify the barriers that impede the use of industrial building systems in the South African built environment. The study used primary and secondary data sources to carry out the research. The methodology adopted for this study was the quantitative method, using questionnaire as the mode of collecting data. A convenience sampling was employed to sample the population. The data was analyzed using SPSS and a descriptive analysis in the form of mean item score was employed to analyze the data. The findings from the surveyed revealed that lack of exposure, lack of encouragement are the top two barriers identified by the respondents as one of primary reasons that industrial building systems are not implemented in the South African context. The findings from this research was consistent with literature and with the current situation in the South African infrastructure. The study concluded with implications of findings, conclusion and recommendations.

Keywords: Industrial · Industrial building systems · Construction

1 Introduction

Industrialised Building System (IBS) is an approach to construction where the elements of construction are designed and constructed in a specific place and specific manner on or away from site and then later put together on a construction site. [1, 2]. The Industrialised building systems has been known in the United States of America (USA) and it spread through to the United Kingdom (UK) and Australia, also adopted in Hong Kong. [3] later adopted by the Malaysians in 1960, where the processes of the industrialized building systems were checked from the European countries by the Malaysian minister of housing, the architects and local government to observe how they operate [4, 5]. The government of Malaysia therefore took it upon themselves to attempt one of their projects utilising the idea of industrialized building system [5]. During the utilization of the conventional method of construction, there have been several issues in the Malaysian construction industry, this issues include the delays in construction work

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and the construction progress, there has been the delay in productivity, the time delays for the project completion, material wastage on construction sites which would sometimes end up at dumping sites and negatively affect the residents who resided close to the dumps where construction people dump the material that they do not want to use anymore, [2] argued that as a result of issues with unsustainability in their construction industry, it's important that such unsustainable practices must be done with. This has led to the drive for the implementation of Industrialised Building System to reduce the issue of waste. In addition, this had led to Malaysian government passing legislation to make the adaptation and the use of the Industrialised Building system in their country through the Construction Industry Development Board (CIDB) mandatory and driving awareness to the discouragement of the use of the traditional construction method. The purpose of this research is to explore the barriers that impede the implementation of industrialised building systems and how the effective implementation of industrialised building systems improve the construction performance process.

2 Literature

In this section, several challenges that impede the effective implementation of IBS will be discussed. Lack of awareness, some of the construction companies and the construction professionals are not aware of the use of the industrialised building systems, which are also called the pre-assembled construction materials. There is a gap whereby the advantages of implementing the industrialised building system construction method are not know or realized [6]. According to study conducted by [7], the findings revealed that there is little or no awareness of IBS in the country, furthermore, findings from [7] revealed that less people knew about how the execution of the industrialised building system is carried out and what the procedures to a successful execution.

Lack of willingness, there is a lack of willingness by construction professionals to use this process in the construction projects, this is often as a result of the idea that construction activities in the South African context is often community related as the majority of the labourers are employed from the community where the construction is carried out, hence there is a willingness to use prefabricated process to avoid unrest in the community, this was argument is in unison with studies from [8] who stressed that labourers are willing to get involved with industrialised building system as they complain about the amount of money they will get paid, this could be as a result that they will be spending less time on site. Also, another reason is the presumption that IBS could be more expensive than the traditional method, hence not making them willing to move from away from the traditional method [9].

Lack of knowledge and skills, Adopting the industrialised building system method in construction projects requires knowledge and skills and therefore the workers or the labourers in the construction project should be trained for the operation of the industrialised building system or will have to be replaced by the other workers who have the skills in IBS. [8]. This was further buttressed by [10], who stated that in in Malaysia they import the industrialised building systems from other countries and that adds to their transportation cost, as well as the personnel who can carry out the activity. In addition, [10] claimed that skill shortage was one of the primary issues which have been highlighted as a cause of slow adoption of IBS, this is evident as surveys revealed that clients, engineers, and contractors have limited knowledge of the use of IBS. Inaccurate design has been identified as a cause for the slow implementation of IBS, this could be as a result of the architect not well informed on the use of IBS, or the engineers also having limited ability in the designing of IBS thus leading to delay in the completion of the projects, as inaccuracy leads to errors in the design, therefore it is highly important that people working towards the implementation of the industrialised building system should have knowledge of the systems and become familiar with these systems [11].

Furthermore, barriers that impede the effective implementation of IBS is construction workers not been ready to change the method of construction, traditional construction method requires the need for unskilled labourers, but the use of IBS would require the need for less labourers on site, but skilled labourers will be required on site [8], this means that in the South African context this will not be possible because of the socio-economic situation in the country. Researchers such as [12, 13] describes IBS as a costly system thus making the implementation difficult, thus making it difficult especially for contractors in the South African construction industry with majority of them small medium operators, thus agreeing with [4] who stated that because lots of capital is required, it makes implementation difficult because of the initial capital required for implementation (Table 1).

3 Research Methodology

A quantitative research design through a questionnaire survey, was adopted for this study. The researcher ensured that the survey was carried out among construction organizations registered with the Construction Industry Development Board (CIDB) in Gauteng province, South Africa. The reason for carrying out the study in Gauteng, is that the province houses many construction organizations as compared to other provinces, in terms of construction output and value [23]. The CIDB construction monitor report revealed in the Gauteng province, almost 4070 construction organizations are registered [23]. These formed the study's population target, which involved both primary contractors and sub-contractors (specialist, generalist, and trade sub-contractors) as categorized by [24]. Considering the number of organizations in the target population, accessing every one of them within the timeframe of the research was impossible. A convenience sampling method was used for this study, with a minimum of five years' experience to lessen the respondents. Thus, it makes it easy to reduce the target population to a more manageable and reachable size that can be used to generalize for the entire population. The research instrument for the research was a structured questionnaire due to its ability to reach respondents and within a short period of time [25, 26]. Furthermore, from literature it has been observed that the questionnaire is a commonly used approach for gathering information in social science research [27], hence its adoption in this study. The questionnaire used was designed in sections, with the first section collecting information of the respondents to ascertain if they are suitable for the study.

Table 1. Barriers to IBS implementation

Heading level	Authors
Negative perspective from clients	[15, 16]
Negative perspective from construction professionals	[15, 16]
Limited experience of IBS by contractors	[16]
High transportation cost	[16]
Poor planning and execution	[8, 17]
Lack of encouragement	[10]
Installation problems	[18]
Poor level of the use of information technology	[16]
Lack of legislation enforcement	[19]
Lack of incentives	[16, 20]
Lack of familiarity of IBS	[8]
Low manufacturing of IBS components	[8]
Need for specific equipment	[11]
IBS technology unsuitable for low rise buildings	[2]
Lack of standards on IBS components	[16]
Poor quality management	[18]
Poor communication	[21]
Quality assurance measures for storage	[22]
Quality assurance for transportation	[18]
Limited technical guidelines	[10]
High interest rates	[5]

The second section focused on the barriers of IBS implementation in the South African construction industry. The questionnaire was assessed on a 5-point Likert scale. The questionnaire was suitably distributed by means of the Google form—an online distribution mode. This mode of dispensing questionnaire was selected due to its ease in reaching several people across a considerable distance [28].

The developed link for the questionnaire was circulated via email to the identified construction organizations. The questionnaire had a cover page which describes the nature of the research, as well as informing the respondents on their voluntary participation and assurance of anonymity in the research. Firstly, the Cronbach alpha test was used to ascertain the research instrument's reliability. An alpha value of 0.932 was derived for the barriers of the implementation of IBS. This show that the questionnaire used was reliable as the alpha-value were closer to one. The next step was descriptive analysis using percentage to analyse the background information and mean score (X) to rank the barriers of IBS. This analysis was conducted using the Statistical Package for Social Sciences (SPSS) version 26.

4 Findings and Discussions

The respondents' background information revealed 50% were quantity surveyors, 18% represented civil engineers, 15% represented construction manager, construction project manager represented 10% and lastly 7% represented architects. This means that quantity surveyor was the most surveyed in this study. In addition, the working experience of the respondents were mostly a minimum of 5 years with a 55% representation which was the minimum working experience this study set for its respondents. The implication of this, means the respondents selected for this study are the appropriate respondents and they are quite knowledgeable about the subject matter. Furthermore, the respondents were asked to rate their level of agreement with the variables of barriers of IBS in the South African construction industry on a 5-point scale, with five being'strongly agree' and one being'strongly disagree. The result in Table 2 revealed all variables used for this study and the overall mean was 3.0 and above, this implies that the respondents agree that all the variables are barriers which impedes the implementation of IBS in South Africa.

5 Discussion of Findings

The comparison of the means for the barriers of the implementation of the IBS in the SA construction industry revealed the following: the barriers have been ranked by their level of effectiveness, according to the responses given by the construction professionals. The top four barriers have be ranked in the following way: Lack of exposure‘ ranked in the first place with an average mean of 4.02, the Lack of encouragement‘ ranked in the second place with an average mean of 3.94, the Not having the technical guidelines‘ ranked on the third place with an average mean of 3.86; Lack of standards of IBS components‘ ranked number four with an average mean of 3.85 and Lots of capital required‘ & Lack of incentives‘ ranked number five with an average mean of 3.83. Therefore the findings are then in line with that of [8] where it was said that most of the construction professionals are not really exposed or familiar with the Industrialised building system technology due to the fact that at the university level, students are not taught in depth about the off-site production and the assembly or erection of the IBS components on construction sites, but rather the very old traditional method of construction. The findings on the Lack of encouragement ranked in the second place supports the study by [8] on the fact that there has not been much encouragement for the construction to make use of the industrialised building system technology more especially from the government bodies. This also supports the study by [10] in the study that in Malaysia the government has not been promoting the use of the industrialised building systems. So, in this case it seems as though the South African construction industry is also experiencing the similar issues as the Malaysians. The study findings that one of the barriers to the implementation of the IBS is there are no technical guidelines to the implementation or the use of the industrialised building system in South Africa aligns with those of [10] on the fact that there has not been any production of the technical guidelines or regulations on the IBS

Table 2. .

Barriers	Overall mean
Lack of exposure	4.02
Lack of encouragement	3.94
Not having technical guidelines	3.86
Lack of standards of IBS components	3.85
Lots of capital required	3.83
Lack of incentives	3.83
Lack of awareness	3.8
Lack of law enforcement	3.74
Lack of skills	3.73
Lack of knowledge	3.7
Poor planning and execution	3.69
Lack of willingness	3.68
Limited supplier of IBS components	3.66
Poor quality management system	3.64
Need for special equipment	3.61
Higher interest rates	3.58
Lack of experienced supervisors	3.56
Low manufacturing capacity	3.55
Poor communication	3.54
Higher transportation cost	3.52
Negative perspective	3.5
Quality assurance measures for transportation	3.46
Quality assurance measure for storage	3.45
Poor quality of materials	3.44
Unsuitable for low rise building	3.36
Poor quality moulds for IBS components	3.33
Inaccurate designs	3.32
Installation Problems	3.32
Unsuitable for small projects	3.31

implementation in the construction projects, hence most of the construction firm do not make use of IBS technology. The findings in the subject study supports the study by [8] which has stated that the unavailability of the IBS standards hinders the implementation of the industrialised building system.

The findings also supported and agreed to the findings of the by [7, 12], in [13] which referred to Industrialised building system as a costly system because the implementation of the system contains high cost, and this IBS was seen as a better method for more production of buildings that with the traditional method. The industrialised building involves the use of huge machinery to prepare the components that are [13] used in the construction process and that is the reason why the IBS requires a lot of capital, so that those machineries or the equipment can be bought. [4]. Gan et al. [14], also stated that one of the factors that affect or appears as an issue to implementing the industrialised building system is that must start implementing the IBS in their construction companies will cost them a lot of money initially. Zakari et al. [29], also stated that the reason for the lack of implementation of the industrialised building system is since the required initial capital investment is too high since there will be a need to acquire the machines, formwork, foreign technology, logistics as well as the salaries of the highly skilled labourers who will be erecting the construction components on site.

The findings also supported the study conducted by [20] on Lack of incentives which revealed that the small constructors have not been getting the incentives on the implementation of the industrialised building system which was very harmful to their finances and holding the back from making use of the IBS mainly. Kamar et al. stated that the incentives for the IBS use from the government are not adequate and therefore they should be increased. This is because there profit the contractors would get when making use of the industrialised building system would be less than that which they could get when using the traditional construction method and the only way they could start using the IBS method is if the government introduce and increase the incentives [19].

5.1 Implications of Findings

The subject study 's main intention on the barriers of the IBS in the SACI was to investigate why the SACI is not making much use of IBS in their construction projects. The study was trying to get comprehension on what the different construction professionals think of about the factors that really hinder the use of IBS technology. The findings of this study recommend that construction professionals in South Africa should seek and get as much exposure as possible on the use of the Industrialised building system technology.

The findings suggest that South African government should encourage the use of the industrialised building systems in the construction projects and issue the incentives on the projects carried out using the IBS technology. The use of IBS in construction should be taught and presented to the construction professionals within the construction firms since it has not been taught at the universities. The formulation of the regulations or the policies on the use IBS are also essential. The study suggests that there should be the technical guidelines available of what is IBS and what are the effects off using it. There should also be more training of the construction labourers and professionals on the IBS from the erection on site up to the maintenance level.

The findings of this study therefore inform us that the construction professionals agree that the above are the actual and main barriers to the implementation of IBS technology in the South African built environment.

5.2 Conclusion and Recommendation

It has been found that the industrialised building system is a process of producing the elements of construction using the construction materials. The production of the elements is done away from the place where the construction will be taking place and on completion taken to site to be installed for a particular purpose in accordance to the projects requirements and the national or regional construction standards. The industrialised building systems can bring about change in the South African construction industry in a sense that the completion times are improved and the quality of the project is not compromised, but despite all of that there were barriers that were discovered to be hindering the implementation of the IBS in the South African Construction Industry (SACI). The introduction of the study on the Industrialised Building systems in the higher institutions of learning, there should be an introduction of the courses and trainings on the use of different advanced IBS in construction. The South African government to enforce the use of the industrialised building systems technology in the South African construction industry.

Acknowledgments. The heading should be treated as a 3rd level heading and should not be assigned a number.

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Blockchain Technology Innovation in Supply Chain Management: Perception of Construction Stakeholders in Developing Countries

Taiwo F. Adegbembo[1], Rotimi Akinrolade[1(✉)], and Douglas Aghimien[2]

[1] Department of Quantity Surveying, School of Environmental Technology, Federal University of Technology, Akure, Nigeria
rotimiakinrolade@gmail.com

[2] Faculty of Engineering and the Built Environment, Department of Civil Engineering Technology, University of Johannesburg, Johannesburg, South Africa

Abstract. The construction industry's high fragmentation, especially in its supply chain, has long suffered from ineffective communication between the multiple parties involved, which has led to sharing false and undated documents, thereby losing trust and causing delays to the project. Blockchain technology, disruptive technology, has been identified to solve these problems and significantly increase project productivity and performance through proper monitoring, transparency, and traceability of materials during construction. The purpose of this study is to investigate the level of awareness of stakeholders within the Construction Supply Chain Management (CSCM) about the adoption of Blockchain technology and its applications. Literature was reviewed on blockchain technology and its application in the construction industry. At the same time, data collection was collected using a quantitative approach (questionnaire) targeting 178 Contractors and Suppliers in Lagos, Nigeria. The collected data were analysed using descriptive analysis by calculating the Mean item score (MIS) and standard deviations. Mann-Whitney U-test was also used to check if a statistically significant difference exists between the views of contractors and suppliers. Data collected were analysed using SPSS. The study revealed that even though stakeholders are familiar with some aspects of blockchain, such as cryptocurrency, they are not extensively aware of the application and potential of blockchain technology in the construction industry, especially in construction supply chain management and logistics management. Therefore, this research recommends that Government and policymakers of emerging economies should stimulate awareness through training and promotion to facilitate investment readiness. Also, they should invest in research and development for blockchain innovation and new solutions on identified case studies.

Keywords: Blockchain · Construction 4.0 · DLT · Innovation · Sustainability

1 Introduction

The construction industry develops some of the world's most important infrastructure projects, such as roads, bridges, buildings, dams, and railways. The complex nature of

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this project requires integrating many professionals, product suppliers, components, and sub-components [1]. Moreover, according to Lau [2], the complexity of construction increases. Therefore, the need to implement these complex projects is also growing, such as the use of advanced tools or technological processes and the location of project information shared through the fair exchange of data and information [3]. In addition, communication is a vital tool for individuals in the construction industry [4].

Effective communication is essential in completing any building project. Since communication is exchanging information to convey a message, it is reasonable to conclude that information is the key to completing any project. However, due to the complexity of the construction industry, there has been ineffective sharing of information, especially in the construction supply chain management (CSCM) [5].

Supply Chain Management (SCM) refers to all phases, from the natural organic form to the final manufactured product. These include planning, purchasing, ordering, inventory, shipping and storage. Today's supply chains are inherently complex, encompassing many categories, with different geographical businesses competing to assist consumers [6]. Furthermore, globalisation, complex regulatory policies, and the various cultural and individual functions in asset networks make it difficult to assess information [7]. In addition, ineffective transactions, fraud, burglary, and inefficient supply chains, lead to a severe lack of trust, which is why there is a need for better sharing and information security.

In recent years, technological advances have been made with an unprecedented amount of solutions to the problems that arise in the construction industry [8]. Internet of Things, Artificial intelligence, cloud technology and robotics, among other industry 4.0 technologies, have changed how the industry operates [9]. In addition, blockchain, an emerging technology in the construction industry, will improve trust amongst construction stakeholders through information security, transparency, and traceability of materials through the supply chain.

2 What is Blockchain?

A blockchain is a distributed ledger technology where all participants on the network have access to the ledger for total transparency. It is a platform that allows shared and coordinated information to spread across multiple locations. This implies that no central administrator nor central storage for data exists [10]. Blockchain is a chain data structure which enables open and fair transactions among participating nodes by utilising the distributed digital ledger technology principle [11]. The distributed digital ledger technology assures blockchain records' integrity, transparency, and auditability. The blockchain records are tamperproof, which means they cannot be readily changed without automatically notifying other nodes [12]. The name blockchain resulted from the fact that this distributed ledger comprises a chain of "blocks" arranged chronologically. These blocks hold a record of legitimate network activity, documents, or transactions [13]. The objective is for most system members to validate the content of each block. Once a block has been entered and validated, it cannot be deleted or changed [3].

Each block might be defined as a chunk of encrypted data in the form of information, transactions or Internet Protocol (IP). Every block has a timestamp, a previous link to the initial block, as well as the details of every past transaction up to the second it was created and immediately chained together. The entire process is end-to-end encrypted. All transactions are connected to a unique cryptographic signature called a hash function. This signature is very easy to confirm and almost impossible to forge.

There are two types of blockchain technology; private (permissioned) and public (permissionless) [14]. Anyone can join the network in the public system; this is why it is called the permissionless type of blockchain technology. This public system enables miners to validate the blocks in the system, and anyone can become a miner if they obey the system's rules [10]. The public system is, therefore, a decentralised system [8]. On the other hand, the goal of a private blockchain system is to provide a feature that allows anyone to read the information but controls who may modify the blockchain [15]. According to Xiong [5], blockchain technology is a promising tool in the supply chain as it allows visibility and traceability as well as ensures that the supply chain process is digitalised. The system also allows for better data security and smart contracting on projects.

3 Supply Chain Management

The supply chain is a network of industries absorbed in various processes and activities that generates value for end-users via upstream and downstream connections [16]. It has been noted that the management of the supply chain is designed to recognise the interdependence of supply chain networks and to ensure that performance is improved through the reduction of inventory cost or waste generation [17].

In the construction industry, the construction supply chains make up about 75% of the turnover of the main contractor [18]. However, the complexity associated with the construction industry makes it difficult to manage supply chains for construction efficiently [19]. Studies have shown that most of the waste generated in construction results from poor material supply chain management [20]. This makes it essential to study and have an effective CSCM. The keys to an effective CSCM are to enable clarity of knowledge and establish collaboration processes for the networks concerned in the construction supply chain.

4 Application of Blockchain Technology in CSCM

4.1 Smart Contract

Smart contracts are computer programs that break down work into the minute, quantifiable task packages while automating the compliance and payment process [21]. In construction, this breakdown of work into smart tasks enables construction stakeholders better recognise their need, objectives, duties and liabilities as well as how these tasks will affect them or counter wise. A contract is smart in that every task or milestone has defined criteria it must achieve before it can be termed as completed, and this will automatically trigger the compensation for the task. It is essential to have a comprehensive view of a project before its execution as well as during execution, where real-time development of the project can be tracked [22]. Controlling the governance of contracts by automation would reduce doubts about the execution of projects. This is because the result and triggers for each outcome are entirely expected and predefined.

4.2 Material Verification and Authentication

The application of blockchain technology in SCM is evident in the verification of the origin of products [23]. Information pertaining to the place of production, the time taken for production, and the delivery process from producer to end user is germane in the effective delivery of products to the client. Giving little information such as the manufacturer's details, location of production, or transportation routes before the product gets to the end user can add to the value derived by the customer and, by extension, create a significant competitive advantage for the organisation providing the product. This information can allow better planning, thereby enhancing operational delivery in time. Therefore, to increase the tracking of the origins of construction materials and their movement through supply networks, technology such as blockchain and radio frequency identification technology (RFID) can be used [13]. The use of the RFID system will bring about the transfer of product information into digital format, allowing access and storage of a large amount of product information simultaneously.

4.3 Payment Management

Among the critical issues experienced on construction projects are cash flow problems and late payment [24]. The construction sector has a chained payment settlement culture, with considerably longer default settlement periods than other sectors. Aside from this long settlement period, the construction industry also faces many non-payment issues [25]. Consequently, more costs are incurred to cover the payment delays. The resultant effect of this problem is the increasing cost overruns experienced in most construction projects. Therefore, managing cash flows to avoid payment delays on construction works has become paramount. This management of cash flow can be achieved using smart contract-enabled blockchain applications. This system allows clients to also directly laisse with suppliers and avoids third parties' interference, which could lead to additional costs and project delays.

4.4 Construction Management

The complex nature of construction projects leads to fragmentation issues amongst organisations and professionals [26]. In addition to this, current construction management procedures have significant trust, information exchange, and process management issues [3]. On the other hand, Blockchain technology allows immutability, trust, accuracy, transparency, and security, among other things, to resolve management problems. Construction drawings and designs, for example, may be provided at different stages of work, and all necessary stakeholders must be informed of such development. Nevertheless, because the stakeholders are operating as distinct organisations, difficulties such as identifying the most recent drawings, determining who issued the most recent drawing and whether it has been included in the architectural/structural/services drawings might emerge. A blockchain system with smart contracts can solve this problem as the most up-to-date information can be updated and made available.

5 Research Methodology

This study assessed the awareness of blockchain technology in CSCM using a quantitative research design. Questionnaires were used as the instrument for data collection due to their ability to cover a wide range of audiences within a short period. The questionnaire was designed based on information gathered from an extensive review of existing works on blockchain and SCM. It was created in two sections, with the first gathering information on the respondents' backgrounds. The second section assessed the awareness and knowledge of the respondents regarding the use of blockchain in CSCM. This section was evaluated using a 5-point scale, with five being very high and one being very low. The questionnaire was distributed among 218 registered contractors and suppliers of reinforcements in Lagos state, Nigeria. Lagos State was considered because it is the commercial nerve centre of Nigeria with a lot of construction activities ongoing [27]. In distributing the questionnaire, a purposive sampling technique was employed, and 178 questionnaires were returned representing a response rate of 81.7%. The collected data were analysed using percentage, mean item score (MIS), standard deviation and Mann-Whitney U Test.

6 Discussion

6.1 Background of Respondents

From the analysis of the background information of the respondents, 29.2% of the respondents were Contractors, and 70.8% of the respondents were Suppliers. 2.2% of the respondents have never handled a project, 43.8% of the respondents have handled between 1–10 projects, 30.3% of the respondents have handled between 11–20 projects, 9% of the respondents have handled between 21–30 projects, and 14.6% of the respondents have handled above 30 projects.

6.2 Awareness and Knowledge of Blockchain Technology

From Fig. 1, 61.8% of the respondents affirmed that they have knowledge of blockchain technology, 27% of the respondents have no knowledge of blockchain technology, and 11.2% of the respondents are not certain about their knowledge of blockchain technology.

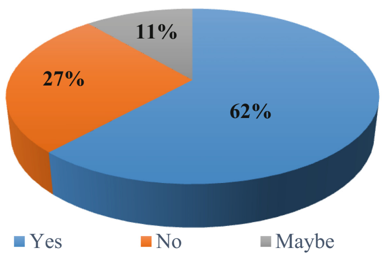

Fig. 1. Awareness of Blockchain Technology

Table 1 shows the level of awareness of respondents on blockchain technology. The level of awareness was ranked based on mean item scores and standard deviation. Table 1 reveals that blocks can be a source of big data, blockchain is one of the pillars of the 4th industrial revolution, and blockchain can be used to improve supply chain management with a mean of 3.88, 3.84 and 3.71 respectively are considered by respondents to be their strongest level of knowledge about blockchain technology, while smart contract works on the principle of blockchain with a mean of 1.97 was ranked the least on their awareness scale.

Table 1. Awareness and knowledge of blockchain technology

S/N	Variables	MIS	SD	Rk
1	Blockchain is a source of big data	3.88	1.04	1
2	One of the pillars of 4IR	3.84	1.11	2
3	It can be used to improve supply management	3.71	1.19	3
4	Irreversibility, undeniableness, uniqueness and anonymity for trades	3.70	1.12	4
5	It provides data to the network on the origins of materials, purchase orders, inventory levels, goods received, shipping manifests and invoices	3.64	1.11	5
6	Greater and timelier visibility of activities	3.64	1.11	5
7	Bitcoin, Ethereum and Spotify work on the principle of blockchain	3.60	1.38	7
8	It can improve material traceability within the supply chain	3.52	1.07	8
9	It can be used in collaboration with BIM	3.52	1.2	9
10	Information shared on the blockchain is unhackable	3.46	1.2	10
11	It can be used to monitor the progress of projects	3.45	1.16	11
12	Information shared on a blockchain network cannot be edited	3.36	1.35	12
13	It enhances collaboration amongst parties in the network	3.33	1.15	13
14	Solution to extra delays, costs and information wastages due to information intermediaries	3.29	1.17	14
15	Backward traceability of information	3.19	1.3	15
16	Changing, hacking, or cheating the system is difficult or impossible	2.82	1.02	16
17	It enhances trust amongst parties in the network	2.27	1.04	17
18	It does not require any physical instrument such as bank bills and bank vaults to store cash	2.07	0.74	18
19	Information does not need a 3rd-party authorisation	2.06	0.87	19
20	Smart contract works on the principle of blockchain	1.97	0.82	20

A Mann-Whitney test was carried out to check whether there is a statistically significant difference between Contractors (Ctr) and Suppliers (Splr) as regards their level of awareness. Table 2 shows that: the blockchain provides each member of the network with far greater and timelier visibility of the activities occurring in the network; information shared on the blockchain is unhackable with a p-value of 0.019 and 0.018, respectively are statistically significant. However, 18 other variables used in assessing their awareness level show that there is no significant difference between the level of awareness of Contractors and Suppliers as their values are higher than 0.05.

Table 2. Level of awareness of contractors and suppliers

S/N	Variables	Ctr MIS	Splr MIS	p-value
1	Blockchain as a pillar of 4IR	4.08	3.75	0.255
2	Greater and timelier visibility of activities	4.08	3.46	0.019*
3	Information shared on the blockchain is unhackable	3.92	3.27	0.018*
4	It provides data to the network on the origins of materials, purchase orders, inventory levels, goods received, shipping manifests and invoices	3.92	3.52	0.109
5	Blockchain is a source of big data	3.92	3.86	0.880
6	It can be used in collaboration with BIM	3.85	3.38	0.132
7	Irreversibility, undeniableness, uniqueness and anonymity for trades	3.85	3.63	0.256
8	Bitcoin, ethereum and spotify work on the principle of blockchain	3.85	3.49	0.461
9	It can improve supply management	3.69	3.71	0.465
10	Information cannot be edited	3.62	3.25	0.258
11	It can solve problems of extra delays, costs and information wastages	3.54	3.19	0.192
12	improve material traceability in supply chain	3.54	3.51	0.783
13	Can monitor the progress of projects	3.38	3.48	0.422
14	Information can be traced backwards	3.08	3.24	0.617
15	Collaboration amongst parties in the network	3	3.46	0.072
16	Changing, hacking, or cheating the system is difficult or impossible	2.73	2.86	0.396
17	It enhances trust	2.38	2.22	0.534
18	Smart contract works on the principle of blockchain	2.08	1.92	0.377
19	No 3rd-party authorisation	1.96	2.1	0.481
20	It does not require any physical instrument	1.96	2.11	0.361

* $p\text{-value} < 0.05$

7 Findings

The findings on their awareness level revealed that 61.8% of respondents affirmed the direct question of whether they are aware of blockchain technology, and 27% of respondents responded negatively. In comparison, 11.2% of the respondents were not certain. When other variables were used to assess respondents' level of awareness, blocks can be a source of big data, and blockchain is one of the pillars of the 4th industrial revolution; blockchain can be used to improve supply chain management.

The percentage of respondents affirming knowing blockchain is about 61% of the total respondents; this shows that stakeholders within the construction industry are aware of the technology owing to the popularity of cryptocurrencies such as Bitcoin, Ethereum etc. However, some of the strongest potentials or areas of application of blockchain technology in the construction industry, as stated by [18], such as increased trust, improved team collaboration and improved transparency, were ranked low by respondents. This indicates that even though stakeholders are familiar with some aspects of blockchain, such as cryptocurrency, they are not extensively aware of blockchain technology's application and potential in the construction industry, especially in CSCM. This is not surprising because blockchain technology is relatively new to the construction industry despite its use in other sectors [21].

8 Conclusion and Recommendation

This study aimed to assess the level of awareness of contractors and suppliers to blockchain technology in supply chain management. It is not surprising that Suppliers and Contractors in the Nigerian Construction industry have heard about blockchain technology with the whole buzz about cryptocurrency and the trend of adopting technology within the construction industry. However, with the ranking of the variables, it is safe to conclude that they are not fully aware of the scope and application of this technology within the CSCM.

Therefore, this research recommends that the Government and policymakers of emerging economies should stimulate awareness through training and promotion to facilitate investment readiness. Also, they should invest in research and development for blockchain innovation and new solutions on identified case studies. While the findings of this study can prove beneficial to academics and industry professionals, care must be taken in generalising the findings as it was limited to Lagos state Nigeria. Further research can be conducted to seek the opinion of construction professionals in other parts of the country and, by extension, other countries where such studies have not been conducted. Also, future works can formulate an adoption m,odel for the effctive ustilisation of the blockchain systems in CSCM.

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Innovations in Construction Organisations in Nigeria

Moyanga Dorcas, Adegbembo Taiwo(✉), and Owoyemi Emmanuel

Federal University of Technology, Akure, Nigeria
{dtmoyanga,tfadegbembo}@futa.edu.ng

Abstract. Innovation serves as a vital element of organization's competitiveness and a premise for enhancing the development of the construction industry. This enhancement/ development depends on the integration and adoption of innovation by construction organizations. Therefore, this study examines the innovativeness of organizations in the construction industry. Primary data were collected from 116 construction organization in Lagos, Nigeria using a well-structured online and printed questionnaire. The data collected were analyzed using descriptive statistics such as frequency and percentages, mean score and factor analysis. Through mean score, the study reveals that AutoCAD, Revit and Mobile technology are the most adopted software while innovative technologies like Building Information Modelling (BIM), Internet of Things, Virtual reality, Big Data, etc. are moderately adopted in the Nigerian construction industry. In adopting factor analysis, the 21 identified innovations were reduced and categorized into 3 principal factors which explains 62% of the total variance. These factors were named early measuring software, early designing software and recent innovative technologies. The study concludes that the innovativeness of organizations and the construction industry in Nigeria is somewhat low as a result of the moderate adoption of innovative technologies. Hence, the study recommends that the management of construction organizations should provide and encourage the use of new software and technologies so as ensure better quality services delivery.

Keywords: Construction industry · Construction organizations · Innovations · Nigeria

1 Introduction

Business and organizations are continuously searching for new ways of offering products and services and/or improving existing ones so as to meet high customer expectations [1]. [2] noted that with more competition, increasing demands of clients and the rapid changes in the environment, the performance of firms is being improved due to innovation. Innovation is an essential element of competition and its absence in firms would in turn make the national economy less competitive. This is so because, innovation is very imperative for developing any country's economy so as to become innovative and competitive [3].

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According to the Organization for Economic Cooperation and Development [4], innovation is described as creating new products, processes and services for enhancing welfare. However, the money spent on research and development (R&D) has brought about the uncomfortable relationship between innovation and the construction industry, compared to other industries. This is seen in the way the construction industry is adjudged for lagging in terms of adopting innovation. In addition, [5] argued that innovation in the construction industry is co-created in a multiparty environment. Specifically, Nigeria is known for its low acceptance of innovation when compared to other developing countries and that poses great challenge to diversifying the economy [3]. Nevertheless, innovation is important for the success and performance of the construction industry. Hence, understanding innovation and its process are the key steps to enhancing innovation [6]. In the past few years, there has been quest to increase innovation activities in the construction industry [7]. In a bit to enhance the adoption of innovation, extant studies have explored the software and technologies adopted in the construction industry. In Nigeria, the adoption level of innovations in the construction industry [8], barriers and drivers of adopting innovation [9, 10], adoption of innovation by construction organizations [11, 12] have been investigated by few studies. However, there is dearth of literature on categorizing and characterizing innovation which is an important strategy for managing innovation adoption. Categorizing the software and technologies would provide better understanding of the new ones and further enhance their adoption. Moreover, classification of innovation holds incredible possibilities for enhancements in the industry [10] and informing decision making by stakeholders [13]. Hence, this study investigated the adoption level of innovations and categorize innovative software and technologies for organizations so as to ensure the development of the Nigerian construction industry.

2 Literature Review

2.1 Innovation and Innovations in the Construction Industry

Innovation is regarded as a strategy used by firms to create competitive advantage and show improvement in service delivery [14]. Also, [15] described innovation as an important aspects of competition that enables firms to create new or improved products so as to increase the market share. Notwithstanding, innovation is defined generally as the development and introduction of new or improved idea, methods, goods or services. [16] defined innovation as the combination of new and/or existing knowledge, resources and so on. Also, innovation is defined by [17] as the multi-stage process of transforming ideas into new product, services to advance themselves in the marketplace. Recently, [18] described innovation as the coming together of ideas and process to develop solution for problems. In addition, Hengsberger [19] see innovation as the process by which new solutions are being renewed and exploit. However, there existed no generally accepted definition of innovation because defining innovation has gone through developmental processes, right from Schumpeter's definition to recent ones. Notwithstanding, the best approach to the definition of innovation is based on defining innovation based on classification and establishing an understanding of the concept of innovation. Classification and categorization of innovation is useful for distinguishing between process and product innovations. Categorizing or classifying brings about clarity on a subject in a structured manner [20]. Classification is important to ensure construction innovations are understood and accomplished [21]. Classification and categorization in practice is being motivated by taxonomies in order to identify the characteristics of innovation and the degree of innovativeness [22]. Coccia [23] reiterated that the classification of innovation is based on the characteristics of the innovation new to the firms and the entire world. The classification of innovation based on the technical change include increment innovation and radical innovations. Some studies classified innovation into process and product innovation. Irrespective of the classification, innovation is associated with introducing or transforming ideas into new or improved products, services, methods, etc. so as to provide solution to problems in any industry or sector.

Based on the types of innovation, [24] posited that the construction industry is embracing new ways of sharing information, adopting emerging concepts of sustainability and related technologies like building information modeling (BIM), etc. Another innovative practice which has to do with supply chain management and helps to enhance inter-firm coordination in construction was proposed by [25], thus allowing the stakeholders to provide input in the decision making during construction. Also, [26] noted that the three-dimensional (3D) printing is an advanced form of the computer-aided-design (CAD) without the tools and fixtures. In addition, [27] submitted that the introduction of digital technologies such as Artificial Intelligence (AI), Internet of Things (IoT), etc. into construction practices can improve the construction industry.

All these studies made efforts to highlight different types of innovation such as software, technologies and services as discovered through their investigation. However, the studies were limited in classifying and categorizing innovation to enhance better understanding of the innovation for implementation. In this study, some innovative technologies applicable to the construction process and the construction industry are being reviewed;

Building Information Model (BIM)

Building Information Modelling (BIM) is defined by [28] as the set of technologies, processes, and policies adopted by users, firms across the project life cycle. BIM unites all project accomplices utilizing a similar data to design, build, and work better projects. The finding of [29] shows that BIM has been taken on principally for efficiency improvement by individual organizations. BIM based estimates gives adequate details from measurement and data extraction of projects by linking the model of the building to the planning software [30].

Exoskeleton

Exoskeleton refers to a system or a wearable device that augments, enables and improves motion or physical activity [31, 32]. Exoskeleton consists of five 3D printed elements to accomplish cost-effective exoskeleton with different user's compatibility [33]. According to [34], exoskeleton might be innovative but it is restricted to indoor activities and limited in lifting heavy objects.

Virtual Reality

Virtual Reality (VR) technology has been in existence for a long time but recently becoming more popular as a result of technological developments [35]. Virtual reality is a technology that involves creating an environment that is simulated for user through the use of software. In virtual reality, a real-life situation is being viewed based on a computer-generated environment by reducing human senses of the real/actual environment [36]. It is noteworthy that VR have the tendency to efficiently improve safety training and improve the skills of recognizing hazards [37]. Furthermore, [38] asserted that virtual reality has changed over time from what it once was to what it is now: a technology that broadens the scope of how a man can engage with his imagination materialized literally. However, the adoption of VR is still relatively low in the construction industry because the industry is lagging in fully accepting innovation [39].

Augmented Reality

Augmented reality is one of the most current technology breakthroughs employed in the construction business for a variety of objectives [40]. Augmented reality is described by [41] as a visualization approach in which virtual 3D representations are superimposed on actual reality using a fixed geographic reference system. According to [27], the six uses of augmented reality include design review, operations and management, design support, stakeholder engagement, construction support and training. Augmented reality is becoming a vital technology in the construction industry due to the availability of smaller mobile device [42]. The widespread use of all construction 4.0 technologies, particularly augmented reality, is still a long way off [41].

Lean Construction

Lean construction is a concept that enhances stakeholders' collaboration in order to maximize value for them in in a project. Lean construction is beneficial for removing all forms of waste, increasing the in-flow of materials, ensuring cost management, achieving quality, and boosting safety in construction [43]. Lean construction is termed innovative since construction professionals use lean tools to manage, monitor, control, and build projects on construction sites, even if they aren't always aware of what they're doing.

Internet of Things

Internet of Things (IoT) is described as information and communication technologies for allowing enhanced services through the linkage of virtual objects to physical activities [44]. IoT is also defined as a system of 'Things' that connect and interact with one another through the Internet or a private network [45]. 'Things' are referred to as 'smart devices' that are connected to a network and enabling people to communicate with minimal engagement [46]. It is noted by [47] that there is an increase in the number of industry-leading contractors and builders utilizing Internet of Things. However, [48] discovered that the low adoption of IoT is as a result of the awareness and readiness to use it.

3 Methodology

The quantitative approach was adopted in examining and classifying the innovations in the Nigerian construction industry. In order to achieve this aim, primary data was collected through questionnaire survey from construction organizations in Nigeria. In this study, the construction organizations comprise of registered consulting and contracting organization in Lagos State, Nigeria. Lagos State was selected because a lot of sophisticated infrastructural and buildings are being developed with the adoption of technologies [49]. The selection and list of organizations was limited to Architectural, engineering, quantity surveying and construction companies which were sourced from their professional institutes and Federation of Construction Industry (FOCI). A total of two hundred and forty-nine (249) organizations were purposively sampled and copies of the questionnaire were distributed to them. Out of 249, one hundred and sixteen (116) copies of the questionnaire were retrieved, representing 47% return rate and found suitable for analysis. The questions were rated based on 5-point Likert scale with weighting factor ranging from 5 (very high) to 1 (very low). Cronbach Alpha Coefficient, mean score and factor analysis were used in analyzing the data. The Cronbach Alpha was adopted to determine the internal consistency of the scale used, the mean score for ranking the level of adoption of innovation and factor analysis adopted to categorize the innovations. The Cronbach Alpha value for innovation adoption is 0.932 and this implied that the scale used in the instrument is reliable since it is greater than 0.600 [50].

The mean score was interpreted based on the rule of thumb given by [51]. That is, values from 1.000 to 1.799 represents very low; 1.800–2.599 represents low; 2.600–3.399 represents medium/moderate; 3.400–4.199 represents high while 4.200–5.000 represents very high. Factor analysis is being use to categorize the construction innovations identified from literature by extracting maximum common variance from all variables and putting them into a common score. In this study, the principal component analysis was adopted to reduce and categorize the software, technologies and new services used by construction organizations. In factor analysis, the factorability and suitability of the data was first determined to ascertain if the variables are factorable before the principal components were rotated and extracted using Varimax method. The data is suitable because it satisfies the 1: 5 item to cases in term of the sample size and greater number of variables with correlation coefficient > 0.3 shows the strength of the relationship between the variables.

4 Results

4.1 Background Information of Organizations

Based on the type of organization; 11.2% of the organizations are architectural firms, 26.7% are quantity surveying firms, 24.1% are contracting firms while 37.9% are engineering firms. This implied that larger percentage of the organization are engineering firms.

4.2 Innovativeness of Firms in the Construction Industry

In this study, innovation is based on the integration and use of software, technologies and new ideas into the products and services [52] in construction irrespective of whether they are new [53]. In lieu of this, Table 1 shows the result on the innovativeness of construction organizations in the construction industry. It is deduced that AutoCAD, Revit and Mobile technology are the software and technology mostly adopted by all the construction organizations though the adoption level is not very high in the construction industry. On the other hand, the adoption level of Building Information Modelling (BIM), offsite fabrication, 3D printing, Internet of Things, Virtual reality, Big Data, lean construction, Block-chain technology and Fusion 360 is moderate. This is because they are found below 3.40 rule of thumb adopted by this study for interpreting the mean score. The moderate adoption of the new software, technologies and services implied that the construction organizations in the Nigerian construction industry have started to improve and innovative with the increasing awareness and adoption of innovations in the construction industry worldwide.

A further analysis was done to categorize the innovative software and technology (variables) adopted by construction organizations in Nigeria using factor analysis. First, the factorability of the variables for factor analysis was established with the KMO of 0.899 and Bartlett's test of sphericity being $p = 0.000$ (refer to Table 2). This indicates that the variables are suitable and adequate based on the minimum value of 0.6 suggested by [54] and the significant value being less than 0.05 [55].

Twenty-one (21) variables (innovations adopted by construction organizations) were orthogonally rotated using Varimax method and out of 21 variables, 3 principal factors were generated and extracted having found above the eigenvalue of 1. The 3 principal components explain 62% of the total variance though the first component explains 44% of the variance. Table 2 shows the extracted 3 principal factors named early measuring and management software, early designing software and innovative technologies. Group 1 which is the early measuring and management software consists of 7 components; Group 2 consists of 10 components while group 3 consists of 2 components.

4.3 Discussion of Findings

This study found out that the most adopted software and technology by organizations in the construction industry are AutoCAD, Revit and Mobile technology. However, BIM, offsite fabrication, 3D printing, Internet of Things, VR, Big Data, lean construction, Block-chain technology and Fusion 360 are moderately adopted in the construction industry in Nigeria. This implied that the construction organizations in Nigeria are slightly innovative since they are stereotyped in the use of old version of software, moderate adoption of new technologies and services as affirmed by [52]. This is the case with the construction industry in other developing countries despite their awareness of innovative software and technologies. Similar study by [56] discovered that AutoCAD is one of the broadly utilized applications with accompanying saving time. In recent times, there should have been improvement in the adoption of innovative technologies yet studies have shown that the adoption is still low [39, 57, 58].

Table 1. Level of adoption of innovation by construction organizations

Innovations	Mean	SD	Rank
AutoCAD	4.05	1.078	1
Revit	3.41	1.180	2
Mobile technology	3.40	1.208	3
BIM—3D, 4D, 5D, 6D, 7D etc	3.29	1.119	4
Offsite fabrication	3.18	1.283	5
3D printing	3.17	1.301	6
Internet of Things (IoT)	3.07	1.242	7
Big data	3.03	1.142	8
Virtual reality	3.03	1.208	9
Lean construction	2.96	1.261	10
Block-chain technology	2.89	1.198	11
Augmented reality (AI)	2.84	1.262	12
Fusion 360	2.81	1.184	13
CoConstruct	2.75	1.184	14
Bluebeam Revu	2.72	1.241	15
Navisworks	2.70	1.270	16
Drones and robotics	2.66	1.209	17
Planswift	2.63	1.176	18
Bexel manager	2.61	1.149	19
CostX	2.57	1.232	20
Exoskeleton	2.33	1.145	21

Innovations in the Nigerian construction industry was categorized into early measuring and management software, early designing software and innovative technologies. Although the early measuring and designing software are the innovations still mostly adopted by construction organization in Nigeria according to [52]. However, the third category discovered in this study is the innovative technologies that the construction industry can adopt to enhance its development. These include but not limited to BIM, Internet of Things, Lean construction, VR, and Block-chain. [10] noted that the perception of the Nigerian construction industry is that the industry is performing well even without these technologies. This belief may however deter or delay the use of these technologies if not given attention by stakeholders in the industry.

5 Conclusions

The study investigated innovations in the Nigerian construction industry and categorized innovative software and technologies. From the analysis, the study reveals that

Table 2. Component extraction for adoption level of innovation

KMO and Bartlett's test: KMO—0.899; sig—0.000			
Factors	Items	Description	Loading
Early measuring and management software	1	Navisworks	0.810
	2	Planswift	0.807
	3	Bluebeam Revu	0.794
	4	Fusion 360	0.792
	5	CostX	0.772
	6	CoConstruct	0.753
	7	Bexel manager	0.689
Innovative technologies	1	Mobile technology	0.735
	2	Virtual reality	0.727
	3	Drones and robotics	0.710
	4	Lean construction	0.689
	5	Internet of Things (IoT)	0.683
	6	3D printing	0.638
	7	Augmented reality (AI)	0.638
	8	Exoskeleton	0.621
	9	Big data	0.588
	10	Block-chain technology	0.579
	11	Building information monitoring (BIM)	0.519
Early designing software	1	AutoCAD	0.858
	2	Revit	0.804

AutoCad, Revit and Mobile technology are the most adopted software and technology by organizations in the Nigerian construction industry. Whereas, new technologies available in the global construction industry such BIM, offsite fabrication, 3D printing, Internet of Things, VR, Big Data, lean construction, Block-chain technology are moderately adopted in the Nigerian construction industry. Furthermore, 21 software and technologies were being categorized into early measuring and management software, early designing software and innovative technologies to facilitate the innovation adoption in the Nigerian construction industry. Summarily, the innovativeness of organizations in the Nigerian construction industry is improving due to the moderate adoption of the category innovative technologies and the adoption of improved versions of old software. Hence, the study recommends that the management (that is, owners and managers) of construction organization should endeavour to purchase the affordable innovative software and technology (for an initial arrangement) and initiate the trainings required to use the innovative technologies. It is suggested that the management of the organizations encourage the use of innovative technologies to sustain competitive advantage.

The study is limited to Lagos state Nigeria, which is just a state out of the 36 states in Nigeria. Further study could be carried out in other states or geopolitical zones of the country.

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Exploring the Protocol for Construction 4.0 Use in South

K'homotho Nester Mokhojane(✉) and Fidelis Abumere Emuze

Faculty of Engineering, Built Environment and Information Technology, Central University of Technology, Bloemfontein 9300, South Africa
{nmokhojane,femuze}@cut.ac.za

Abstract. The reported study is about developing a protocol for enabling Construction 4.0 in South Africa by utilising appropriate digital technologies. The scoping review methodology was used to compile the paper. The findings of the related literature review indicated a lack of case studies to authenticate and provide a pathway on how to best implement digital technologies to enable Construction 4.0 in South Africa. The general conclusions showed that there is less literature that can test the various technologies empirically which can be used to transform the construction sector to a fully digitised sector. There is no guidance on the way to proceed when intending to implement digital technologies to digitise the local construction sector, given the chronic challenge of excessive time overruns on projects. The findings indicate a need for the formulation of a protocol aimed at digital transformation in South African construction. These findings thus reinforced the need to empirically test the available digital technologies in South Africa on whether they are best suited to enable a transformation, which will promote favourable project delivery outcomes.

Keywords: Construction 4.0 · Digitization · Transformation · Project delivery · South Africa

1 Introduction

The local construction sector is projected to grow towards an upward trajectory, along with the level of project-related risk. The diverse nature of construction related projects has increased pressure on construction companies to preserve their financial solvency in relation to their forecasted growth in the modern market segment. The primary purpose of the research will be to try to ascertain how digital technologies can enable Construction 4.0 in so far as ensuring construction companies can undertake construction projects in a more effective manner. The South African economy has the construction sector as the fourth most significant sector in terms of contribution to the gross domestic product (GDP) [19]. Construction projects are technically challenging, prone to significant risk, physically and physio-logically demanding undertakings that are frequently implemented and delivered by participants with varying cultural differences, backgrounds, political systems, and languages [26] In addition, digital progress has

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impacted all industries, leading in a new technological era now known as the Fourth Industrial Revolution (4IR). This new technological era is satisfying consumer demand for better ways of doing things. Innovation has led the charge on improved productivity and sustainability, and redefined the skills, the roles and responsibilities and competencies required to achieve success (World Economic Forum, 2020). Multiple innovative digital construction technologies are available to the construction sector to enhance practicality and functionality of the site based activities, resulting in overall improvement of the performance of construction companies. Furthermore, the Diffusion of Innovation theory suggests that majority of these technologies, their adoption in the construction sector has been poor as is the case of many developing economies, such as South Africa. This low adoption rate, results in low productivity of the sector being prevalent.

4IR has seen the emergence of Industry 4.0. Industry 4.0 resulted in the emergence of the term Construction 4.0. Construction 4.0 is modelled directly of the concept of Industry 4.0; the principle of Construction 4.0 is shaped on the basis of integration of various tools and technologies (both in the digital and physical layers) that provide the ecosystem platform from which the built environment assets are designed and executed. Construction 4.0 can also be interpreted more directly as the innovation of numerous construction management tools and techniques, driven by Industry 4.0 emerging technologies, that enables for a possible emergence of a truly construction site that is regarded as 'smart'. Construction 4.0 can also be implemented as an activity of the application of cyber (digital and cloud-based)—physical (site) systems which enable a digital transformation of the local sector intended for the sole purpose of attaining maximum project performance of the sector. Lastly, Construction 4.0 can be explained as the integration of cyber-physical digital technologies that support a digital construction site, digital modelling (Building Information Modelling (BIM); Digital Twin (DT)), simulation, and virtualization. So far, there is no specific Construction 4.0 model applicable to the South African construction sector. In enabling Construction 4.0 in South Africa, digital technologies would assist to solve the problem of excessive schedule overruns on projects which often also translates to cost overruns and poor-quality issues on project delivery.

Scholars also note several challenges in the local adoption of digital innovative technologies. Sawhey et al. [25] state the emergence of the Fourth Industrial Revolution (4IR) has resulted in a set of particular frameworks of Industry 4.0, the construction sector also could leapfrog to more efficiency in terms of improved project and business performance. Such a transformation can be a reality by the emerging of existing digital and newly introduced digital technologies forming part of the paradigm that is Industry 4.0 (Osterreich & Teutenberg 2016).

The growing rates of digitisation and the enhanced pace of technology adoption could potentially be a source of an augmented lift to South Africa's economic prosperity in the not too distant future [21]. A recent study scrutinised the economic performance of seventy-one (71) economies in the developing world in the last half century. The study identified from those developing economies eighteen (18) outperformers that had a consistent growth in terms of GDP over decades. Those countries from the developing world provide valuable economic lessons for South Africa. These developing countries that have been identified as outperformers economically have a pro-growth agenda of income, demand and productivity. As a central-component of that pro-growth agenda, they have fostered companies that are highly productive and also enabled for industries that are highly competitive. Utilising technology to greatly improve the level of innovation and project productivity, South Africa could emulate these economies. Thus, the objective of this review paper is to highlight the need for a set of guidelines in the form of a protocol that will establish a system of rules that explain the correct conduct, practises, and procedures in the formal enablement of Construction 4.0.

2 Literature Review on Construction 4.0 in South Africa

2.1 Scoping Review

In this section, a breakdown of the literature was reviewed, and the literature led to the identification of knowledge gaps that includes lack of adoption of digital technologies for enabling Construction 4.0. This literature reviewed was important to further identify publications related to the use of digital technologies to enable Construction 4.0 in South Africa over a 16-year period. The main keywords that were used in this paper were: Construction 4.0, Digitization, Transformation, Project Delivery, South Africa. Several scholarly databases were explored, such as Google scholar, EBSCO, Science Direct and Emerald to be precise. About one-hundred and thirteen (113) published papers were searched, comprising of conference papers and journals. The number was later refined based on appropriate titles and abstract, whereby several thirty-three (33) papers were of interest. To make it a point that the titles and abstract fit this survey all the papers retrieved were manually explored and analysed. Therefore, a conclusion of this study's investigation was that research on the "use of digital technologies to enable construction 4.0" topic over the last 16 years has been increasing as indicated. Only those papers deemed relevant to the subject matter were read, scrutinized and analysed further. This assisted with the identification of trends key interest areas that were covered by numerous papers, namely: 'Barriers to use of digital technologies, Assessment of stakeholders' inclination in the adoption of construction 4.0 technologies, Digital technology transformation, The use of digital twins for enabling construction 4.0, The utilization of 3DP for the enablement of construction 4.0, The usage of BIM for the formal enablement of construction 4.0', which represented the research scope within the 'construction 4.0' topic. The papers were classified according to the years. This classification shows that most of the research on Construction 4.0 was done in 2020 (18 papers) followed by 2021(11 papers) and lastly in 2018 (8). This is an indication that research on the usage of digital technologies to enable construction 4.0 has been increasing over the years and there is more exposure and understating around this space. However, it could indicate that the literature collected in this study could be limited. The continued exploration and findings around Construction 4.0 is a key mitigation strategy to avoid underutilisation of these technologies.

2.2 Opportunities Offered by Digital Technologies to Enable Construction 4.0

There are multiple well-known projects in South Africa that have suffered from the crippling challenge of severe time-overruns. The well documented Eskom projects, Medupi and Kusile power stations are but some of these projects (Tshidavhu and Khatleli 2020). A megaproject can be explained as an endeavor exceeding $1 billion United States Dollars (USD) (Flyvbjerg 2014). Practically, schedule overruns are a hallmark in megaprojects implementation (Aljohani et al. 2017). Megaprojects are very costly, they can be inclusive of numerous technical and contractual risk factors that can result in significant project delays or ultimately significant technical failures during the project's execution (Ma et al. 2017). The construction sector is notorious for its slowness to adapt, and traditional practices remain the most-used project delivery methods (Fulford and Standing 2014; Ahiaga-Dagbui et al. 2015). Innovative technologies, on the other side of the spectrum are not adopted fully by these companies. There are multiple digital innovative technologies accessible on the sector which focus on the improvement in the practicality and technicality of site-based activities and to enhance the construction project performance of local construction companies.

Abimbola [2] states that research conducted indicates that there are opportunities for the transformation of the construction sector towards Construction 4.0 and thereby increasing the sectors overall performance. Oke et al. [28] highlighted numerous barriers hampering the adoption of digital technologies. Majority of the role players have limited to no knowledge of their capabilities in terms of improving projects' productivity. Abimbola [2] indicates that there are various available digital technologies, offering an abundance of opportunities in improving historical challenges within the sector. This transformation has been widely accepted to be the blueprint for the Construction 4.0 framework. However, there are no clear guidelines on how this transformation can be smoothly implemented as there is no clear guideline or policy to aid implementation.

Gartner (2017) elaborates that the Framework for Construction 4.0 uses Cyber-Physical System (CPS) at its centre and links with a hub housing digital tools to create a digital ecosystem. This ecosystem is where independent cohorts of digital enterprises and role players can share integrated digital platforms for mutually beneficial purposes, improved project, and business performance. Sawhney et al. [25] mention that the Construction 4.0 framework is dependent on an integration of various digital tools and technologies (both in the digital and physical layers) where the Construction 4.0 framework is seen as a guide in terms of how projects are to be designed, executed, and managed. The protocol would assist in the identification of specific digital tools within the digital layer and how they could pair up with digital technologies on construction sites such as Augmented Manufacturing (3DP) to enable a digitized construction site.

3 Methodology

The sector has been slow to reap on numerous opportunities that technology and the progress in the availability of project data resulting in improved project performance, the uniformity and guarantee in terms of the quality of the project and business outputs. In spite of several historical attempts to augment a digital transformation, the sector currently has persistent shortcomings such as fragmentation in the process, ineffectiveness relating to flow of project information, and the role players working collaboratively. Therefore, the study is aimed at assessing the level of effectiveness of the introduction of a set of protocol guidelines which provide a guideline on best practises during implementation.

The methodology followed for this research is based on a narrative literature review. Onwuegbuzie et al. [29] describes a narrative literature review as an unbiased dissection, thorough, analytical evaluation of the existing knowledge on a subject matter. They are integral research components in the research process and assist in the drafting of a theoretical framework. Narrative literature review can be sub-divided into four areas being the following: general literature review, theoretical literature review, methodological literature review and historical literature review. For purposes of this research project, methodological literature review was chosen. Onwuegbuzie et al. [29] describes methodological review is defined as where the methods and design relative to the type of research are outlined. These reviews narrate the positives and negatives of the methods chosen and present possible orientation. This was the method best suited to identifying how the set of protocol guidelines can best be utilized in utilizing digital technologies for implementation of Construction 4.0 in South Africa.

4 Findings and Discussion

In reviewing the available literature using the methodological literature review approach, it was found that there is a strong willingness within the sector in the adoption of Construction 4.0. However, barriers to adoption are several as listed below on Table 1. Only the top ten (10) barriers were identified from the literature and grouped into order of importance or order based on a support by analyzed articles.

From the above findings it can be argued that that there is a need for the development of a protocol that forms a system of rules that explain the correct conduct, practises, and procedures in the formal enablement of Construction 4.0. The focus of the research is because within all these barriers, what can be ascertained is that there is no clear and concise way to implement digital technologies as identified within the three most-commonly referenced Construction 4.0 models as listed under Table 2. This is supported by the high ranking of three barriers; The Lack of standards on how to implement (15 papers), Legal and Contractual uncertainty (11 papers) and Regulatory Compliance 11 (papers). El Jazzar et al. [13] endorses the findings by mentioning that the implementation barriers identified in the enablement of a digitised sector, being the absence of global standards and associated guiding model or framework for implementation is a major blockade.

Osunsami et al. [32] in a recent research project of investigating the preparedness of role players in adopting technologies driven by Construction 4.0 supports the findings in this paper by also concluding that there is a strong drive to enable construction 4.0 among construction role players. The likelihood of a fusion of construction 4.0 principles is still relatively low. The basis of our research is that with the formulation of a set of protocols which will guide adoption of digital technologies to implement Construction 4.0 provides us with a gap in knowledge which can further be investigated. However, there needs to be a clear pathway looking at the South African context on how the digital layer will interact with the physical layer, which is what is currently missing. There are existing frameworks that could aid in this regard as presented in Table 2, however not all the digital technologies will be applicable. How the identified technologies will interact with each other needs to be supported by a clear set of guidelines which will assist to achieve, adopt and implement Construction 4.0.

Table 1. Implementation barriers: Construction 4.0

Barriers to implementation of construction 4.0		
Barriers	Descriptions	Sources and/or key references
Implementation challenges	1. High implementation costs	[1–12, 14, 15, 17, 19, 20]
	2. Low investments in Research and development (R&D)	[2, 3, 5–7, 9, 10, 12, 13, 15–20]
	3. Need for enhanced skills	[1, 2, 4–9, 11–15, 17]
	4. Longitudinal fragmentation	[3–9, 11, 12, 14, 15, 20]
	5. Lack of standards	[1–5, 8–12, 14 17, 19, 20]
	6. Data security. Data protection and cybersecurity	[1–11, 16, 19]
	7. Legal and contractual uncertainty	[1, 2, 4, 5, 7–12, 14, 19]
	8. Regulatory compliance	[1–3, 6–12, 19, 20]
	9. Fragmented industry structure	[1–3, 6–12, 19, 20]

References in the table above are as follows; 1 = El Jazzar et al. [13]; 2 = Sawhney et al. [25] 3 = Osunsami et al. [32]; 4 = Hossain et al. [15]; 5 = Oesterreich et al. [27]; 6 = Cooper et al. (2018); 7 = Dallasega et al. [12]; 8 = Alaloul et al. [3]; 9 = Klinc et al. [18] 10 = Munoz-La-Rivera et al. (2020); 11 = Prieto (2021); 12 = Ibrahim et al. (2019); 13 = Craveiro et al. (2019); 14 = Oke et al. [28]; 15 = Chowdhury et al. (2019); 16 = Aigbavboa et al. [26]; 17 = Taher (2021); 18 = Forcael et al. (2020); 19 = Windapo (2021); 20 = Osunsami et al. [32]

5 Gaps in Knowledge

Construction 4.0 can resolve the inherent problems experienced by construction projects as it can improve the productivity. Osunsanmi et al. [32] state that despite the numerous values offered by innovative technologies in industry 4.0, up to this point the sector has been unable to realise all the possible advantages and potentially challenge the other sectors such as manufacturing which has commenced reaping the rewards due to the peculiar characteristics of the industry.

In the different stages of the project lifecycle consisting of planning, design, execution, and management, there is room for innovation to be further investigated. This therefore calls for adaptions of innovation during each stage of the lifecycle, but with emphasis on stages of design and construction on how they can enable Construction 4.0. The importance of enabling Construction 4.0 through innovative digital technologies has been well established in the reviews of the pieces of key literature (Sawhney et al., [25], El Jazzar et al., [13], Munoz-La-Rivera et al., 2020, Osunsanmi et al. [30], Manzares et al., 2020, Prieto., 2021, Hatoum., 2021). The issue is which of these proposed digital technologies will best be suited to a local context by overcoming digital collaboration bottlenecks in the construction industry [28]. Adequate proof exists to support that adopting digital technologies will enable Construction 4.0 in developed countries

(Perrier et al., 2019). The state of affairs is adverse in developing nations as there is no tangible evidence relating to the transformation in terms of utilising digital technologies in the sector [22]. The key to a digital transformation that seeks to enhance project performance is embedded in comprehension of the project related risks involved is important [2]. Without undertaking empirical research in the field and analysing current projects, it will be difficult to know which of the available digital technologies will be able to override the local challenges in the sector.

The implementation barriers that have been established in this research as well as other referenced material, it's clear not all the listed digital technologies will best serve the case of South Africa to transform the sector from traditional methods to Construction 4.0, hence there is a need to identify only those digital technologies that can best assist to transform our local construction sector to achieve Construction 4.0 by forming the basis of a set of guideline protocols to be developed to ensure a successful attainment of the enablement of Construction 4.0.

6 Basis for the Formulation of a Protocol for Construction 4.0

The importance of why the sector requires a transformation from traditional construction to Construction 4.0 has been well established in the following pieces of literature (El Jazzar et al. [13], Sawhey et al. [25], Prieto. 2021, Ibrahim et al. 2019, Craveiro et al. 2019 and Munoz-La-Rivera et al. 2020). The concept of Construction 4.0 developed from the urgent requirement for the sector to simplify the fragmentation and to approach the necessary attainments required in the industry. Ibrahim et al. (2019) state that technology inline with the Industrial Revolution 4.0 is gradually improving, the sector is facing more futuristic and complex design requirements, green building, smart home and diversity of material, which necessitates for the construction role players to transform from conventional practices to leverage more on digital and modern technology. Craveiro et al. (2019) supports this by stating that this transformation, which by analogy to manufacturing has been termed as Construction 4.0, will assist construction companies to improve effectiveness in terms of increased productivity, reduction in project delays and budget overruns and improved safety, quality, and resource-efficiency. The transformation of the sector is crucial as several emerging economies have achieved strong growth by leveraging on digital technologies to improve project performance and innovation, South Africa can emulate these economies (Mickinsey 2019).

In transforming the local sector to Construction 4.0, the use of digital innovative technologies is paramount. However, in the review of preliminary literature there seems to a contrast in various arguments, theories, methodologies, and approaches in the literature, regarding how best to transition from conventional to digital construction. One of the differences identified, is which of the available digital technologies would best be suited to make this transition in South Africa. There are three (3) models widely discussed around the field of Construction 4.0. These three models are coherently different from each other. The comparison of the three models is shown below in Table 2, also shown are the digital technologies within each layer.

All the three models listed presented below were analysed based on available literature and the results were utilised to provide inputs into the proposed protocol to be developed which will be tested on current construction projects.

Table 2. Available construction 4.0 models

	Construction 4.0 models		
Model type	3-layer transformational trend model	3-layer approach model	4-layer implementation model
Authors	Sawhney et al.[25],	Munoz-La-Rivera *et al.*(2020)	El Jazzar et al.[13],
Layers within each model	1. Digital layer, 2. Digital tools and 3. Physical layer	1. Building information modelling (BIM), 2. Lean construction (LC) and 3. Integrated project delivery (IPD)	1. Construction 4.0 technologies 2. Construction 4.0 lifecycle 3. Construction 4.0 integration and 4. Construction 4.0 requirements
Digital technologies	12 digital technologies listed	39 digital technologies listed	7 digital technologies listed

7 Conclusions

The implementation of digital technologies to enable Construction 4.0 is a necessity to achieve maximum project effectiveness. The study highlighted the barriers involved when attempting to use digital technologies for enabling Construction 4.0 in the local sector. The findings of the study conclude that due to the inefficiency or non-existence of regulatory compliance, legal and contractual compliance, a lack of standards and adequate infrastructure. There is little guidance or technical know-how in how to best implement the available digital technologies to enable Construction 4.0 in South Africa.

In conclusion, the study recommends that since there may be a lack of sufficient digital infrastructure locally as compared to the developed world to adopt Construction 4.0 successfully only specific digital technologies form part of the proposed protocol design. The research study serves as a basis for future research projects intending to advance a specific model or frameworks purely aimed at utilising specific digital technologies to enable Construction 4.0 because of the inability of South Africa to adequately support a full digital technology interoperability ecosystem as presented in the existing Construction 4.0 frameworks for developed nations. Lastly, the study serves as a contribution to the enablement of Construction 4.0 in South Africa.

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Global Trend in Retrofitting Using Smart Technology: A Scientometric Review

Cyril Ejidike[1], Modupe Mewomo[1](✉), and Timothy O. Olawumi[2]

[1] Department of Construction Management and Quantity Surveying, Durban University of Technology, Durban 4001, South Africa
22175606@dut4life.ac.za, Modupem@dut.ac.za
[2] School of Engineering and Built Environment, Edinburgh Napier University, Edinburgh, UK
T.Olawumi@napier.ac.uk

Abstract. Retrofitting an existing structure enhances its energy efficiency, aesthetic appearance, and thermal comfort while also reducing the building's energy costs. Buildings account for 40% of global energy consumption, which is also responsible for CO_2 emissions than any other economic sector. The achievement of high energy performance, thermal comfort, and cost optimization for new buildings has become more realistic with the rise in the use the innovative technology in building construction. However, studies have increased the contribution of smart technology in retrofitting a building, but the extent of the work remains unmapped. Hence, the domain knowledge must be documented, especially regarding the global perspective of smart technology in retrofitting the building. Therefore, this study critically reviews existing literature on smart technology use in retrofitting using a scientometric analysis approach. VosViewer software was employed to analyze the retrieved research corpus. Findings revealed momentum in retrofitting studies in 2017. The smart technology most used in retrofitting is smart meters, heat pumps and photovoltaics. The scope of the study is limited, with the majority of studies focusing on trade-offs between energy costs and thermal comfort. Also, the Energy and Buildings journal is the most cited and published research outlet in building retrofitting with technologies. The United States was identified as the most productive nation in the subject matter, while South Africa is the most productive country in sub–Saharan Africa.

Keywords: Retrofitting · Network trends · Scientometric · Smart technology

1 Introduction

Cities are predicted to house 70% of the world's population by 2050 [1] and are projected to account for nearly three-quarters of global (direct) final energy use [2]. It entails significant environmental and social sustainability challenges in the built environment [3]. The building sector accounts for 40% of global annual energy consumption, increasing yearly, making the sector a primary energy consumer [4]. Meanwhile, the sector is also responsible for 39% of greenhouse gas emissions than any other economic sector [5]. In Africa, the building sector accounts for 61% of final energy use and 32% of greenhouse

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gas emissions CO_2 [6], which contribute significantly to global concerns such as global warming, environmental degradation, and ozone layer depletion [7]. The goal to achieve sustainability in the built environment depends on the ability of countries to reduce the level of fossil-based energy consumption [8]. The advent of innovative and efficient smart technology has facilitated high energy performance, thermal comfort, and cost optimization for new buildings [9].

Moreover, although some new building developments meet the requirement of near-zero energy building, the energy consumption and CO_2 emission in the building sectors will still be high as most of the global building stock are existing buildings [9]. Hence, it is essential to emphasized the retrofitting of the building towards minimizing the energy consumption (heating, cooling, and lighting) and cost of operation to achieve sustainability in the built environment [10]. According to Asadi et al. [11], developing a list of appropriate retrofit measures for specific projects remains a significant technical and methodological research gap; despite an emerging range of retrofit technologies. Therefore, this study explores these smart technology approaches used in building retrofitting and design.

2 Building Retrofitting

The retrofitting of existing buildings allows for significant energy and non-energy performance improvement with mature and off-the-shelf technologies [9]. According to Saleem [12], retrofitting can be described as adding new components (hardware and software) to an existing building to improve its performance. Also, retrofitting involves eliminating, installing, rearranging, or replacing one or more components of a building [4]. The U.S. Department of Energy defines building retrofit or renovation as a chance for existing structures to improve their energy performance across their lifecycle [13]. Meanwhile, the application of smart technologies is a set of functionalities supplied by hardware and software components that work together to create seamless connectivity within a building, such as smart devices and smart systems [14].

Several studies have applied smart technologies for building retrofitting. For instance, Zhai et al. [15] regard deep-energy retrofitting of commercial buildings as a key pathway toward low-carbon cities. Zhai et al. used an integrated energy-efficient measure portfolio that links the lighting occupancy and heating control sensor to achieve optimal light distribution in a building. Glad [16] used a thermostat, smart meter, and billing to control occupant energy consumption and water-filled radiators to control water usage. The smart meter collects data at constant intervals, providing occupant usage data, while single-handle taps and low-flush toilets helped save water consumption. Skea [17] advocated using biomass boilers, heat pumps, solar thermal energy, and smart metering as an alternative to reducing energy consumption from non-renewable sources. Also, Asadi et al. [18] presented a multiobjective optimization model to assess technology choice in a building retrofit project quantitatively. Such as insulation materials for walls, roofs, and solar collectors. Desogus et al. [19] employed resistive temperature detector sensors to measure the surface temperature of the ceiling and wall.

Meanwhile, Zhu et al. [20] applied ground water-source heat pump system technology for hotel building retrofit to save the water source consumption and electricity used in heating and cooling in a clean and new way, which improved the building performance of the hotel. Bhati et al. [22] investigated the use of smart meters to detect behavioural patterns and proactively turn off the lighting and appliances, thereby conserving energy in smart homes. Bonamente et al. [23] highlighted the benefits of innovative renewable energy technology such as photovoltaic and energy-efficient lighting systems to reduce buildings' operational carbon emissions.

Hence, the current study aims to thoroughly review one-decade research breakthroughs in building retrofitting technology applications with bibliometric analysis techniques. This study's objectives include (1) identifying the most influential journals and countries in the field and (2) identifying the research focus on building retrofitting and salient research themes. The study findings would increase the knowledge base on building retrofitting by providing a broad overview of the trend and structure. To the best of the authors' knowledge, this is the first study that uses a scientometric technique to analyze extant literature related to building retrofitting using smart technology.

The study was limited to the scope of building retrofitting technology despite the noteworthy findings. Furthermore, the study mainly examined research publications published between 2011 and 2021. Also, it omitted the advancement of optimization applications for retrofitting decision-making. This type of analysis is critical for discovering new trends in the subject that can be researched further in the future. As a result, the current paper is distinct from [24].

3 Methodology

The choice of a database is critical when conducting scientific reviews as it directly impacts the quality of the outcome [25]. The primary bibliometric data sources include the Web of Science (WoS), SpringerLink, Google Scholar, ProQuest, ScienceDirect, Scopus, PubMed, Dimensions Microsoft Academic. WoS and Scopus are the most widely utilized databases in science mapping. Since 1900, WoS has indexed more than 21,000 peer-reviewed journals, resulting in about 1.9 billion cited references from over 171 million entries [26]. Therefore, this study selected WoS as the primary database for retrieving published research articles because of its scientific soundness and comprehensiveness [26].

3.1 Data Collection

The study used journal articles as the article type since it has been peer-reviewed for quality and reliability. Search terms such as "building retrofit", OR "smart technology", OR "retrofitting building" were used to identify relevant literature within the Web of Science Core Collection from the year 2011 to 2021, making it a one-decade research output discovery.

Scientometric is defined as applying quantitative research methodologies to the evolution of science as an information process [27]. He et al. [28] pointed out that the goal of scientometric research is to examine the intellectual landscape of a knowledge domain, the issues that scholars have been striving to answer, and the methods they have devised to attain their objectives. Olawumi and Chan [29] further affirmed that scientometric analysis is one of the most widely used approaches for evaluating and examining the research development and performance of academics, faculties, colleges, countries, and journals in a given subject matter. The scientometric analysis provides a more comprehensive yet concise capturing and mapping of a scientific knowledge domain by finding structural trends and delineating critical research horizons. Other scientific methodologies, such as the bibliometric technique, are also helpful [37]. Although Amirkhani et al. [26] emphasized that scientometrics and bibliometrics are similar, they both deal with quantitative analysis of publications or other types of communication that deal with scientific output and value.

In construction research, these methodologies are widely accepted and encouraged, as they assist the researcher in comprehending the current research trend [32]. In scientometrics, the number of times publications cite each other is used to determine their relatedness. Also, researchers use this method to determine the field core trends [31]. Meanwhile, co-occurrence analysis is used to evaluate the association between research sources, keywords, and the like in publication data.

3.2 Visualisation of Data

This study used VOSviewer to perform the analysis of the bibliometric data retrieved. Figure 1 shows the overall research approach for the study.

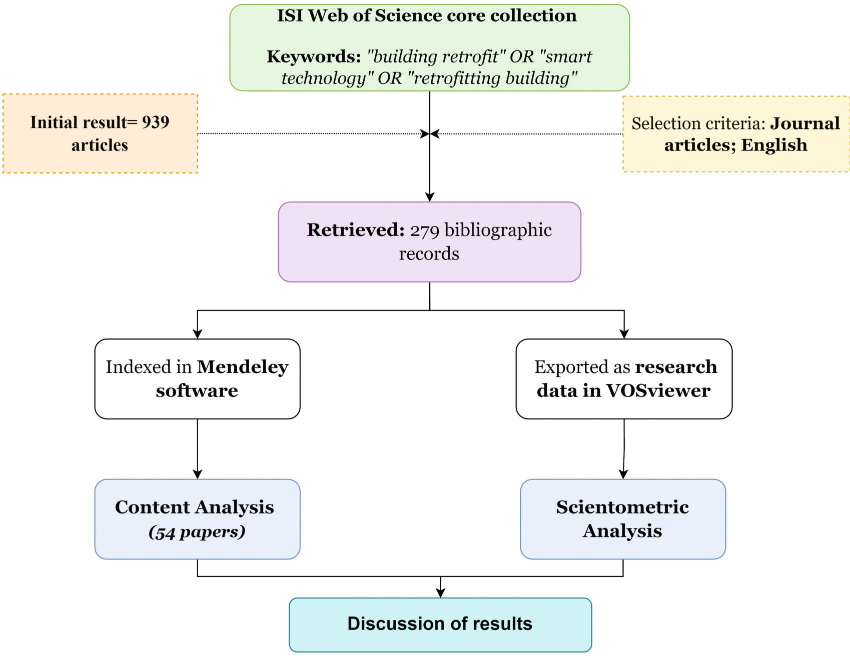

Fig. 1. Overview of research approach

4 Results and Discussion

4.1 Trends of Publications

The first research article using smart technology in building retrofit was conducted by Moreno-Munoz et al. [32]; the study focuses on integrating smart technology into building to improve energy efficiency. The article has 11 citations. Figure 2 shows the publication distribution of the articles on retrofitting technology applications between 2011 and 2021. The result indicates that retrofitting started gaining interest between 2012 and 2013, with eight publications each. The year 2020 has the highest number of publications with 58 articles. The results show that interest in retrofitting technology applications has increased. The trends of publications are expected to grow due to increasing demand for the reduced environmental impact of the energy used in the building, coupled with the introduction of optimization model methodologies in retrofitting for financial decision making of stakeholders to achieve sustainable development in the built environment.

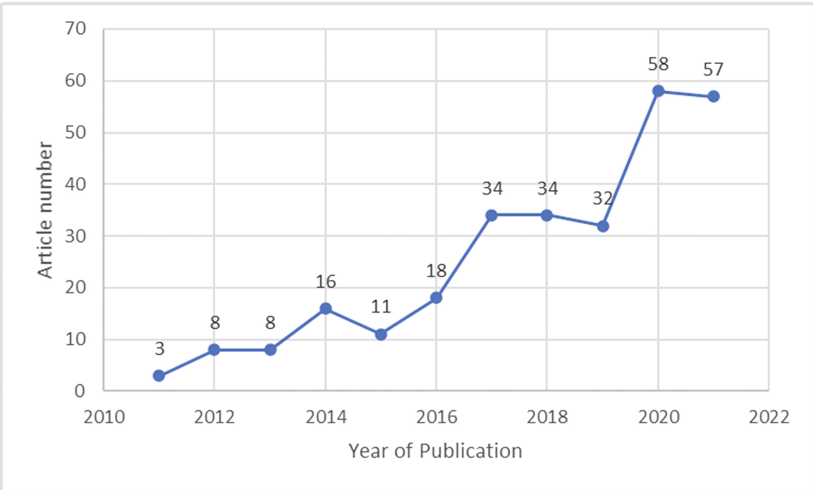

Fig. 2. Distribution of research publications from 2011 to 2021

4.2 The Co-occurrence of Keywords Analysis

The keywords analysis is a vital bibliographic analysis that identifies the major research areas within the discipline [33]. The networks created using keyword analysis provide a holistic view of a research field by revealing tangled relationships within a domain's research topics/subtopics. The formula is based on the frequency of co-occurring keywords in publications and the strength of their correlations Omrany et al. [33]. The VOSviewer software was utilized to explore the co-occurring keywords network. In the co-occurrence analysis, all keywords were considered, including those used by authors and those indexed by publishing journals [34]. The minimum number of occurrences of a keyword was set at 10. The analysis results with a minimum threshold of 35 keywords are shown in Fig. 3. The size of the nodes represents the number of periods keywords have been used in the literature. The thickness of connecting links shows the density of connections, and the closeness of notes indicates solid interconnections between them.

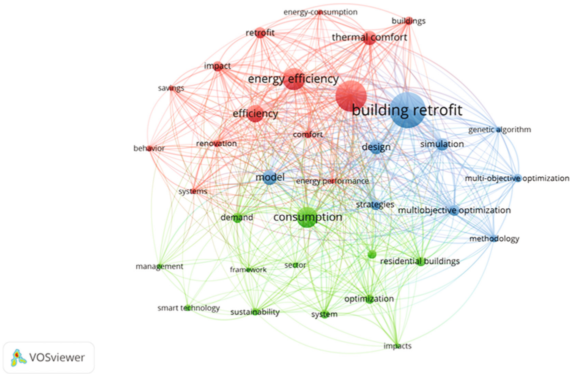

Fig. 3. Co-occurrences keywords.

Figure 4 shows the top 20 keywords with the highest co-occurrence values and their link strength, showing that they have gotten greater attention and are closely linked to other keywords. The keywords such as 'performance,' 'consumption,' 'energy efficiency,' 'multiobjective optimization', 'efficiency,' 'building retrofit,' and 'thermal comfort' indicate those with higher occurrences and total link strength, which shows that they have received more attention and are highly linked terms. Smart technology that occurred on the string search list was included. Hence, a higher value is expected. Despite this expected result, these keywords are kept in the analysis because excluding them may omit essential keywords linked to them.

It can be observed that these keywords and others, such as the design and model, are located near the borders of the clusters, indicating that they are cross-cutting keywords with a solid linkage to different clusters. These and other keywords, such as "consumption" and "building retrofit," are found at the cluster's borders, indicating cross-cutting terms with solid ties to multiple clusters and subjects. As a result, to improve the sustainability potentials of existing buildings, efforts must be directed toward improving energy efficiency and reducing CO2 emission and water consumption, which are the primary aim of retrofitting [43, 44]. The higher value of the terms "energy efficiency" and "performance" implies that much attention has been paid to developing the energy performance of buildings. The study's findings are consistent with previous studies, which show that close attention has been paid to improving existing buildings' performance and energy efficiency through retrofitting [46, 47]. The term "smart technology and multiobjective optimization" shows hardware and software applications, indicating the importance of technology in achieving sustainability in the built environment [48, 49].

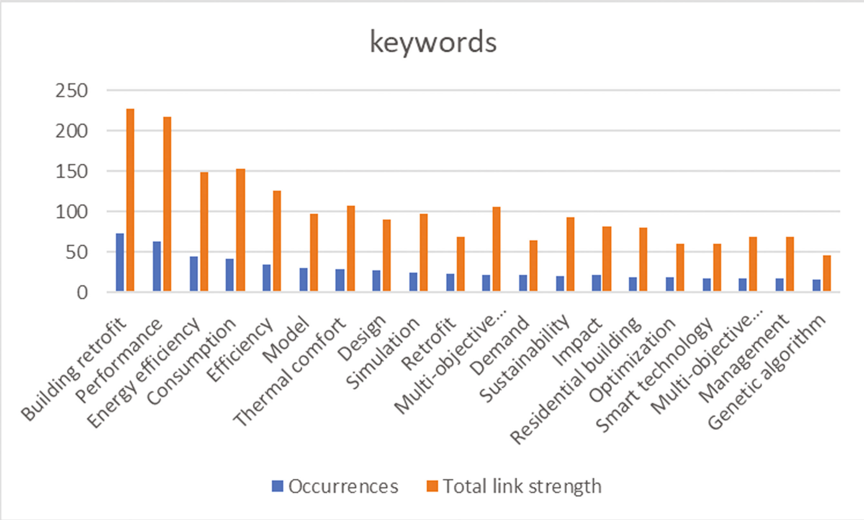

Fig. 4. Twenty keywords with the highest occurrence

4.3 Trending Research Topics

The cluster provides insight into the current trends through the co-occurrence analysis in popular retrofitting research topics. Developing such an understanding lays the foundation for future technology and expansion in the sector. The list below indicates three significant clusters. Red is the largest cluster that includes 14 keywords. It is primarily due to increased building energy efficiency. The top five co-occurrence keywords are as follows: performance (217), energy efficiency (154), efficiency (126), thermal comfort (108), and impact (82) (see Table 1 for the complete list of keywords clusters). Red clusters indicate the focus in the built environment on mitigating the effects of energy consumption in the building construction sectors, which dominates existing buildings. The keywords are closely related to retrofitting of buildings. The importance of energy-related policies cannot be underscored in buildings, transitioning our facility towards net-zero building and achieving sustainability [29, 33]. The second cluster (green colour) has 12 keywords related to management, framework, and policy in the building sector. The clear focus is on developing a retrofitting polices roadmap to achieve energy efficiency and CO_2 emissions reduction for a sustainable built environment [50, 51]. The third cluster (blue) consists of 9 keywords. It mainly focuses on methodologies and computer-aided tools to support decision-making in building retrofitting, such as the model, multiobjective optimization, genetic algorithm, and design technology application. The simulation mathematical building performance optimization formulas allow for adequate decision-making support to the bast retrofitting measure to adopt in a particular project while considering the thermal comfort cost of retrofitting, CO_2 emission reduction, and energy efficiency measure [4, 9].

Red cluster (Behavior, Building, Comfort, Efficiency, Energy efficiency, Energy consumption, Impact, Performance, Renovation, Retrofit, Saving, and Thermal comfort). Green cluster (Consumption, Demand, Energy, Framework, Impact, Management, Optimization, Residential building, Simulation, Sectors, Smart building technology, Sustainability, and System). Blue cluster (Building retrofit, Design, Genetic algorithm, Methodology, Model, Multiobjective optimization, Multiobjective optimization, Strategies, Genetic algorithm, and Methodology).

4.4 Citation Analysis of Journals and Countries

Three methods are primarily used to correlate citation between sources: bibliographic coupling, direct citation, and co-citation analysis [26]. The co-citation method quantifies the strength of association between two papers cited by the same documents [49 38]. The direct citation approach investigates relationships between two publications in which one cites the other. The process of bibliographic coupling is used to find relationships between publications that cite the same publications. According to Klavans and Boyack [46], co-citation and bibliographic coupling correlations are indirect correlations and provide less reliable data on the connectedness of articles than direct citation correlations.

Furthermore, for direct citation correlation, Amirkhani et al. [26] claimed that the best and quickest way for identifying emerging research fields domains is to compare co-citation and bibliographic coupling correlations. Direct citation analysis, however, has its limits. Some articles, for example, may lack direct citation correlations with other items and, as a result, cannot be assigned to a source [26]. Therefore, the direct citation was utilized to identify the most dominant journal by setting the minimum number of source documents to 1 and the minimum number of citations of a source to 50. The results in Fig. 5 show that Energy and Building (2245), Building and Environment (649), Sustainability Cities and Society (342), and Sustainability (236) are the dominant journal sources of research citation.

Author citation. The scientometric analysis of the most contributing authors in building retrofitting with the application of technologies revealed that Antunes, Carlos Henggeler (725), Asadi Ehsan (676), Da silva Manuel Gamerio (676), and Xia Xiaohua (112) are the most contributing authors with the minimum of 5 documents and minimum of 50 citations. Additionally, this information helps identify research groups and assist research partnerships and policymaking.

Citations by countries. The countries with the greatest contributions to the growth of the retrofitting topic were identified by bibliographic coupling. The term "bibliographic coupling" refers to studying the relationships between two publications that cite the same document. [26]. The result in Fig. 6 illustrations the analysis carried out for a minimum of 100 citations per country. The findings indicate that the United States (1241), Portugal (965), and Italy (842) are the most cited countries. However, most of the citations are from developed countries.

Furthermore, it can be observed that the studies from African countries are not well cited, except for South Africa, which had 133 citations in the field of building retrofitting. South Africa has been a frontline in sub-Saharan Africa in reducing energy consumption

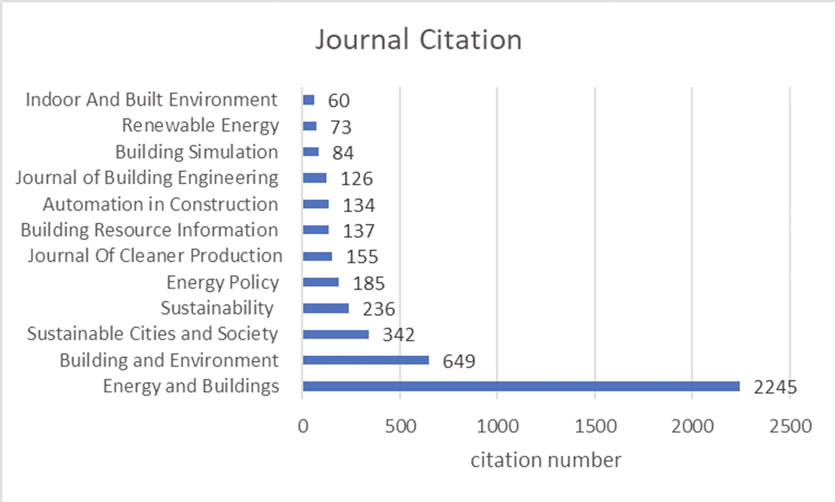

Fig. 5. Citations by journal

Table 1. Authors citations

Author	Institution	Country	Citation
Antunes, Henggeler	University of Coimbra	Portugal	725
Asadi Ehsan	RMIT University	Australia	676
DaSilva Gamerio	University of Coimbra,	Portugal	676
Xia Xiaohua	University of Pretoria	South Africa	112
Augenbore Godfried	Georgia Institute of Technology	United States	98
Ascione, Fabrizio	University of Naples Federico II	Italy	93
Bianco Nicola	University of Naples Federico II	Italy	85
Deb Chirag	Institute of Technology in Architecture	Switzerland	79
Freire Fausto	University of Coimbra,	Portugal	74
Caputo Paola	The University of Palermo	Italy	71
Schlueter Arno	Institute of Technology in Architecture (ITA),	Switzerland	54

and CO_2 emission [47]. The citation can be attributed to reducing energy consumption and CO_2 emission.

5 Conclusions

The need to create a climate-friendly built environment has called for a collective effort from countries worldwide to reduce greenhouse gas emissions in their environment. Human-induced activities and climate change have led to several challenges in recent

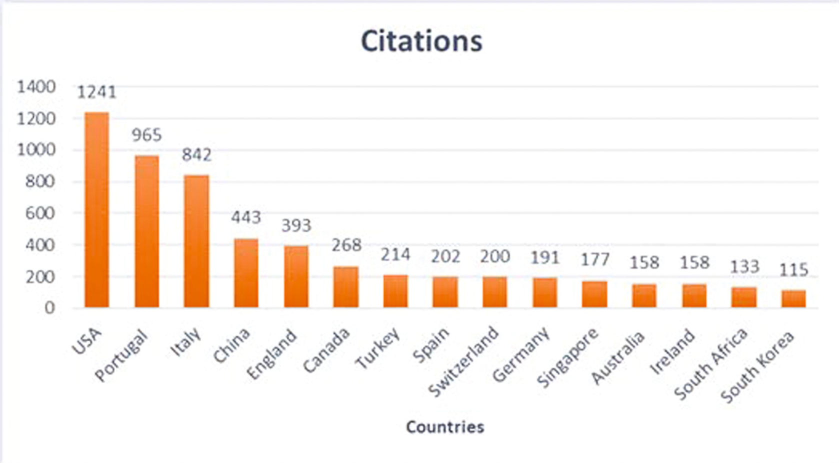

Fig. 6. Countries citation

years, and carbon emissions are the leading environmental concerns caused by fossil fuel consumption. The built asset itself consumes vast global energy. It contributes to the degradation of the environment, air pollution, high construction waste, and ineffective consumption of water and electricity in the built environment, which causes a poor environment for human inhabitants.

In addressing this challenge, attention should be directed to the new buildings and the retrofitting of existing building stock because they are the primary consumer of the vast energy usage in the built environment. In the subject of retrofitting research, the study via the illustrated research networks provides useful insights to researchers, practitioners, and governmental organizations. The study's findings revealed that retrofitting with technology started gaining interest in 2011 with a few publications. It has garnered increasing interest from relevant stakeholders over the years. The study showed that interest in retrofitting is importantly directed to the alternative ways to offset the rising energy cost primarily caused by heating, water, cooling, and lighting in a building. However, there are limited studies on digital or smart technologies that address ineffective electricity and water consumption and the maintenance of existing buildings.

A major focus of these research articles is the need to find alternative ways to reduce the cost of heating (energy) and maintain the building performance rather than demolishing old buildings as a more viable option. Also, it revealed that these studies focused on the trade-offs between thermal comfort and energy usage reduction strategies. Furthermore, most citations are from a few journals of which 'Energy and Buildings' and 'Building and Environment' stand out as key research outlets. Also, the most productive country is the USA, with the highest citation. In Africa, South Africa had the highest citation. The most contributing authors in building retrofitting with the application of technologies were also revealed.

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Impact of Big Data Usage in the Construction Industry

Opeoluwa Akinradewo(✉)

Faculty of Engineering and the Built Environment, Cidb Centre for Excellence and Sustainable Human Settlement and Construction Research Centre, University of Johannesburg, Johannesburg, South Africa
opeakinradewo@gmail.com

Abstract. Big data is acknowledged in many industries for its ability to be analyzed computationally, contrasting manual data. With the construction industry successfully improving its technology adoption level, big data utilization has been observed in recent numerous construction projects. The main aim of this study was to assess the impact of big data usage in the South African. The study was conducted using the quantitative approach. A well-structured questionnaire was used to conduct the survey on 190 construction professionals in the South African construction industry in three provinces, Gauteng Province, Kwa-Zulu Natal and the Western Cape province. The study participants were construction professionals which include quantity surveyors, construction managers, construction project managers, architects and engineers. The results obtained were analysed using descriptive analysis such as mean item score and standard deviation. The findings also revealed that big data usage improve the efficiency of cost management significantly. From this study, it may be concluded that the utilization of big data in the construction industry predict projects performance and improve management of costs significantly. The study recommended that construction professionals must be fully aware of these challenges to mitigate against the failure of the industry to grow through this innovative technology. This study furnished construction professionals with knowledge on the impact of big data usage in the South African construction industry.

Keywords: Big data · Big data usage · Construction industry · Impact

1 Introduction

The construction industry is one of the most dominant and important industries with popular features such as being vast, diverse, complex, unique, and never static [1]. In a natural manner, the building industry has multiple trades, disciplines, companies, suppliers, stakeholders all working on the same project. Furthermore, some projects in the construction industry according to [2] are exceedingly large and generate huge volume of data throughout the project life cycle. According to Çetin [3], there are millions of emails, works and documents used in an infrastructure project. The large volume of data from projects designs, schedules, finances, Enterprise Resource Planning (ERP) systems all create the voluminous construction data [4]. This amount of data is quite a

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lot for traditional computing systems to handle and this mass amount of data is what we term as big data.

Generally, advanced technology led to the emergence of the era of big data in the present-day. Also, the rapidity of the data generated has led towards data explosion hence big data gain its traction [5]. The rapid growth of big data is impacting the building industry [6]. Information and communication technologies are swiftly developing, big data is envisioned to form new models for construction project management and allow effectiveness of designs and construction activities [7]. Big data is already revamping the construction industry into and out of its different phases, from the design phase down to the completion phase. The construction industry is using big data to make progress in productivity by making use of devices such as wearables, sensors and smartphone which track the movement of things on site and collect data which will then be analysed and used as a reference in future [8]. The author added that more precise project budgets and estimates can be produced using data readily available in existing sources. Also, from these sources, information about the costs of resources and their availability can be collected to determine how available funds can be used. The profitability of certain projects can be determined by comparing this data with other projects payments [9]. Furthermore, improved planning, improving the digital structure of the company, optimising and securing data, simplifying, optimising and organising storage needs in a cost-effective manner are some of the many contributions of big data in the construction industry [10]. Based on these identified contributions of big data, this study is set to assess the impact of big data usage in the construction industry.

2 Overview of Big Data

From our everyday life and work, data is being generated at an exponential rate [11]. The rapid development of big data over the years slowly leads people to realize the different utilities and huge value concealed behind data. Consequently, to form a comprehensive knowledge of the field of big data is vital [12]. Koseleva [13] assert that big data "is a popular phenomenon that aims to provide an alternative to traditional solutions based on databases and data analysis". The authors add that big data "refers to datasets that are terabytes to petabytes (and even exabytes) in size, and the massive sizes of these datasets extend beyond the ability of average database software tools to capture, store, manage, and analyze them effectively". The variety of data generated by ever-present commercial and social activities, uploading of videos, generation of product, communication via cellular phones, website visits, and messages make clear that big data has entered the life of people [14]. To support this study, Koseleva [13] added that with technologies such as sensor, wireless transmission, and network communication technology, smart mobile devices and cloud computing developing quickly, it is certain that huge amounts of data are accumulated in nearly all aspects of our lives.

A numeral interpretation of the latter if from a study by Gartner [15] where the author predicted that "6.4 billion connected devices would be in use worldwide in 2016 and that the number will reach 20.8 billion by 2020". Access to data and storage is not all big data is about; analysing data for the purpose of making sense of them and making use of their value is among what its solutions aim for. Currently, the creation of communication and information technology represented by IoT, big data and cloud computing is developing swiftly, which through integration with other technologies, is speeding the growth of intelligence and ecology [13]. Big data make use of distributed processing and database, cloud storage and virtualization technology to execute distributed data mining for enormous data [14]. In addition, big data recover useful information by digging deep into the three common types of data namely; structured, semi-structured and unstructured [12].

3 Impacts of Big Data Usage in the Construction Industry

Large capacities, fast processing speeds, and the diverse nature of big data make it an ideal choice for improving the value of things themselves. These valuable data help us predict trends and patterns of the future by using big data technology [14]. Construction management has always been impacted by technology, from research to practice, but there are new demands for technology. Therefore, new data can contribute to the trend towards a more intelligent built environment, providing insights into the complete lifecycle of a building [16]. With the help of big data, knowledge about construction costs, designs, and processes can be gained [17]. The authors uttered that the objective is to develop tools and methods for managing construction projects intelligently, efficiently, and sustainably. Furthermore, the authors identified that integration of areas such as Building Information Modeling (BIM), and other systems is possible with the use of big data. Xingye, [14] added to this study and concluded that a knowledge base such as this can be used to support decision making, innovate technical systems, and project managers can be educated and trained. Another impact of big data is that, for the construction industry, location-aware data can provide useful insights into urban planning, as it provides early information on the use of public spaces and infrastructure by people during the project conception phases [17].

According to Bakht [18], an analysis of big data captured from social media can provide information on stakeholders' impacts on infrastructure megaprojects. Williams [19] demonstrated that by collecting new data and applying analytical methods, a more expert understanding of project management maturity can be gained. According to Tanga [20], an effective data handling process facilitates the decision-making process and assists in managing projects successfully. Akinradewo [6] discussed some early successful applications of data-driven design and planning, including how they can benefit building teams. For instance, designers can optimize early prototypes by capturing and analyzing key building performance metrics, like energy use intensity. A further impact of big data firms can use feedback data from building occupants to compare design concepts with the reality, and to help the building team better understand how people interact with space [17]. The authors further demonstrate that behaviour can be observed using big data in construction. The use of big data allows for more accurate predictions, which results in more effective decisions. Additionally, the authors concluded that big data can provide new insights into the cost, design, and process of project management [17].

According to Konikov [21], it can be safely assumed that big data can be a powerful tool for enhancing construction operations' environmental performance. Bilal [22] added that various tasks, such as profit margin estimation, can be revitalised using this overwhelming project data. Using this capability, estimators can make accurate projections by considering project-specific insights. As a result of these insights, the project team can predict the end of a project's life cycle and forecast actual project performance by that time [22]. In the rapidly evolving world of information and communication technologies, big data will play a significant role in the development of new paradigms for managing construction projects and improving the efficiency of design and construction operations [7]. Moreover, the performance of construction projects can be accurately predicted using big data, and uncertainties can be detected early in the design process [14]. Strategies that control future project costs can be formulated based on the cost-related data gathered from past projects [22]. As a result, big data can significantly improve the efficiency of cost management [7].

Table 1. Identified impacts of big data

S/N	Impacts of big data usage	Authors
1	Provide insights into the lifecycle of a building	[17]
2	Aid with the knowledge of costs	[17]
3	Aid with the knowledge of designs	[17]
4	Aid with the knowledge of construction processes	[17]
5	Support decision making	[14]
6	Innovate technical systems	[14]
7	Educate and train project managers	[14]
8	Provide insights into urban planning	[17]
9	Provide information on the use of public spaces and infrastructures	[17]
10	Provide information on stakeholders' impacts on infrastructure megaprojects	[18]
11	More understanding of project management	[19]
12	Compare design concepts with the reality	[17]
13	Observe workers behaviour	[17]
14	More accurate predictions of project outcomes	[17]
15	Enhance construction operations' environmental performance	[21]
16	Revitalise profit margin estimation	[22]
17	Forecast project performance	[22]
18	Improve the efficiency of design and construction operation	[7]
19	Formulate strategies that control future project costs	[4]
20	Improve the efficiency of cost management	[7]
21	Generate extra value to construction projects	[7]

A further impact is that construction images data, for instance, can be used to detect unsafe worker behaviours and thus reduce the occurrence of accidents on site [23]. Not least important, big data can also generate extra value to construction projects [7]. It is mainly the potential impact of big data usage on project results that motivates its utilization, the author concluded.

To operationalise the identified possible impacts of big data in the construction industry, Table 1 gives a definition of the variables.

4 Research Methodology

This research was carried out using a quantitative approach. This approach is known to be deductive in nature. This is because it simplifies situations to a point where they can be measured, tested and examined. The methodology allows the researcher to determine the methods, tools and techniques to be used for data collection. For this study, a questionnaire was put together and sent out to the participants to gather the necessary information. The research was conducted in three provinces of South Africa, namely; Gauteng, KwaZulu Natal and the Western Cape. The study participants were construction professionals; quantity surveyors, construction managers, construction project managers, architects and engineers. A sample according to McCombes [24] is the specific group of individuals that you will collect data from. The non-probability sampling technique was adopted for this research and two types of this techniques were used, namely, convenience sampling and snowball sampling. For this study, 190 respondents were contacted in the three identified provinces, but 165 responses were retrieved which were subjected to analysis. The Statistical Package for Social Science (SPSS) software was used to analyse the quantitative data retrieved through mean item scores, standard deviations, and Cronbach's alpha to determine the reliability of the study. The Cronbach's alpha analysis revealed a value of 0.973 which indicated that the data collection instrument is reliable.

5 Result and Findings Discussion

The highest educational level of the respondents revealed that of the 160 respondents, 40% are master's degrees holders, 26.7% are bachelor's degrees holders, another 26.7% are diploma degrees holders, and 6.6% are doctorate holders. For the respondents' professional qualification, the results reveal that 43.3% of the respondents were quantity surveyors, 35% were construction managers, 13.3% were construction project managers, 6.7% were mechanical engineers, and only 1.7% were civil engineers. Analysis of the years of working experience reflected that 40% of the respondents had working experience in the construction industry that ranged from 0 to 5 years, 28.3% of the respondents had a working experience that ranged from 5 to 10 years, another 28.3% of the respondents had a working experience that ranged from 10 to 15 years of and 3.3% of the respondents had a working experience that ranged from 15 to 20 years.

Table 2 below shows respondents' ranking of the impacts of big data in the South African construction industry. The results indicated that the top three ranked impacts were 'forecast project performance' which was ranked first, with a mean item score of 4.17 and a standard deviation of 0.642; 'improve the efficiency of cost management' which was ranked second with a mean item score of 4.15 and a standard deviation of 0.659; and 'formulate strategies that control future project costs' which was ranked third with a mean item score of 4.12 and a standard deviation of 0.666.

The three possible impacts of big data which were least ranked were 'compare design concepts with the reality' with a mean item score of 3.85 and a standard deviation of 0.799 which was ranked seventeenth; 'provide information on the use of public spaces and infrastructure', 'provide information on stakeholders' impacts on infrastructure megaprojects' and 'innovate technical systems' which were all ranked eighteenth

Table 2. Descriptive analysis of the identified impact of big data in the South African construction industry.

Impacts of big data in the South African construction industry	Mean item score (MIS)	Standard deviation (SD)	Rank (R)
Forecast project performance	4.17	0.642	1
Improve the efficiency of cost management	4.15	0.659	2
Formulate strategies that control future project costs	4.12	0.666	3
Improve the efficiency of design and construction operation	4.08	0.645	4
More accurate predictions of project outcomes	4.08	0.766	4
Provide insights into the lifecycle of a building	4.08	0.787	4
Revitalise profit margin estimation	4.07	0.578	7
Generate extra value to construction projects	4.05	0.622	8
Aid with the knowledge of costs	4.05	0.699	8
Observe workers behaviour	4.05	0.699	8
Aid with the knowledge of construction processed Support decision making	4.02	0.748	11
Support decision making	4.02	0.748	11
Enhance construction operations' environmental performance	3.98	0.624	13
More understanding of project management	3.95	0.790	14
Aid with the knowledge of designs	3.92	0.766	15
Educate and train project managers	3.92	0.809	15

(*continued*)

Table 2. (*continued*)

Impacts of big data in the South African construction industry	Mean item score (MIS)	Standard deviation (SD)	Rank (R)
Compare design concepts with the reality	3.85	0.799	17
Provide information on the use of public spaces and infrastructures	3.78	0.715	18
Provide information on stakeholders' impacts on infrastructure megaprojects	3.78	0.761	18
Innovate technical systems	3.78	0.783	18
Provide insights into urban planning	3.73	0.800	21

with a mean item score of 3.78 and a standard deviation of 0.715, 0.761, and 0.783 respectively; and lastly, 'provide insights into urban planning' which was ranked twenty-first with a mean item score of 3.73 and a standard deviation of 0.800.

The findings from the survey which indicated that the principal impacts of big data usage are forecast project performance, improve the efficiency of cost management and formulate strategies that control future project costs, support the research of Yu [7], which identified that big data can be used to predict construction project performance and to identify uncertainties early in the design process. In addition, the findings are also in line with the findings of Bilal [4], who stated that past projects data can be used to formulate strategies for controlling future project costs, and Yu [7] who added that the use of big data can improve cost management significantly.

It was also apparent that compare design concepts with the reality; provide information on the use of public spaces and infrastructures; providing information on stakeholders' impacts on infrastructure megaprojects; innovate technical systems and provide insights into urban planning were perceive by the respondents to be the least significant impacts of big data usage. The findings of the least impacts of big data usage in the construction industry being providing information on the use of public spaces and infrastructure, provide insights into urban planning oppose those of Sorensen [17], who identified that for the construction industry, location-aware data can provide valuable insights into urban planning, as it provides early information on the use of public spaces and infrastructure by people during the project conception phases. Furthermore, the findings in contrary to those of Bakht [18], who observed that an analysis of big data captured from social media could provide information on stakeholders' impacts on infrastructure megaprojects. Since the literature supports the findings that proper usage of big data is likely to predict the performance of a project, manage costs efficiently and create strategies that will control future costs, this implies that the impacts of big data are similar in most countries. The findings that contradicted the literature could be attributed primarily to the four responses from mechanical engineers, since their profession does not revolve around these variables.

6 Conclusion and Recommendation

The studies from the literature revealed that big data could contribute to the trend towards a more intelligent built environment, providing insights into the complete lifecycle of a building. In addition, with the help of big data, knowledge about construction costs, designs, and processes can be gained. Furthermore, strategies that control future project costs can be formulated based on the cost-related data gathered from past projects. In this way, big data can significantly improve the efficiency of cost management. The survey results obtained from the respondents revealed that in the South African construction industry, the foremost possible impacts of big data usage are forecast project performance, improve the efficiency of cost management, formulate strategies that control future project costs, improve the efficiency of design and construction operation, and more accurate predictions of project outcomes. Based on these findings, it can be concluded that big data usage in the construction industry is likely to forecast project performance, improve the efficiency of cost management, formulate strategies that control future project costs, improve the efficiency of design and construction operation, and provide more accurate predictions of project outcomes. Big data will play a pivotal role in the future of the construction industry. Regardless of the established positive impacts, there are still several challenges that require the attention of the industry. Therefore, construction professionals must be fully aware of these challenges to mitigate against the failure of the industry to grow through this innovative technology. The study was limited to construction professionals in three provinces of South Africa due to cost and time constraints. Future studies could attempt to identify possible ways to help train construction personnel to in.

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A Preliminary Investigation of the Readiness to Adopt Digital Technologies in a Developing Construction Industry

Lekan Damilola Ojo[1](✉), Ayodeji Emmanuel Oke[2], and Clinton Aigbavboa[3]

[1] Department of Architecture and Civil Engineering, City University of Hong Kong, Kowloon Tong, Hong Kong
ldojo2-c@my.cityu.edu.hk

[2] Department of Quantity Surveying, Federal University of Technology, Akure, Nigeria

[3] Department of Construction Management and Quantity Surveying, University of Johannesburg, Johannesburg, South Africa

Abstract. Adopting digital technologies (DTs) in construction projects delivery is crucial to enhancing project performance, the safety of construction workers and overall sustainability. Besides, the advent of the Coronavirus pandemic brings an urgent need to employ DTs in the construction industry to curtail the spread of the virus by limiting avoidable contact while maintaining efficiency. Meanwhile, developing countries appeared to be slow at embracing DTs in delivering construction services. Therefore, this study investigated the readiness to adopt DTs in the construction industry through an online survey administered to construction organisations. The data retrieved were analysed with correlation and multiple stepwise regression analyses. The results of the analysis indicated that readiness to adopt DTs is associated with the perceived benefits to construction organisations, while top management support for DTs is linked to the understanding of the benefits of DTs to construction service delivery and technological competence in the establishment. Mores so, top management support is a key driver for fast-tracking the readiness to adopt DTs in the construction industry. The study recommends a top-down approach of training on different DTs and their importance to construction service in the construction industry, especially for developing nations. Through the knowledge acquired, the top management officials could provide funds to purchase DTs tools, train their employees, and improve the outcomes of construction projects.

Keywords: Construction · Digital technologies · Innovation · Readiness

1 Introduction

In recent decades, the global state of innovations and technological advancements has been rising due to pressure to improve productivity, increased sustainable practices, and safety enhancements [24]. This increasing trend in technological advancements cut across all sectors of the global economy. The construction sector has, over the years, had

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a fair share of an innovative and technological resurgence in many standard practices [23]. New technologies, which are also known as digital technologies (DTs), such as building information modelling (BIM), internet of things (IoT), scanning technology, sensor technology, virtual reality, augmented reality, safety monitoring, unmanned aerial vehicles, remote-controlled construction equipment, and 3D printing, and so on have been introduced into construction practices [18]. Cao et al. [8] argued that the degree to which a technology is adopted depends on the change management practices employed within the industry. However, with the low rate of innovation adoptions that plague the construction industry [15], these technologies' acceptance and subsequent incorporation remained undetermined, especially in the developing world.

In developing countries, the construction industry amounts to about 15% of national gross domestic products [18]. Pérez-Luño et al. [17] opined the competitiveness and survival of construction sectors in most developing countries depends on the readiness to embrace innovations and technological changes. The chances of economic growth contributions of construction industries are anchored on their readiness and willingness to increase innovation levels [24]. In the new era of innovations, DTs are leading innovations poised to increase productivity, enhance safety, and position the construction industry for the next phase of economic competitiveness in the developing world. Therefore, this study aimed to investigate the readiness to adopt DTs on construction projects in a developing country.

2 Literature Review

Morledge [15] classification of the construction sector as a "laggard" based on technological adoption. Historically, the slow rate of innovation adoption poses a question as to why the sector seems to take the back seat compared to other industries. The fragmentation within the construction industry is identified as one of the many reasons the adoption of new ideas seems challenging [24]. Theoretically, organisational culture, change management and industry prioritization are a few limiting factors to innovative idea adoption in the construction industry [4]. However, many factors have been flagged as determinants of the adoption rate of innovations in the industry. These determinants are defined generally on personal, organisational, social, and industrial levels.

On individual factors, studies showed perspectives, and user satisfaction of the technology influence the adoption level of such innovation. Personal factors are one of the most critical determinants of the adoption mindset [3]. Talukder [21] defined organisational factors including training, organisation policies on change management, managerial support and incentives to accommodate the new technology [8]. Besides, organisations need to provide facilitating conditions, including the extent and type of support required for individuals willingness to use innovation technologies [4]. However, social factors are defined as human-to-human interaction effects on technology [21]. Assessments by peers, perceived beneficial components of service, advertisements, and the social base of the new technology affect the changing mindset of individuals responsible for adopting new technologies in the industry. Such factors are normative beliefs [3].

To give a perspective to these factors, the applications of DTs in the construction industry are organisational driven. Top management's readiness to incorporate the DTs into the organisation's day-to-day use is key to successful adoption. Therefore, considering many literature determinants and the construction sector's specificity in developing countries, a conceptual model for this study is presented in Fig. 1. There are various theories within the cycle of technological adoption in organisation. Some studies adopted a typical theory [1], while others used multiple theories [22].

Traditionally, organisations meet the need of their clients using conventional methods. However, technological development and advancement has led to the adoption of innovative methods in the delivery of services, predominant in developed countries [16]. In fact, the pace of embracing DTs in construction industry is slower compared to other industries. Meanwhile, the benefits of DTs to the performance of organisational task can inform the decision to adopt it according to *technology adoption model* [7]. *Resource-based view theory* in which organisations consider in-house capabilities and resources also play a crucial role in the readiness to adopt DTs [5]. The decision may be enhanced when the benefits of DTs is discovered by senior officers in the establishment for the deployment all the establishment's resources. Finally, the trust construct depicts *institutional theory* which is widely discussed in literature [22].

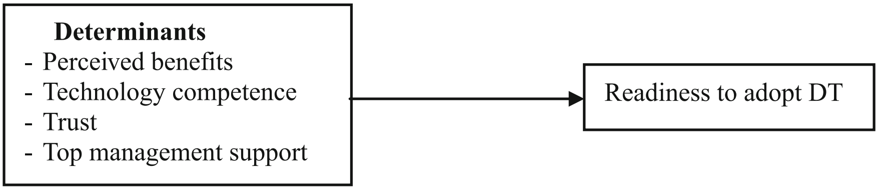

Fig. 1. Conceptual model of determinants of DT adoption

3 Methodology

This preliminary study adopted a survey research design to investigate the readiness to adopt DTs in construction organisations. The questionnaire consisted of three sections: (1) background information; (2) determinants of DTs comprising of perceived benefits, technological competence, trust, and top management support; and (3) items describing the readiness to adopt DTs. The questionnaire was adapted from validated measurement items in previous studies [6, 9, 13, 22]. The survey was designed on a seven-point Likert scale ranging from strongly disagree to strongly agree and administered online to various construction organisations in, Nigeria. The study could not be directed at a particular region or state due to the adopted sampling approach. A total of thirty-eight completed questionnaires were retrieved from seventy construction organisations, representing 54% response rate. Few responses rate in online surveys is not unusual in construction research [10]. The data is more than 30 which is often regarded as minimum for central limit. Besides, the data is sufficient to report a 'preliminary' result through various statistical methods of Statistical Package for Social Sciences (SPSS version 25).

Mean score and standard deviation were used to analyse the variables of the factors used in the questionnaire, while reliability test, correlation, and multiple stepwise regression analysis were adopted for further analysis to determine the readiness to adopt DTs. Mean score was used to determine the level of agreement on the items of the survey, while the level of dispersal in the respondent's opinions was checked with SD. Meanwhile, the ranking according to the mean values was not considered. The bi-variate interactions between the factors were checked with correlation analysis, and the predictors were determined with multiple stepwise regression analysis.

4 Analysis and Results

4.1 Background Information of Respondents

Most of the respondents have more than five years of work experience in the construction industry (52.6%) and possessed bachelor or postgraduate degrees qualifications (89.5%). The respondents cut across contracting organisation (34.2%), consulting firm (18.4%), government establishment (18.4%), developer (13.2%), and others (15.8%). The respondents were mostly engaged in building works (76.3%), and civil works (39.5%). The DTs often used are BIM, unmanned automated vehicles (Drones), virtual realities, cloud computing, augmented reality, etc., majorly for design visualization (66.7%), estimation and billing (61.1%), facility management (2.7%), supply chain management (2.7%), energy conservation and monitoring (2.7%), and record keeping (0.6%) at different stages namely briefing, site investigation, pre-construction, construction, and post-construction stages. Based on the respondents' background information and use of DTs in various construction stages, the respondents can be adjudged to be professionally qualified, and their opinions would be suitable to achieve the aim of this research.

4.2 Descriptive Statistics and Reliability Analysis

Table 1 shows the mean score, and standard deviation of the variables used to measure perceived benefits (D1), technology competence (D2), trust (D3), top management support (D4), and readiness to adopt DTs (A1). The reliability of the factors was also checked with Cronbach's alpha value to determine the internal consistency [19]. The alpha values of the factors range from 0.723 and 0.935. These alpha values are above 0.6 which is often regarded as benchmark in determining the reliability of factors in statistical analysis [11]. Therefore, the factors can be adjudged satisfactory and reliable for further analysis. The descriptive statistics for all the variables are well above the threshold of 3.50 [12]. Thus, the items can be considered important. Meanwhile, the standard deviations of the dataset are above 1.00, indicating variability in the respondents' opinions on the variables [2].

4.3 Correlation Analysis

Table 2 shows the correlation between the variables at 0.05 and 0.01 significant levels (two-tailed). The factors were measured by summing the items in Table 1 through data transformation in SPSS [20]. The results of the analysis show that perceived benefits

Table 1. Descriptive statistics and reliability analysis

Factors	Variables	M	SD	Alpha
D1: Perceived benefits	d1: My organisation expects better supply chain applications for using digital technologies	4.68	1.74	0.900
	d2: My organisation wants to expand markets for existing products and services with using digital technologies	4.71	1.86	
	d3: My organisation desires to improve coordination with suppliers, clients, etc., through digital technologies	5.13	1.44	
	d4: My organisation wants to generate competitive advantage via digital technologies	5.11	1.56	
D2: Technology competence	d5: My organisation is dedicated to ensuring that employees are familiar with digital technologies	5.26	1.61	0.908
	d6: My organisation contains a high level of digital technologies-related knowledge	4.79	1.74	
	d7: The technology infrastructure of my organisation is available for supporting new digital technologies	5.05	182	
D3: Trust	d8: I feel assured that some problems were easily solved through the digital technological provided	5.24	1.38	0.723
	d9: I feel more comfortable using digital technologies on construction projects	5.79	1.17	
	d10: In general, I feel digital technologies are now robust and safe	5.63	1.13	
D4:Top management support	d11: Top management champions digital technologies-enabled environment in your firm	4.68	1.69	0.935

(*continued*)

Table 1. (*continued*)

Factors	Variables	M	SD	Alpha
	d12: Top management provides feedback and guidance via digital technologies in decision making process	5.03	1.81	
	d13: Top management believes that cost of digital technologies in our firm is a long-term investment	5.34	1.62	
	d14: Top management actively use digital technologies	4.71	1.89	
	d15: Top management is willing to provide resources to enable the use of digital technologies	4.97	1.79	
A1: Readiness to adopt DTs	a1: I intend to use digital technologies in the following months	5.13	1.70	0.905
	a2: I predict I would use digital technologies in the following months	5.10	1.48	
	a3: I plan to use digital technologies in the following months	5.31	1.38	

Note M = Mean, SD = Standard deviation

(D1), technology competence (D2), trust (D3), and top management support (D4) correlated significantly with readiness to adopt DTs (A1) at a 0.01 significant level, while only perceived benefits (D1) and trust (D3) linked together significantly at 0.05.

Table 2. Correlation between determinants of DT adoption

Factor	D1	D2	D3	D4	A1
D1-Perceived benefits	1				
D2-Technology competence	0.757[a]	1			
D3-Trust	0.412[b]	0.442[a]	1		
D4-Top management support	0.858[a]	0.865[a]	0.431[a]	1	
A1-Readiness	0.619[a]	0.542[a]	0.440[a]	0.524[a]	1

Note [a] = significant correlation at 0.01, [b] = significant correlation at 0.05

4.4 Multiple Regression Analysis

Due to the limitation of bivariate correlation in testing the linear relationship between two single variables only, multiple regression analysis with stepwise estimation was employed to investigate the relationships between determinants of DTs adoption and readiness to adopt DTs (see Table 3). Two predictive models were developed in the multiple regression analysis indicating that top management support for DTs (D4) could be predicted by the perceived benefits of DTs (D1), and technological competence (D2) in the establishment, while readiness to adopt DTs (A1) can be mainly determined by the perceived benefits of DTs (D1).

Table 3. Multiple Stepwise Regression Analysis

Model	B	Std	Sig	VIF	R	Adj. R^2
Top management support ← Other determinants of DTs adoption						
Constant	– 0.456	1.902	0.812		0.919	0.836
D1-Perceived benefits	0.834	0.168	0.000	2.344		
D2-Technology competence	0.642	0.137	0.000	2.344		
Readiness ← Determinants of DTs Adoption						
Constant	6.817	1.924	0.001		0.619	0.366
D1-Perceived benefits	0.455	0.094	0.000	1.000		

Based on the results of the multiple stepwise regression analysis, two equations (eq. I and II) could be deduced for top management support (D4) and readiness to adopt DTs (A1), respectively. The perceived benefits (D1) and technology competence (D2) were the main determinants of top management support with significant value less than 0.05; while only perceived benefit of DTs is the only predictor of readiness (A1) to adopt DTs on construction projects based on the significant p-value.

$$\textbf{Top management support (D4)} = -0.456 + (0.834 * \text{Perceived benefits}) + (0.642 * \text{Technology competence}) \tag{1}$$

$$\textbf{Readiness(A1)} = 6.817 + (0.455 * \text{Perceived benefits}) \tag{2}$$

5 Discussion of Findings

Based on the correlation and multiple regression analysis (Tables 2 and 3), the relationships between determinants of DTs adoption and readiness to adopt DTs are illustrated in Fig. 2.

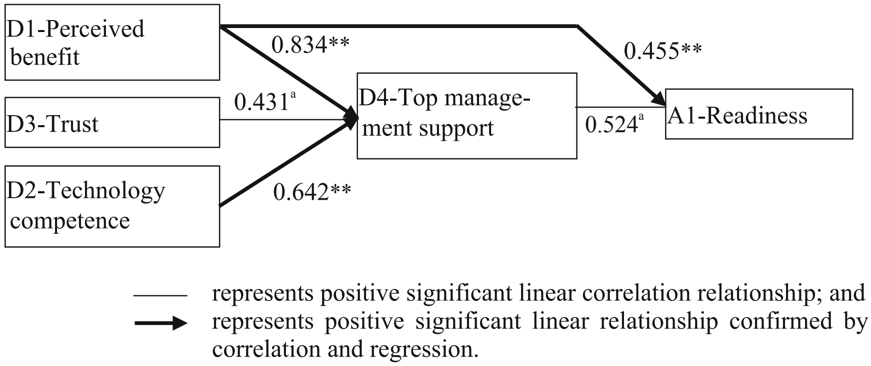

Fig. 2. Multiple regression model of readiness to adopt DTs

The multiple stepwise regression analysis shows that top management support for DTs was majorly determined by the perceived benefits of the DTs and technology competence of the establishment. This result confirmed the findings that senior management's knowledge of the importance of technical device to an organisation service delivery is vital to determine the use of DTs in such establishment [13]. Understanding the perceived benefits help the senior management to explore the untapped expertise and skills of their employees in the use of DTs for the advancement of the organisation. Thus, the technical competence of the organisation staff and the knowledge of DTs benefits the establishments and further propels the readiness to adopt DTs. This finding is also in line with the submission of [1] that technical knowledge, availability of trained staff, and technological devices are essential to facilitate the readiness to use DTs in construction organisations.

In addition, the correlation results also indicated that trust plays a significant role in getting top management support for DTs in construction organisations. In real practice, confidentiality of organisational information and data from competitors is crucial to the top management officials. Most often, privacy is always a major barrier why people desist from using technological devices, especially when the user is deficient of the required knowledge [14]. This result also aligned with previous studies finding that trust is vital to gaining users' approval [22]. Therefore, the manufacturer's assured 'security' of the DTs is critical to achieving top official support. In sum, technology competence and understanding of DTs benefits must be laced with 'trust' that acquiring the DTs would not expose confidential data of the organisation to other competitors in the industry.

Finally, through the top management support, construction organisations' readiness to adopt DTs are enhanced. The top management support in the form of provision of DTs facilities, software, etc., encourages the subordinates to learn relevant skills to deliver expected tasks. In fact, the organisation with top management support for DTs attract technology-savvy partners, promote organisational image and service delivery.

6 Conclusion and Recommendations

This study conducted a preliminary investigation on the readiness to adopt DTs in the developing construction industry through an online survey. The data retrieved were analysed with descriptive and inferential statistics, namely mean score, standard deviation, reliability analysis, correlation analysis, and multiple stepwise regression analysis. Based on the correlation and multiple stepwise regression analysis, a readiness to adopt DTs model was developed. The results indicated that top management support for DTs adoption is mainly determined by the knowledge of the benefits of such DTs and the technical competence in the organisation. Besides, trust simply correlated with top management official support for DTs, and thereafter, the organisation readiness to adopt DTs is enhanced.

Based on the results of the analysis, several recommendations were posited. First, knowledge of the benefits of DTs and technical competence are vital to gain executive support for the DTs. Therefore, *a top-down training approach to educate construction practitioners on the use and importance of various DTs is recommended for construction organisations in developing countries.* This approach would assist the top management officials to provide necessary funds, facilities, software, etc., for the middle and junior staff in construction organisations. Through a top-down training approach, the subordinates would be encouraged to update their competence and skills in using DTs.

Secondly, the analysis results show that trust is essential to gain management support for using the DTs. Therefore, *it is advised that manufacturers of DTs should ensure end-to-end encryption in the design of electronic devices for construction service delivery, especially when cost information and other vital information are to be transferred through them.* The DTs manufacturer should clearly indicate a privacy-statement note to guarantee that the information sent through the electronic tools is protected from the third party. Receivers of such information sent via DTs should also keep every data with the utmost professionalism and ethical conduct.

This study is a preliminary to large survey to investigate the readiness to adopt DTs in various construction enterprises in Nigeria and other developing countries in Africa. This implies that the results of the large survey may be different from this study, and other statistical methods such as structural equation modeling (SEM) may be applied. To achieve this, a larger sample size is also important to have broader view of the subject matter and for making comprehensive discussion and conclusion on the readiness to adopt DTs in developing construction organisations.

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Smart Low-Cost Housing Estate Management: A System Thinking Approach

Desmond Eseoghene Ighravwe(✉) and Daniel Mashao

Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa
ighravwedesmond@gmail.com, dmashao@uj.ac.za

Abstract. Smart low-cost housing estate management is a significant issue in developing countries because this kind of estate is evolving in the global South. Hence, this article contributed to this management discussion by proposing a system-thinking model for smart estate management. The model uses the technical and non-technical criteria of smart cities to generate a model for decision-making. The model formulated used different causal loop diagrams for estate smartness evaluation. The proposed framework can help stakeholders in the construction industry make medium and long-term strategic decision-making. The government could use this framework to decide on policies that will be implemented to improve smart housing estates.

Keywords: Low-cost housing estate · System thinking · Developing countries · Stakeholders

1 Introduction

The information and communication technologies (ICT) used in a smart building provide a variety of applications and ways to improve the estate's daily operations. ICT is used as an integrating platform to connect businesses in an estate. Smart buildings have grown in popularity since ICT has enhanced buildings' security [14] and improved buildings' maintenance [7]. ICT deployment in buildings is crucial for emergency management among residents, particularly in communities with senior residents. Furthermore, ICT helps residents communicate with the outside community, allowing them to have minimal touch with prospects. It also allows residents to control their utilities, such as energy and water [11]. As a result, stakeholders in the built environment are interested in the smart estate. However, there are knowledge gaps in low-cost housing estates regarding ICT transition.

To close this gap, smart low-cost housing estate challenges must be carefully analyzed to give a roadmap for their widespread adoption in low-cost housing developments. It is worth noting that discussions on smart buildings are linked to the specific benefits of building management [10]. For example, Dong et al. [9] published a thorough investigation of the usage of sensors in the built environment. The need to employ smart systems to control and manage energy usage in buildings was emphasized by [11]. Still,

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in energy management, a predictive control (MMPC) technique for managing thermal energy in buildings exists [20]. The impact of smart building monitoring systems in a constructed environment was reported by [14]. Dey et al. [7] showed that intelligent technologies can be used to manage to build heating and ventilation. Attoue et al. [1] predicted a building's internal temperature.

As a result of the preceding, smart building management is a multi-faceted activity that extends beyond the issue of energy and comfort. It covers every aspect of building management. While a less thorough examination is necessary for smart building management, it is impossible to determine for estates, which contain a variety of buildings with different smartness requirements. Such needs are estate dependent; for example, the smartness of low-cost housing estates is less complicated than the smartness of high-cost housing estates. Automation is one aspect that contributes to estates' varying levels of smartness. Compared to a low-cost estate, updating the smartness of a high-cost housing estate does not take as much effort. However, due to their widespread use in developing cities such as Lagos, Nigeria, stakeholders want to improve the smartness of low-cost estate housing developments. This article aims to add to the growing body of knowledge about smart low-cost housing estate management. It presents cross-sectional areas where smart estate could be evaluated. The appropriate management of this estate will aid the government's attempts to address smart housing shortages in urban areas.

1.1 System Thinking Model

System dynamics (SD) provides a means for creating a "What-if" scenario for a decision-making problem [21]. Hence, it is used to design a smart, low-cost housing estate management sustainability framework. The framework comprises four pillars of the smart estate—waste management, energy management, water management and e-governance [3, 4, 18, 22]. Below are specific details about these pillars:

1.2 Waste Management Sub-Model

The built environment considers waste management a critical issue that enhances a smart city level. Scholars opined that waste to energy, recycling, and wastewater treatment should be managed smartly to increase city smartness (Table 1). Figure 1 shows the system-thinking model for waste management evaluation in a smart city.

Table 1. Model criteria for the waste management sub-model

Criteria
Waste to energy [22]
Waste recycling [19]
Wastewater treatment [6]
Waste to compost [23]

1.3 Energy Management Sub-model

Energy management is pivotal to smart estate attainment because of the many benefits its anchors in the web of this kind of city. From supporting smart gadgets to providing electricity for equipment, scholars have discussed energy efficiency and building management as central themes for smart estate assessment (Table 2). Figure 2 shows the system-thinking model for energy management evaluation in a smart estate.

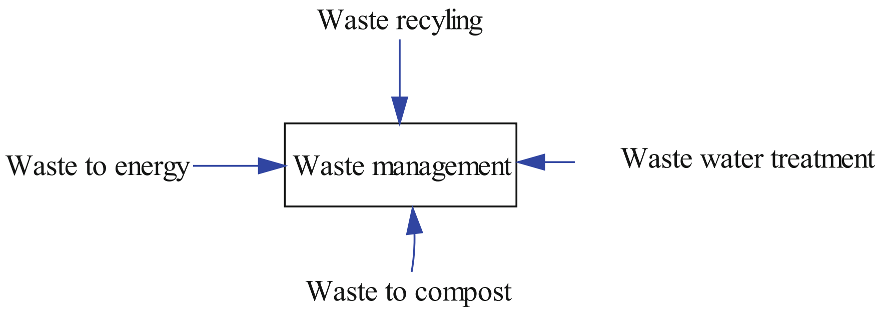

Fig. 1. Proposed model for waste management evaluation in a smart estate

Table 2. Model criteria for the energy management sub-model

Criteria
Renewable energy sources [12]
Energy efficiency [8]
Green buildings [18]
Smart electricity meter [15]

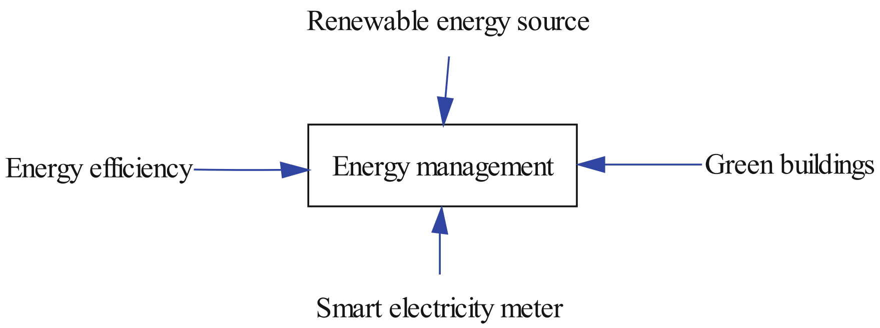

Fig. 2. Proposed model for energy management evaluation in a smart estate

1.4 Water Management Sub-model

Water management is one of several low-cost estates in sub-Sahara Africa experiencing problems. Hence, stakeholders expect this problem to be adequately addressed before an estate could be termed as smart. Some selected criteria for such assessment are presented in Table 3. Figure 3 shows the system thinking model for water management evaluation in a smart estate.

Table 3. Model criteria for the water management sub-model

Criteria
Smart water meters [15]
Leakage detection technology [2]
Water quality management [4]
Intelligent water pumping [16]

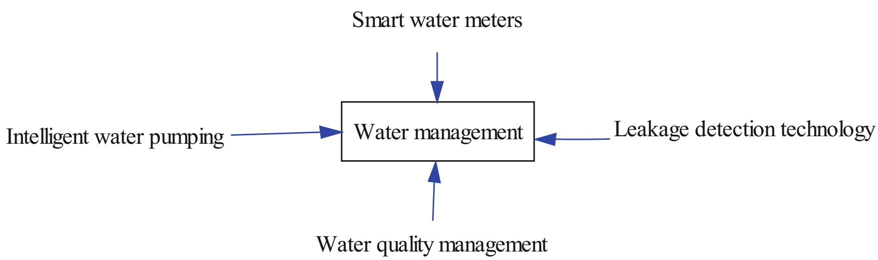

Fig. 3. Proposed model for water management evaluation in a smart estate

1.5 E-Governance Sub-model

Environment and people management are critical to classifying an estate as smart because of the intricate relationship between these parameters. Stakeholders in the built environment expect to see an estate with a robust citizen engagement, electronic service delivery, and video crime monitoring system before considering it a smart estate (Table 4). Figure 4 shows the system thinking model for e-governance evaluation in a smart estate.

1.6 System Thinking Model for City Smartness Evaluation

Figure 5 presents the proposed system-thinking model for city smartness evaluation. Technically, its implication will require an 'IF-Then' rule to generate practical information for city smartness evaluation. The model is set up using the information presented in Figs. 1, 2, 3, 4 and 5.

Table 4. Model criteria for the e-governance sub-model

Criteria
Citizen engagement [5]
Grievance redress [13]
Electronic service delivery [3]
Video crime monitoring [17]

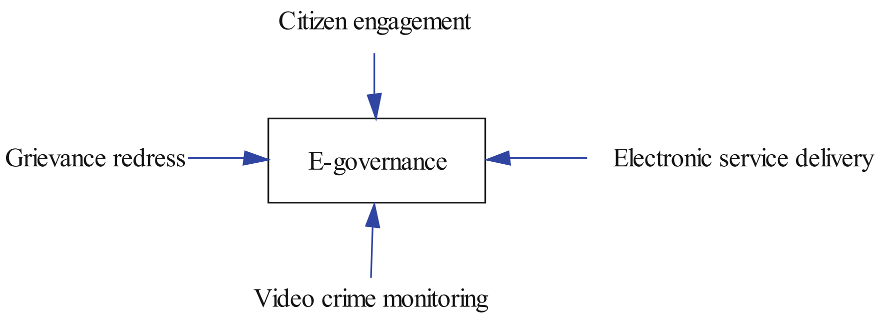

Fig. 4. Proposed model for e-governance evaluation in a smart estate

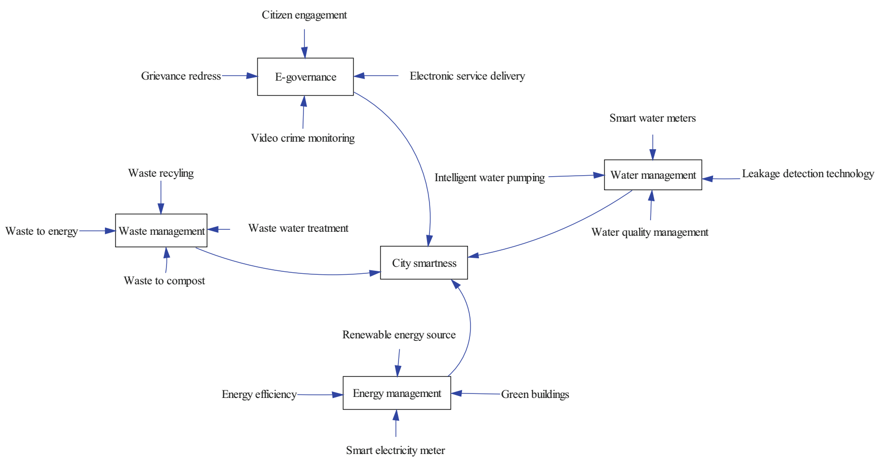

Fig. 5. Proposed system thinking model for an estate smartness evaluation

2 IF-Then Model

This study used a fuzzy modelling approach to present the mathematical expressions for the different components in Figs. 1, 2, 3, 4 and 5. To achieve this purpose, the membership function is defined for each of the criteria in these figures. Illustratively, this study considered the memberships for the criteria parameters. Similarly, the same memberships are considered for the performance measures.

The if-then rules for the waste management aspect of the proposed system thinking model are given as follows:

If *Waste to energy* is v_1^{waste}, *Waste recycling* is w_1^{waste}; *Wastewater treatment is* y_1^{waste} and *Waste to compost* is z_1^{waste}	Then the waste is O_1^{waste}
If *Waste to energy* is v_2^{waste}, *Waste recycling* is w_2^{waste}, *Wastewater treatment is* y_2^{waste} and *Waste to compost* is z_2^{waste}	Then the waste is O_2^{waste}
If *Waste to energy* is v_n^{waste}, *Waste recycling* is w_n^{waste}, *Wastewater treatment* is y_n^{waste} and *Waste to compost* is z_n^{waste}	Then waste is O_n^{waste}

The if-then rules for the energy management aspect of the proposed system thinking model is given as follows:

If *Renewable energy sources* is v_1^{energy}, *Energy efficiency* is w_1^{energy}, *Green buildings* is y_1^{energy} and *Smart electricity meter* is z_1^{energy}	Then *energy* is O_1^{energy}
If *Renewable energy sources* is v_2^{energy}, *Energy efficiency* is w_2^{energy}, *Green buildings* is y_2^{energy} and *Smart electricity meter* is z_2^{energy}	Then *energy* is O_2^{energy}
If *Renewable energy sources* is v_n^{energy}, *Energy efficiency* is w_n^{energy}, *Green buildings is* y_n^{energy} and *Smart electricity meter* is z_n^{energy}	Then *energy* is O_n^{energy}

The if-then rules for the water management aspect of the proposed system thinking model is given as follows:

If *Smart water meters* is v_1^{water}, *Leakage detection technology* is w_1^{water}, *Water quality management* is y_1^{water} and *Intelligent water pumping meter* is z_1^{water}	Then *water* is O_1^{water}
If *Smart water meters* is v_2^{water}, *Leakage detection technology* is w_2^{water}, *Water quality management* is y_2^{water} and *Intelligent water pumping meter* is z_2^{water}	Then *water* is O_2^{water}
If *Smart water meters* is v_n^{water}, *Leakage detection technology* is w_n^{water}, *Water quality management* is y_n^{water} and *Intelligent water pumping meter* is z_n^{water}	Then *water* is O_n^{water}

The if-then rules for the e-governance aspect of the proposed system thinking model is given as follows:

If *Citizen engagement* is $v_1^{e-governance}$, *Grievance redress* is $w_1^{e-governance}$, *Electronic service delivery* is $y_1^{e-governance}$ and *Video crime monitoring* is $z_1^{e-governance}$	Then *e-governance* is $O_1^{e-governance}$
If *Citizen engagement* is $v_2^{e-governance}$, *Grievance redress* is $w_2^{e-governance}$, *Electronic service delivery* is $y_2^{e-governance}$ and *Video crime monitoring* is $z_2^{e-governance}$	Then *e-governance* is $O_2^{e-governance}$
If *Citizen engagement* is $v_n^{e-governance}$, *Grievance redress* is $w_n^{e-governance}$, *Electronic service delivery* is $y_n^{e-governance}$ and *Video crime monitoring* is $z_n^{e-governance}$	Then *e-governance* is $O_n^{e-governance}$

The if-then rules for the city smartness aspect of the proposed system thinking model are given as follows:

If *waste* is v_1^{waste}, *energy* is w_1^{energy}, water is y_1^{water} and *e-governance* is $z_1^{e-governance}$	Then city smartness is $O_1^{smartness}$
If *waste* is v_2^{waste}, *energy* is w_2^{energy}, *water* is y_2^{water} and c is $z_2^{e-governance}$	Then city smartness is $O_2^{smartness}$
If *waste* is v_n^{waste}, *energy* is w_n^{energy}, *water* is y_n^{water} and *e-governance* is $z_n^{e-governance}$	Then city smartness is $O_n^{smartness}$

The SD model presented could be deduced that the proposed theoretical framework will enhance the analysis of smart cities, especially in Africa, where sparse information is available on this issue. different instances of city smartness can be generated with the model. The If-Then aspect of the framework will allow stakeholders to contribute to this issue management.

3 Conclusions

Two issues with smart estate management were highlighted in this study. One of them is a list of criteria for this management problem. The other is to develop a link between the criteria that have been identified. This study presented the steps for resolving the issues. First, it looked at the criteria for resolving the management issue. Then, this study selected specific criteria for each of the four pillars of smart cities—waste management, energy management, water management, and e-governance. After that, causal loop diagrams for each pillar were displayed. The causal loops were connected to provide a system-thinking model for evaluating smart real estate. This study presented if-then rules to implement the proposed model using the causal loop information. From the if-then rules generated, further research can be conducted to study low-cost housing estates' smartness. Hence, this study has contributed a novel approach to dealing with smart city issues, especially in situations where crisp information about the constituent elements of a smart city's parameters is unavailable.

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Levels and Period of Exposure to Chemical Irritants in Relation to Symptoms of Skin Diseases for Construction Specialised Personnel in Zambia

Prisca Tente(✉) and Erastus Mwanaumo

Department of Civil and Environmental Engineering, School of Engineering, University of Zambia, Lusaka, Zambia
pmtente@yahoo.co.uk, erastus.mwanaumo@unza.zm

Abstract. Construction does not only bring about economic development but also hazards that are detrimental to worker's health. Construction activities such as wet concrete mixing, wall filling, and painting require the use of chemical which become irritants on workers' skin resulting in symptoms of skin diseases. The skin diseases could be costly and may result in emotional and physical morbidity. According to Occupational Health Institute of Zambia, skin diseases are prevalent in construction and arise from exposure to chemical irritants. Some studies have shown that there is a relationship between levels, period of exposure to chemical irritants and occurrence of symptoms of skin diseases. This paper reviews the levels and period of exposure to chemical irritants in relation to the occurrence of symptoms of skin diseases for construction specialised personnel in Zambia. A questionnaire survey involving 100 workers was used on the road and building projects. The sample size was limited to 100 because the numbers of workers were reduced due to Covid-19 by the Ministry of Health. Bricklayers, carpenters, batchers, tilers, demolition workers, painters and labourers were purposively sampled. The ethical clearance was approved by the University of Zambia Natural and Applied Sciences Research Ethics Committee. Data was analysed quantitatively using descriptive statistics. Results showed that the higher the exposure levels and the longer the period of exposure to chemical irritants, the higher the likelihood of developing symptoms of skin diseases. The study recommends reduction of levels and period of exposure to chemical irritants through provision of skilled suited gloves, introduction of half day shift work and tool box talks before any work activity.

Keywords: Exposure levels · Chemical irritants · Construction workers · Period · Skin symptoms

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1 Introduction

Construction industry is key to the economies of the world through infrastructure development. Nevertheless, construction work brings about hazards that cause ill health and accidents that affect workers [1]. Hazards, in form of chemical irritants are associated with construction activities such as working with wet concrete, wall filling, painting, tile fixing, working with epoxy and road priming. Some common chemical irritants found in construction are cement, metal, epoxy resin, solvents, oils and greases, asphalt, acids and alkalis and abrasive materials especially in wet works [2]. These chemicals become irritants to workers' skin and cause skin diseases. Primary irritants injure the person's skin if sufficient exposure takes place and account for 75 per cent of the occupational dermatitis [3]. Several studies have revealed that the levels and period of exposure to chemical irritants are important to the development of symptoms of skin diseases.

2 Literature Review

Construction is the most affected by the skin diseases compared to other industries [4]. One of the common skin diseases in construction is irritant contact dermatitis which is caused by a chemical or physical agent [5]. Contact with wet cement may cause pain and burning sensation [6]. Cement contains potassium dichromate which causes skin diseases [7]. The prevalence of skin diseases in India's construction industry in a study by Mashqoor et al. [8] was at 60%. In the United States of America, the prevalence among Latino migrant construction workers was 23% [9]. Timmerman, [5] found that the prevalence in the Netherland construction industry was 25.4%. According to Esmail and Sakwari [10], prevalence was 54% among building workers in Tanzania. In Zambia's construction industry, the prevalence of skin diseases was 14% [11]. The most common symptoms of skin diseases are itching, redness, thickened, fissured and scaly skin and lesions [12]. Skin diseases are costly to society [13] and may result in emotional and physical morbidity [14]. The effects of skin diseases are not only detrimental to the health of the workers but also affect construction projects as the results of loss of man-hours. The workers become ineffective on the project, thereby failing to meet construction schedules.

The skin diseases come about as the skin gets exposed to chemicals. In a study by Mashqoor et al. [8] 78% of the workers did not have any Personal Protective Equipment (PPE). This means that the workers did not have protected to reduce exposure. Similarly, in the studies by Bedoya-Marrugo et al. [15] and Shah and Tiwari [16], 70% and 50% of workers did not use PPE respectively. These workers without PPE experienced high exposure levels to chemical irritants as the skin was directly exposed to chemical irritants and were likely to develop symptoms of skin diseases. This would have been the reason for high prevalence of skin diseases in the construction industry. Period of exposure to chemical irritants have also been associated with occurrence of symptoms of skin diseases. Shah and Tiwari [16] found that there is a relationship between increased duration of exposure and skin conditions. In the study by Bedoya-Marrugo et at. [15] it was found that the period of exposure to cement was directly proportional to likelihood of developing dermatitis. Esmail and Sakwari [10] also found that exposure in terms of work duration was associated with the occurrence of skin diseases. Prolonged duration of exposure is associated with more morbid skin conditions [8].

There are five control methods that are used to reduce exposure to chemical irritants namely; elimination, substitution, engineering control, administrative control and use of PPE. Elimination method involves the complete removal of hazards. However, elimination method is not possible in construction because of the staple materials like cement and concrete. Substitution method is replacing the hazardous chemical irritant with a lesser hazardous chemical. Mwanaumo et al. [17] suggested that there is a relationship between hazard recognition and specification of less harmful materials. The example of substitution method is the use of chromate-reduced cement [18]. Engineering Control involves systems designed to reduce the risk of workers' exposure to hazards. An example of engineering control is the use of face shields to protect the face from exposure to chemicals. Administrative controls include provision of health training, social security services and good personal hygiene to prevent skin diseases [16, 19]. Timmerman [5] suggested that construction workers should be made aware of the risks and prevention of skin problems during their vocational training. A good example of administrative control is the legislation that was passed in European Union countries of decreasing amount of hexavalent chromium in cement from 43.1 to 29.0% which led to a decline in chromate sensitization among construction workers [5]. The use of PEE such as gloves, overalls, boots, goggles and respirators is recommended as the last intervention and should be accompanied with the other controls.

In Zambian, the strategies in 7th National Development Plan 2017–2021 planned in the quest to be a middle-income country by 2030 has resulted in an increase in construction projects. This entails more workers being employed, an increase in the use of staple materials and possible contact to chemical irritants contained in the construction materials. According to a research by Tente [11], one of the common occupational diseases in the construction industry was skin diseases. The Occupational Health Institute of Zambia associated the skin diseases to exposure to dust and chemicals. Construction companies in Zambia, however, are hesitant to adhere to Occupational Safety and Health Laws [11]. The aim of this paper is to determine the levels and period of exposure to chemical irritants in relation to symptoms of skin diseases for construction specialised personnel in Zambia. Likewise, to recommend ways of reducing levels and period of exposure to safeguard workers' health.

3 Materials and Methods

A cross-sectional, quantitative study was conducted between May and November 2021. A sample size of 100 workers was selected using a conventional method after reviewing literature. The sample size was limited to 100 as there was a reduction of workers as one of the requirements for Covid-19 Prevention Guidelines by the Ministry of Health. An interview-based questionnaire was administered face to face as some workers were not able to read and write and also to avoid taking much time as the works on both sites were behind schedule. The questions included gender, age, job title, levels and period of exposure and symptoms of skin diseases. A road construction and a building sites were used as case studies to get the experiences of both sections and 50 respondents were selected from each so as to get equal chances. Both sites had one main contractor and several subcontractors as it was mandatory in Zambia to subcontract 20% of all the works for construction projects. The workers were arrived at after a thorough literature review on the workers who are likely to be more exposed to chemical irritants. Hence, bricklayers, carpenters, batchers, tilers, demolition workers, painters and their handymen were purposively sampled and then randomly selected. The ethical clearance was approved by the University of Zambia Natural and Applied Sciences Research Ethics Committee (NAREC). The data was analysed quantitatively using IBM SPSS version 1.0.0.45. Descriptive statistics were used to determine the prevalence of the symptoms of skin diseases and how it relates with levels and period of exposure to chemical irritants. Pearson Chi-square and degree of freedom were used to test the degree of association between the independent and dependent variables. The level of significance of $\rho < 0.05$ and confidence interval of 95% was considered as statistically significant.

4 Results

The results showed that 91% workers were men and 9% were women. This gives an indication of very few women in construction. The common age of the workers was between 26 and 35 years old which was 40% followed by 26% who were between 35 and 45years old. Those who were less than 25 years were 21% and those between 45 and 55 years were 10%. Older workers who were more than 55 years were 3%. The results also revealed that 70% of the workers were exposed to high levels of chemical irritants. In addition, 62% were exposed between 3 and 8 h in a day while 32 were exposed for more than 8 h. The prevalence of the symptoms of skin diseases was 78%.

4.1 Levels of Exposure to Chemical Irritants and Type of Construction

The average means of levels of exposure to chemical irritants in the road and building construction were 4.34 and 4.6 respectively. The standard deviations were 1.04 for road and 0.86 for building construction which is an indication that 95% of the data points were falling within ± 2SD. This means that the values are closer to the true value and the information can be predicted about the population. According to the independent sample test, there was no significance between levels of exposure to chemical irritants and type of construction as shown in Table 1. The p-value was 0.051 which is more than p-value of 0.05 for significance. Moreover, the 95% confidence interval was − 0.64 and 0.12 which crossed zero which shows no significance.

4.2 Levels of Exposure to Chemical Irritants and Job Title

The means for carpenters, bricklayers, painters, handymen and road workers were less than the median which is an indication that the measure of distortion of symmetric is to the left (negative skewness) as shown in Table 1.2. Batchers, demolition workers

Table 1. Independent samples test for levels of exposure and type of construction

		Levene's TEST		t-test for equality of means			
		F	Sig	t	df	95% Confidence interval of the difference	
						Lower	Upper
Levels of exposure	(=)variances assumed	3.92	**0.051**	– 1.36	98.0	– 0.64	0.12
	(≠)variances assumed			– 1.36	94.5	– **0.64**	**0.12**

and tilers had the means equal to the median showing normal distribution. The standard deviations were all within ± 2SD. Despite the comparison of means showing that demolition workers and tilers have high levels of exposure, cross tabulation showed that bricklayers had 36.5% exposure levels compared to others. However, there was no statistical relationship between levels of exposure and job title as Pearson Chi-square was 15.58, degree of freedom (df) = 14 and p-value of 0.34 which is greater than 0.05 for significance.

Table 2. Comparison of means of levels of exposure to chemical irritants and job title

Job title	Mean	N	Std. deviation	Median	Skewness
Carpenters	4.50	8	0.93	5.00	– 1.44
Bricklayers	4.53	36	0.94	5.00	– 1.94
Painters	4.75	12	0.45	5.00	– 1.33
Batchers	4.00	2	0.00	4.00	
Handymen	4.46	24	0.98	5.00	– 2.31
Tilers	**5.00**	3	0.00	5.00	
Demolition Workers	**5.00**	4	0.00	5.00	
Road workers	3.73	11	1.42	4.00	– 0.69
Total	4.47	100	0.96	5.00	– 1.92

4.3 Prevalence by Type of Symptoms of Skin Diseases and Job Title

The prevalence of symptoms of skin diseases was 78%. From the 78% prevalence, 39% was scaly hands or fingers, 18% was red bumps on hands or fingers, 11% was vesicles on hands or fingers and 10% was itchy hands or fingers. Cross tabulation results showed that of the 39% prevalence of scaly hands or fingers, 41% prevalence was among bricklayers and 21% among painters as shown in Table 1.3. There was a statistical relationship between symptoms of skin diseases and job title as the Pearson Chi-square was 4.78, df = 28 and p-value was 0.046 which is less than p-value of 0.05 for significance.

Table 3. Occurrence of symptoms of skin diseases by job title

Symptoms	Itchy hands or fingers with fissures	Scaly hands or fingers	Vesicles on hands or fingers	Red bumps on hands or fingers
Job title				
Carpenters	0 (0%)	3 (8%)	0 (0%)	2 (11%)
Bricklayers	2 (20%)	16 **(41%)**	7 (64%)	9 (50%)
Painters	0 (0%)	8 **(21%)**	0 (0%)	1 (6%)
Batchers	1 (10%)	1 (3%)	0 (0%)	0 (0%)
Handymen	4 (40%)	6 (15%)	3 (27%)	2 (11%)
Tilers	1 (10%)	1 (3%)	1 (9%)	0 (0%)
Demolition Workers	0 (0%)	2 (5%)	0 (0%)	2 (11%)
Road workers	2 (20%)	2 (5%)	0 (0%)	2 (11%)
Total	10 (100%)	39 (100%)	11 (100%)	18 (100%)

4.4 Exposure Levels and Occurrence of the Symptoms of Skin Diseases

All the means for the symptoms of skin diseases were less than the median indicating that the measure of distortion of symmetric was to the left (negative skewness) as shown in Table 4. There was a small range of standard deviations and they were all within ± 2SD indicating that values are closer to the true value. The level of exposure was recorded from scale variable to categorical variable (low, average and high) to enable cross tabulation and test for significance. Exposure level of 45% was associated to scaly hands or fingers as shown in Tables 5. And 1.4 which had the highest mean of 4.82. There was a statistical relationship between the levels of exposure to chemical irritants and occurrence of symptoms of skin diseases as p-value was 0.006 which is less than p-value of 0.05 for significance. Pearson Chi-square was 21.4 and df was 8.

4.5 Period of Exposure and Occurrence of Symptoms of Skin Diseases

The common skin symptoms as already indicated was scaly hands or fingers. The results from cross tabulation between period of exposure and occurrence of skin diseases in Table 1.6 shows that of all those workers who developed scaly hands or fingers, 48.4% were exposed between 3 and 8 h. There was a statistical relationship between period of exposure to chemical irritants and occurrence of symptoms of skin diseases as Pearson Chi-square was 17.8, df = 8 and p-value of 0.023 which is less than p-value of 0.05, indicating significance.

Table 4. Comparison of means between exposure levels and symptoms of skin diseases

Symptoms	Mean	N	Std. deviation	Median	Skewness
Itchy hands or fingers with fissures	4.50	10	0.71	5.00	– 1.18
Scaly hands or fingers	**4.82**	39	0.45	5.00	– 2.59
Vesicles on the hands or fingers	4.45	11	0.82	5.00	– 1.15
Red bumps on hands or fingers	4.56	18	0.98	5.00	– 2.26
None of the above	3.77	22	1.38	4.00	– 0.75
Total	4.47	100	0.96	5.00	– 1.92

Table 5. Cross tabulation between exposure levels and symptoms of skin diseases

Exposure levels	Low	Average	High
Symptoms			
Itchy hands or fingers with fissures	0 (0%)	1 (11%)	9 (11%)
Scaly hands or fingers	0 (0%)	1 (11%)	**38 (45%)**
Vesicles on hands or fingers	0 (0%)	2 (22%)	9 (11%)
Red bumps on hands or fingers	2 (33%)	0 (0%)	16 (19%)
None	4 (68%)	5 (56%)	13 (15%)
Total	6 (100%)	9 (100%)	85 (100%)

Table 6: Cross tabulation between period of exposure and symptoms of skin diseases

Period of exposure	< 2 h	$3 \leq 8$ h	> 8 h
Symptoms			
Itchy hands or fingers with fissures	1 (17%)	1 (2%)	8 (25%)
Scaly hands or fingers	2 (33%)	**30 (48%)**	7 (22%)
Vesicles on hands or fingers	1 (17%)	7 (11%)	3 (9%)
Red bumps on hands or fingers	0 (0%)	12 (19%)	6 (19%)
None	2 (33%)	12 (19%)	8 (25%)
Total	6 (100%)	62 (100%)	32 (100%)

5 Discussion of Results

The aim of this paper was to determine the levels and period of exposure to chemical irritants in relation to skin diseases for construction specialised personnel in Zambia. The results showed that 90% of the skilled workers were men and 9% were women. This gives an indication that there are few skilled women in the construction industry.

The common age group was between 26 and 35 years who made up 40% of the workers. Those who were below 35 years were 61% which shows that that there are more young skilled workers in the industry who are exposed to the chemical irritants are more likely to develop symptoms of skin diseases. Moreover, the number of skilled young workers would have been more if there was no restriction on sampling. Sampling was done on the workers who had worked in the construction industry for 3 years and above. The restriction was done on assumption that the workers who had worked for 3 years and above would have had experienced exposures and eventually symptoms of skin diseases. These young people are likely to get repeated exposures as they have more years to work in their field of specialisation for more years. This may mean that they are more likely to get the long term effects of the symptoms of skin diseases which come with repeated exposure to chemical irritants such as chronic skin diseases [3].

5.1 Levels of Exposure to Chemical Irritants

The results showed that 70% of the workers were exposed to high levels of chemical irritants. This would have been as a result of not having or using suitable PPE to reduce exposure levels. There was a relationship between levels of exposure and the occurrence of symptoms of skin diseases. The higher the exposure levels the higher the likelihood of occurrence of symptoms of skin diseases. This is similar to findings of Shah and Tiwari [16], Bhuiyan et al. [18], Mashqoor et al. [8] and Bedoya-Marrugo et al. [15] who associated the prevalence of symptoms of skin diseases to not wearing the PPE. The argument was that not wearing PPE resulted in high exposures and eventually the occurrence of symptoms of skin diseases. Scaly hands or fingers was more associated to higher levels of exposure. Scaling of the skin is the loss or peeling off of the outer layer of the skin which can affect quality of life of workers and affect their ability to perform their work effectively. The results showed that all the skilled workers who participated in the study were exposed to chemical irritants that were likely to cause symptoms of skin diseases.

There was no relationship between levels of exposure to chemical irritants and type of construction. This would have been because skilled workers performed similar works and that the chemical irritants are similar in both road and building projects. One similar chemical irritant is working with wet cement. On the job title, the comparison of means gave an indication that demolition workers and tilers were likely to be more exposed as their means were high. Nevertheless, the results of cross tabulation showed that bricklayers are more exposed to chemical irritants compared to the other skills. Despite no statistical relationship between levels of exposure and job title, there was a statistical relationship between job title and the occurrence of symptoms of skin diseases. Bricklayers were more likely to develop symptoms of skin diseases. This finding is similar to Saji et al. [20]. On the contrary, Esmail and Sakwari [10] found that carpenters were more likely to develop skin diseases. The reason for the difference may have been that bricklayers were handling wet works that are associated with high exposure to chemical irritants.

5.2 Period of Exposure to Chemical Irritants

Most workers were exposed between 3 and 8 h per day. This confirms the legal work shift of 8 h for workers per day in Zambia. The results showed that many workers worked more hours as those who worked for less than 2 h were only 6%. Those who were exposed beyond 8 h had to work overtime to make more money. The workers were all working for either an hourly rate or daily rate. Working more hours meant making more money. Unfortunately, the more hours they worked the more likelihood of them developing symptoms of skin diseases. This is because there was a statistical relation between period of exposure and the occurrence of symptoms of skin diseases. This is similar to findings of Shah and Tiwari [16], Bhuiyan et al. [19], Bedoya-Marrugo et at [15], Saji et al. [20] and Esmail and Sakwari [10], who found that the period of exposure to chemical irritants is associated with the occurrence of skin diseases. In the case of Saji et al. [20] and Esmail and Sakwari [10], the period of exposure was considered in years while in this study hours were used.

5.3 Implications of the Findings

Findings indicate that skilled workers are exposure to high levels of exposure and longer period of exposure to chemical irritants which lead to symptoms of skin diseases. To reduce period of exposure, workers should be encouraged by management to work in shifts so that continuous exposure is avoided. This can be done by working half day shifts on the tasks that have high levels of exposures. It is recommended that skilled workers are put on fixed monthly wages to avoid working for longer periods. To reduce levels of exposure, it is recommended that management provide full proper PPE. Emphasis should be on the quality and skilled approved PPE as encouraged by Timmerman [5]. For example, to ensure that chemical irritants do not penetrate through the gloves and subsequent contact with the skin, bricklayers should be given well fitted, chemical resistant polyvinyl chloride (PVC) gloves. Personal hygiene and use of cream such as Vaseline after work should be encouraged. Washing reduced the continuous contact of chemicals with the skin. Vaseline on the other hand, moisturizes the skin thereby protecting and aiding in the healing of skin wounds. It should be applied after the skin is washed roughly [21].

More importantly, the findings may mean that safety and health guidelines were not enforced effectively on sites. It is recommended that Zambia formulates the National Occupational Safety and Health (NOSH) policy to improve safety and health on sites. At present, Zambia has no NOSH policy. In the short term, it is recommended that workers receive safety and health training before they are employed and given toolbox talks on the hazards associated with their work activities before any work is performed. Several studies such as Shah and Tiwari, [16], Timmerman [5], and Esmail and Sakwari [10] have revealed that training on handling hazards and how workers can protect themselves is useful for skin diseases prevention. In addition, it is recommended that skilled workers get the safety and health training in vocational training. This is for them to be aware of the hazards and risks associated with their skills. When they are employed, pre-employment training and the toolbox talks would be as a reminder for them to adhere to good safety and health practices while working.

6 Conclusion

The exposure to chemical irritants in construction was high and there was a prevalence of the symptoms of the skin diseases among the skilled in both road and building construction workers. There was a relationship between levels of exposure to chemical irritants the occurrence of symptoms to skin diseases. There was also a relationship between period of exposure to chemical irritants and occurrence of symptoms to skin diseases. This means that the more workers are exposed to high levels of chemical irritants and the longer the period of exposure, the higher the likelihood of them developing symptoms of skin diseases. To reduce period of exposure, workers may be encouraged to work in shifts so that continuous exposure is avoided. Moreover, reducing levels of exposure may be done by providing skilled approved gloves to ensure that chemical irritants do not penetrate through the gloves. In addition, tool box talks on hazard identification and care should be conducted before any work activities.

This was a cross sectional study which was limited to a questionnaire survey and symptoms of skin diseases. This may have affected the findings, thus a longitudinal study where patch testing and follow-up checkups are used is recommended.

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Impact of COVID-19 on the Productivity of Small and Medium Enterprises Within the Construction and Consulting Engineering Companies in South Africa

Sinothi Nizo Blessing Ndlovu and Modupe Cecilia Mewomo(✉)

Department of Construction Management and Quantity Surveying, Durban University of Technology, Durban, South Africa
modupeM@dut.ac.za

Abstract. The purpose of the study was to investigate the impact of COVID-19 on the productivity of small and medium enterprises within the construction and consulting engineering companies in South Africa. A thorough literature review was carried out on COVID-19 and its implications for the small and medium enterprise sector. The study adopted the exploratory research design to provide an in-depth of the research phenomenon. Moreover, it took the form of a qualitative research approach to offer more insight into the impact of the COVID-19 on small and medium enterprises. The literature review was limited to only the study conducted between the periods of the COVID-19 pandemic (2019–2022). Desktop research was undertaken to identify and analyse relevant information that pertains to the subject matter. The secondary data sources used were journals, books, reports, and published literature related to the COVID-19 pandemic and financial performance within the South African context. The content analysis was adopted to sort the data and compare different pieces of information to summarise data into useful information. The findings showed that the COVID-19 pandemic significantly affected the productivity of small and medium enterprises in South Africa and across different regions of the world. Besides, the results indicated that most small and medium enterprises experienced a significant drop in their production in the early stage of the outbreak. This study is significant because it contributes to the body of knowledge on the COVID-19 pandemic and its impact on small and medium enterprise productivity. This study will serve as an essential tool for government and small and medium enterprises on how to mitigate the consequences of the COVID-19 pandemic. Moreover, the study will help promote the sustainability and growth of small and medium enterprises.

Keywords: COVID-19 pandemic · Productivity · Small and medium enterprises

1 Introduction

Globally, small and medium enterprises (SMEs) contributes to alleviating poverty, inequality, and unemployment in the society. The SME sector is an essential source

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of employment, especially for low-skill workers and the youth [18]. A study revealed that globalization and technological changes have created new opportunities for SMEs. In advanced countries, the contribution of SME sector has been well documented [28]. It has been argued that countries in the European Union (EU) recognised the SME sector as a driver to economic growth since it contributes to poverty alleviation and job creation [28]. Evidence suggested that SME sector contributes towards delivering the key objectives of the Europe 2020 strategy to reach smart, sustainable, and provision of employment [28]. In the EU-28, the SME sector accounts for more than 99% of all enterprises [29]. Of the total, 93% are micro-enterprises, 6% are small enterprises, and 1% are medium enterprises. Research [42] suggests that micro-enterprises contributed 30% to job creation, while SMEs contributed about 20% and 17% towards employment creation. In total, the SME sector contributes about 66% of total employment in the EU. Based on the value-added standpoint of view, the SME sector accounts for more than 57% of total value-added, with more equally distributed shares among SMEs [42]. Additionally, evidence shows that SMEs employed more than 52% of the private workforce and 51% of the United States of America (USA) Gross Domestic Product (GDP) [42], while in the United Kingdom (UK), they accounted for 62% of total employment and 25% of the GDP (32). In China, the SME sector employs 80% of the workforce and contributes 60% of the GDP [56].

The importance of SMEs in the developed countries mentioned above is not different from the developing countries, especially in Africa. In Africa, SMEs are also considered the engines of economic growth and development. Statistics showed that about 90% of SMEs account for economic growth through employment creation, tax provision, poverty alleviation, and enormous contribution to GDP [43]. For instance, in the Sub-Saharan Africa region, the SME sector accounts for 95% of all firms [30, 41]. Mentioned that SMEs in Africa are even more significant given their role in reducing poverty, boosting the countries' GDP, and providing employment in the society. In South Africa, the SME sector contributes more than 76% employment opportunities. The [52] indicated that in 2015, more people of about 5.8 million were employed in the small business sector compared to about 3.6 million people employed in large businesses" [8]. Also confirmed that the SME sector creates 65% employment opportunities making it the most significant private employer in South Africa.

Although SMEs are the engines of growth, they faced several impediments which affect their survival [5, 47]. These challenges include but are not limited to funding, government regulations, human capital, access to the market, technological innovation, and outbreak of COVID-19 pandemic. Among these challenges, the COVID-19 pandemic had severe consequences on the growth and survival of the SME sector [49]. COVID-19 has exacerbated the challenges faced by SMEs as it is having a devastating impact on the survival and operation of SMEs globally. The [25] confirms that COVID-19 pandemic had left all sectors of the economy globally devastated although preventive measures to curb its spread are in place. The period of closure and movement prevention policies adopted by governments in many countries have greatly affected SMEs, paralysing their operations, weakening their financial positions, and exposing them to financial risk [49, 50]. SMEs have suffered from a shortage of workers and production inputs because of distortions that marred supply chains, which negatively affected their sales [21, 54].

Against this backdrop, this paper aims to investigate the impact of the COVID-19 on the productivity of small and medium enterprises within the construction and consulting engineering companies.

1.1 Historical Background of the Covid-19 Pandemic

In March 2019, the corona virus, also known as COVID-19 pandemic was first detected in Wuhan City-Hubei Province, China, which hereafter changed the way of life, working, relationships, economies, needs and rights of the global population [31]. The corona virus is a type of virus that effects mammals, animals and humans. According to [23], within a short period, COVID-19 outbreak spreads quickly to other parts of the world. COVID-19 is a disease caused by severe acute respiratory syndrome coronavirus 2, which has affected most parts of the globe. Given the wide spread of the COVID-19 outbreak and death mortality, the World Health Organization (WHO) on January 30, 2020, declared the SARS-CoV-19 outbreak an international public health emergency [59].

South Africa confirmed its first of COVID-19 infection on 5th March, 2020. Since March 2020 when the Minister of Health confirmed the first South African positive test of COVID-19, the virus became an integral part of everyday life in South Africa [44]. Given the widespread of the virus, South Africa went into a hard lockdown to limit the spread of the disease. Following the promulgation of the lockdown on 27 March 2020, the government of South Africa issued regulations enforcing limitations of gatherings to 50 people amongst other measures such as travel restrictions, self-isolating, and closing of schools and businesses [57]. The complete lockdown was untenable, despite the several interventions put in place by the government. The economic implications of the nationwide shutdown made it unsustainable [61]. Since then, the government has reduced the levels of lockdown restrictions in phases to permit the economy to function once again. The largest public health crisis in living memory, which has also generated a major economic crisis, with a halt in production in affected countries, a collapse in consumption and confidence, and stock exchanges responding negatively to heightened uncertainties. While world-wide, the number of COVID-19 continues to increase at the time of writing of this paper.

1.2 Conceptualization and Contextualization of SMEs

Extant literature suggests that no consensus exist among scholars concerning the acceptable definition of SMEs. Thus, the conceptualization and contextualization of SME varies significantly from one context to another or scholar to scholar. For example, in European Union, SMEs are defined using the criteria such as the firm's size and eligibility for funding [15]. SMEs can be defined based on the criteria, including the amount of capital invested, workforce employed, and sales turnover [20]. Also, in most countries, the criteria for classification can be determined based on capital and the number of employees. For instance, in Uganda, SMEs are considered the engine of economic growth, development, and transformation through innovation and wealth creation [14]. Also SMEs has been defined as firms with not more than 250 employees [2]. Ghana Statistical Service (GSS) considered SMEs as those firms with 30 to 99 employees [3].

However, in China, SMEs have fewer than 300 to 2000 and with less than Y30 to Y300m. According to [11], since 1949, the conceptualisation of SMEs in China has changed in response to the changing realities of the economy and business environment. For example, what appears to be a small enterprise in some SMEs in China may be considered as big organisations in different countries. The EU defines SMEs as follows: (i) fewer than 250 employees; (ii) annual turnover of 40 million Euros maximum; (iii) annual total balance sheet of 27 million Euros maximum; (iv) 75% minimum of company assets owned by the management; and (v) owner-managers or related families personally manage the business [8]. Although these criteria for defining SMEs vary among countries, they provide a systematic approach to defining SMEs.

1.3 Profile of the South African Small and Medium Enterprise Sector

Post-1994, South Africa witnessed severe socio-economic challenges that require urgent solutions [10]. These challenges are the high unemployment rate, skills shortage, high illiteracy rate, escalating crime rate, and rural poverty. SMEs are considered vehicles through which the above challenges can be addressed. The South African SME sector is diverse and operates in different industries such as retailing, wholesaling, tourism, mining, farming, manufacturing, construction, and service.

Since the last decades, the Department of Trade and Industry (DTI) has been publishing comprehensive reports on the South African SME sector [13]. However, as the economies evolve and adjust to new phenomena, so is the SME landscape in South Africa. This may be particularly true due to the major socio-economic, political, and technological events of the last few years. Some of these events are namely; the financial crisis of 2008 and 2009, political instability, and now the COVID-19 pandemic. According to [36] the South African social and economic development strategies are dependent on harnessing entrepreneurial potential and supporting SMEs. Since the passage of the 1995 White Paper on small, micro, and medium enterprises (SMME) development, the investment in the SME sector by the South African government has become evident. Apart from the DTI, other institutions or agencies such as the Ministry of SMMEs and Small Enterprises Development Agency (SEDA) were created to support the SME sector to contributes towards economic growth [7]. South Africa's SME sector accounts for more than 90% of business operations and contributes to more than 50% of employment and GDP [36].

1.4 Hypothesis Development

The restrictions imposed by governments in most countries to curtail the spread of the infectious disease among people, such as social distancing, quarantines, and travel ban have affected the supply chain and slowed many economies. The implications of this pandemic have been felt across all sectors, including SME. Scholarly researchers such as [49, 50] have suggested that the lockdown restrictions and policies adopted by governments across different countries have greatly affected SMEs, paralyzing their operations and productivity. Moreover, it has been found that SMEs suffered from the decreased production inputs because of distortions that marred supply chains, which negatively impacted their productivity capacity [21, 54].

It was reported that due to the shutdown of various organisations, there would be a reduction in production level of about 1/5 to 1/2 with demands from customers also declining by about 1/3 [48]. Furthermore, [23] observed that the lockdown and quarantine measures adopted by the government to limit the spread of the virus have led to serious decrease in capacity use, resulting in the decline in productivity. The outbreak of the virus has resulted in a decreased production, especially in China and USA, affecting businesses heavily dependent on trade [22]. The primary supplier of inputs for manufacturing and production industries, has restricted shipment of goods, which tremendously impacted business operations in many countries, including South Africa [22]. A survey conducted by [46] revealed 98% of the sampled firms raised concern about the negative impact of the pandemic on business operations. It was discovered that the chemical industry is predicted to reduce its global production by 1.2%, the worst growth for the sector since the 2008 financial crash [42]. Also, it has been found that the stringent lockdown regulations have led to a disruption in the supply chain, which caused a reduction in the production of goods from factories [46].

A study found that COVID-19 pandemic has really impacted the operations of SMEs in Ghana [32]. In Jordan, a study conducted by [4] indicated that the crucial issues affecting the performance of SMEs at time of crisis is the possibility to provide the raw material required for production, resulting in a decrease of production. In Iraq, it was reported that the SMEs in the construction and manufacturing sectors have witnessed 68% reduction in production [43]. Evidence from South Africa suggested that 9% of SMEs had ceased operations permanently, because of the unavailability of raw materials [59]. Based on the above, the following hypothesis was proposed.

H_1: COVID-19 pandemic positively impacts productivity of small and medium enterprises.

1.5 Theoretical Framework That Underpins the Research

Extant literature suggests that various theories support the growth and survival of SMEs. Nevertheless, the most appropriate theoretical framework that underpins the study is the strategic management theory. It is believed that in this turbulent business environment occasioned by the COVID-19 pandemic, firms review long time strategies to remain sustainable. This assumption underpins the importance of the strategic management theory. Chandler was among the first scholars to provide a systematic account of corporate strategy and described the strategic and structural development of organisations, noting that "structure follows strategy" [9]. Around 1970s, the conceptualisation of strategy emerged around the formulation of policies, strategic planning, and adaption of organisations to their business environments. Researchers such as [24, 53] described the strategic elements of a firm based on goal formulation, environmental analysis, strategy formulation, strategy implementation, strategy evaluation, monitoring and control. The notion of strategy was introduced as a technique for organisations to achieve their goals and objectives [38]. Strategy refers to "how the company creates a value for customers and stands out from other competitors in the market". In other words, strategy can be understood as a perspective, position, plan or pattern of behaviour [56]. From the above explanations, it can be argued that the strategic management theory emerged to decide on organisational goals and means to achieve the goals.

Scholars such as [38, 58] and believe that the strategic management theory firms to develop a long-term vision, identify main, identify critical suppositions, to convert data into reliable information; realistically evaluate the company at present and its potential, balance relationship between growth added to investigation and development and innovation with the current operation; coherently plan with the vision and mission defined by the company, incorporate all the individuals involved in the execution and all those affected in the elaboration to be part of the actions.

1.6 Conceptual Model That Underpins the Research

Figure 1 shows how the COVID-19 pandemic has impacted the productivity of businesses, including SMEs. Based on the systematic literature, the conceptual was developed to explain how the COVID-19 pandemic impacted the productivity of the SMEs within the construction and engineering industries. This global epidemic crises, including COVID-19, have exposed SMEs to various kinds of challenges and may put them at risk [1]. As mentioned above, evidence suggests that SMEs have suffered from a shortage production inputs because of distortions that marred supply chains, which negatively affected their sales [21, 54]. A study shows that the COVID-19 has impacted SMEs current performance and the overall business performance in many countries [38]. Thus, it can be argued that the COVID-19 pandemic affects the day-to-day operations of firms.

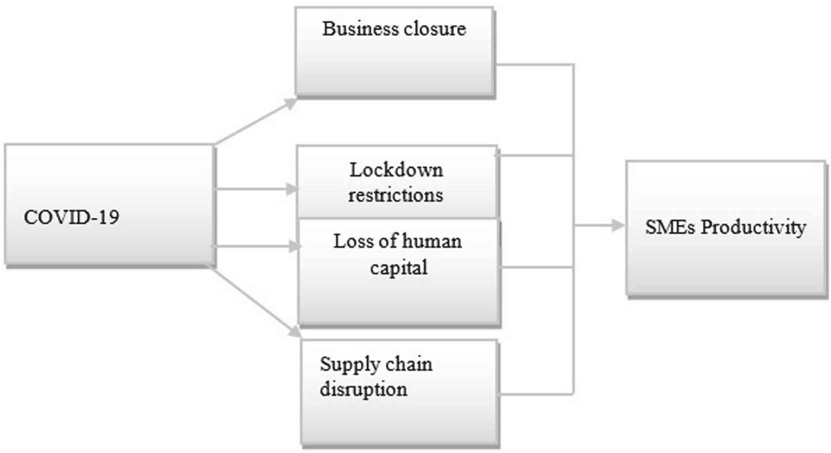

Fig. 1. COVID-19 and productivity of small and medium enterprises.

2 Research Design and Methodology

The purpose of the research was to investigate the impact of COVID-19 pandemic on the productivity of SMEs within the construction and engineering industry in South

Africa. To achieve the purpose of the study, a systematic literature review was conducted on the impact of the COVID-19 on SME globally. The literature review was limited to only the study conducted between the periods of the COVID-19 pandemic (2019–2022). Articles were retrieved from the databases of Scopus, Web of Science and Google Scholar. Keywords such as 'Covid 19 Pandemic, productivity, small and medium enterprises in South Africa were utilised in the search for the relevant articles. The study adopted the exploratory research design to provide an in-depth description of the research phenomenon. The study took the form of qualitative approach to provide adequate understanding of the impact of the COVID-19 pandemic on the productivity of SMEs. The content analysis was conducted to analyse the findings from previous literature.

3 Findings

The findings from this study indicate that the COVID-19 affects firms' productivity, including SMEs. Extant literature suggests that the outbreak of the COVID-19 affect the day-to-day operations of all firms. For instance, [32] examined the impact of global COVID-19 pandemic SMEs in Ghana and found that the COVID-19 pandemic has really impacted the operations of SMEs. In Jordan, a study conducted by [4] indicated that the crucial issues affecting the performance of SMEs at time of crisis is the possibility to provide the raw material required for production, resulting in a decrease of production. In Iraq, it was reported that the SMEs in the construction and manufacturing sectors have witnessed 68% reduction in production [43]. Evidence from South Africa suggested that 9% of SMEs had ceased operations permanently, because of the unavailability of raw materials [57].

4 Conclusion

The study examined the impact of the COVID-19 pandemic on SMEs productivity. A systematic literature review was conducted to address the aim of the study. The findings revealed that the COVID-19 pandemic negatively impacted the productivity of SMEs not only in South Africa but globally. Moreover, it was discovered that the COVID-19 pandemic engendered a global crisis that brought about supply and demand shocks. The disruption in the supply chain has resulted in decline in firms' production. For example, the findings showed that 9% of SMEs had ceased operations permanently, because of the unavailability of raw materials [57].

Limitations and Directions for Future Research

This study investigated the impact of COVID-19 pandemic on SMEs productivity. By implication, the findings from the study relate only to COVID-19 pandemic and SMEs productivity. Hence, future research on COVID-19 pandemic should examine other aspects of SMEs such as sustainability, performance, growth and development. Moreover, the scope of the investigation was limited to desktop research. This suggests that there is a lack of empirical research on COVID-19 pandemic and SMEs productivity. Therefore, future research on COVID-19 pandemic and SMEs productivity should be based on field research.

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Agile Risk Management Practices in the South African Construction Industry Project Delivery

Molefi Nketekete and Oluwayomi Babatunde(✉)

School of Construction Economics and Management, University of the Witwatersrand, Johannesburg, South Africa
MolefiNketekete1@students.wits.ac.za, Oluwayomi.Babatunde@wits.ac.za

Abstract. Risks in construction projects can be dynamic and complex in nature. Construction projects continue to succumb to the impacts of these varied risks thus requiring innovation in risk management practice (RMP). Like most developing countries, the South African Construction Industry (SACI) is not an exception in terms of consistent record of project failures. To date, there are different practices in risk management that are being utilised across the SACI. However, there are knowledge gaps in the RMP that require an agile approach for improving project delivery within the SACI. Furthermore, it is vital to note that agile approaches ensure *inter alia* constant improvement and innovation, as opposed to traditional methods. As such, introducing an Agile RMP (ARMP) tool is essential to transform the SACI in terms of project delivery success as findings have shown. This exploratory literature review-based study is aimed to analyse the effectiveness of traditional Risk Management (RM) methods and assess the need for an ARMP approach relative to improving project delivery within the SACI using eleven (11) snowball sampled articles. Through content analysis, the study revealed the need for further research on agile methods and training among others. However, this requires an in-depth investigation and inputs from stakeholders in the future. In so doing, this will reduce the effects of prevalent risk management's knowledge gaps among project stakeholders. Furthermore, it is vital to introduce digitalisation-enable innovative agile methods for identifying and assessing risks that affect the construction projects whilst stipulating pragmatic training tools essential for improving the project delivery. Ultimately, the formulation of an ARMP framework appropriate for the SACI will contribute to sustainable construction projects.

Keywords: Agile risk management practice · Project delivery · Risk management · Risk management practice · South African construction industry

1 Introduction

It is has been well documented that the construction industry is one of the major economic contributors for any country despite being prone to challenges that impede the effective project delivery over the years [1, 13, 51]. Despite this, it is stipulated that numerous risk management (RM) concepts have been introduced in research despite

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being hardly recognised by the industry [36]. Similarly, there are claims about the existence of shortfalls pertaining to the influence of research in construction management in terms of innovations [34]. Innovative ideas are now channelled towards explanatory methods which are focused on project risks and or uncertainties [33]. Meanwhile, some findings indicate inadequate coordination between research and the construction industry [37]. As such, some findings show that the construction industry is still behind in terms of innovation since managers are reluctant to accept change and technological developments *vis-à-vis* digitisation [27]. This is followed by claims that the industry is scoring the lowest among others in terms of digitisation ratings in some developed countries like the United Kingdom [10].

Since the construction industry is exposed to a surfeit of complex risks that impede project delivery, there are far-reaching and debilitating effects on the entire economy [13, 44]. Recently, the SACI has incurred investment losses across different construction platforms because of poor project deliveries [19]. Among other challenges, there are infrastructural backlogs within the SACI despite interventions in addressing the socio-economic development of the country [20, 32]. Meanwhile, Hillson once stated, “Risk is the uncertainty measured and uncertainty is a risk that cannot be measured” [2]. Therefore, the construction industry is susceptible to various risks that require astute RM to minimise losses [49]. Significantly, RM is considered a systematic process comprising of *inter alia* risk identification, assessment, and response [2]. As such, it has been encouraged that RM tools be utilised consistently throughout the project lifecycle (PLC) in order to supress the risks’ impacts [4]. Despite this, there is a claim that RM frameworks are ineffective as proved by incessant project failures [42].

Meanwhile, it is recommended that should the RMP be infused in to the organisational culture and processes it will provide resilience as a mitigation measure towards improving project delivery [14]. However, gaps in managing risks in the construction industry are evident since tools have certain limitations [2]. Likewise, there is a poor record of RMP in across Africa alongside rampant inexperience of project managers [31, 41]. Therefore, proactive managerial strategies are necessary to introduce innovative RM methods as opposed to the traditional approaches [4]. Being agile signifies appreciating proactive concepts since it deals with risks instantaneously and it is regarded as an iterative approach as opposed to the traditional methods [3, 4]. As such, this research paper’s objectives is to; (1) present how an ARMP theoretical tool can be an indispensable and innovative RM tool essential for improving project delivery whilst sustaining the SACI; (2) examine and assess innovative theoretical agile methods relative to their application in project RM; (3) review the current RMP within the SACI *vis-à-vis* how agile it is within the confines of innovation from a literature perspective.

2 Literature Review and Conceptual Framework

Collaborative research is being credited for its impetus on innovation for businesses including construction [37]. The future of the construction industries relies on appreciating innovation hence the notion termed a computing paradigm [26]. Therefore, the literature review for this paper focuses on how innovative an ARMP can be relative to improving performance of the SACI since a sustainable construction performance requires innovation [27]. The concept of sustainable development evokes that the development shall promote current self-sustainability whilst envisaging the same for the future [52]. Despite this, the construction industry has showed a slow progress in terms of adopting modern innovations *vis-à-vis* digital technologies hence scored the lowest growth rating [10]. It has been revealed that in modern times, projects are influenced by new technologies among others and so is the concept of agile project management [50]. Traditional methods are considerably ineffective since they are inclined towards paper-oriented methods thus affecting project performance aspects like communication despite the growing appreciation for digitisation [10].

Meanwhile, developing countries like South Africa, dearth of management awareness and control in construction projects, misunderstandings, poor workmanship, escalation of materials prices, skills mismatch, overruns in time and costs, and late contractors' payments among others are endemic challenges [5, 21, 51]. Moreover, the SACI is regarded by some as less rewarding, less prestigious, characterised by poor health and safety standards, and exposed to economic volatility among others [29]. Since the emergence of COVID-19, there have been disruptions in materials supply among others within the SACI thus requiring proactive RM interventions [4, 9, 18]. There are also challenges that hinder interventions from the government to resuscitate and provide a leeway for the SACI [24]. It is also reported that RM implementation is still a major challenge in projects [14]. To date, the SACI is still succumbing to the proliferation of diverse risks hence the declining performance [44].

2.1 Risks and Risk Management Process

For effective management, risks are classified according to their types under one acronym titled PESTLE, i.e. *political, economic, socio-cultural, technological, legal, and environmental* [43]. Alternatively, risks are grouped according to their sources e.g. internal or external among others [23]. Whereas, in the developing countries, risk are categorised in relation to the market, country, project, technical, and capacity development among others [12, 46]. Countries like South Africa, experience price fluctuations, budget constraints, corruption, lack of RM skills, cost and schedule overruns, poor communication, and defective design among other common risks [13, 17]. Since risks are dynamic in nature, there are numerous tools, techniques, and frameworks for RM available to select from [42].

Notably, RM is a systematic process comprising of risk identification, risk assessment, and risk response whilst putting in place contingency plans [2, 12, 40]. Alternatively, risks are determined at the identification stage followed by analysis, response, and monitoring [48]. In the developing countries, project managers use these traditional techniques for risk identification; checklists, expert interviews, past experiences, and brainstorming, for risk analysis; risk matrix, Monte Carlo simulation, fussy logic, FMEA, and expert analysis, whilst for risk response; risk retention, risk reduction, risk sharing, risk control, risk avoidance and risk transfer [12]. However, there is a shortfall in terms of innovative research to address and invigorate the RM practice for optimum utilisation of these techniques [41]. This evident inadequacy has resulted in numerous flaws in the RMP [12]. Therefore, a need for an innovative research and training is necessary to bridge these gaps [11]. Therefore, an agile approach has been identified as an ideal solution hence a comparative analysis between traditional and agile method in Table 1 is necessary to inform the SACI.

2.2 Agile Approaches

Agile methods in modern times have emerged in the practice of project management as an innovation relative to improving project delivery as opposed to following the traditional methods [8, 14]. Generally, the key areas for innovation entail adaptability, documentation, value adding, and collaboration among others since agile embraces universal solutions [14].

Table 1. Traditional versus agile approaches [3]

Traditional	Agile
• Focused on establishing requirements	• Adapts to changing client requirements
• Periodical meeting and reports used in progress monitoring	• Daily meetings used to monitor progress
• Professionals are at the helm of decision-making	• Collective decision-making process
• The leader is in charge	• Every member is engaged
• Documentation is mandatory	• Focused on the project performance
• Reactive to changes	• Proactive to changes
• Sustainable development	• Sustainable development

2.3 The Methodology

This research follows an exploratory literature review using two well-known research databases in the field of construction being Emerald Insight and Sabinet. Search queries addressing the research questions below were adopted to filter the information relevant to the inquiry as similar to some studies [33].

(RQ1) How best can the RMP address the construction project challenges?
(RQ2) How can an ARMP approach help improve project delivery within the SACI?

Since it has been difficult to interact with participants, selected works were identified to represent the population of interest hence a snowball sampling method was applicable for this qualitative inquiry [16]. Information was gathered from peer-reviewed open access articles published within five years to date. The findings are presented in Table 2 indicating the number of attempts on each database. Each database is filtered accordingly using similar keywords addressing each respective research question. However, the search queries had to change since some outcomes were irrelevant to the topic and or ambiguous in nature. As a result of repetitive search attempts in the Emerald Insight

(A) and Sabinet (B), six (6) relevant results were attained in relation to how best the RMP can be effective in the construction industry. When addressing research question two (2), a total of five (5) relevant results were attained. This process is consistent with snowball or chain process sampling since the researcher is able to apply filters up to where the participants meet the criteria for reliability [16].

Table 2. Search results

Attempts	Key words	Outcome
Relative to RQ1 (total 6)		
A1	"construction project" (all content), "risk management" (all content), "risks" (title), "Construction industry" (all content)	8 (5 irrelevant) – Emerald
A2	"construction project" (title), "risk management" (all content), "risks" (all content), "South African Construction" (all content)	1 – Emerald
B1	"construction project" (title), "risk management" (anywhere), "risks" (anywhere), "South African Construction" (anywhere)	5 – Sabinet
Relative to RQ2 (total 5)		
A1	"agile" (title), "innovation" (all content), "risk management" (all content), "construction" (all content)	2 – Emerald
B1	"agile" (anywhere), "innovation" (anywhere), "risk management" (anywhere), "construction" (anywhere)	121 – Sabinet (many irrelevant)
B2	"agile" (anywhere), "innovation" (anywhere), "risk management" (anywhere), "construction" (title)	2 – Sabinet
B3	"agile" (tile), "innovation" (anywhere), "risk management" (anywhere), "construction" (anywhere)	3 – Sabinet

3 Results, Analysis and Discussions

The two (2) research questions were aimed to capture the information in terms of the status quo of the RMP within the SACI. Whilst being mindful of the research objectives, the analysed content eased in the screening process for relevant innovative RM strategies. This research strategy has assisted in assessing how agile approaches are viewed in the context of RM relative to performance improvement.

Findings relative to RQ1

In order to understand how the RMP can address identifiable challenges in construction projects relative to RQ1, the filtered eleven (11) articles have been analysed respectively using search queries. Some of the researchers' works do not directly articulate how the RMP is supposed to address risks instead suggested pertinent tools [35]. For instance, one article proposed situational awareness systems relative to the transformation of construction project management. Likewise, solutions such as collaborative procurement, early contractor engagement, cost reimbursement, collaborative tools, and joint venturing have been recommended for mitigating identified challenges [27]. The rest of the findings are as follows (Table 3).

Table 3. Findings relative to RQ1

Researcher(s)	Findings relative to RQ1
[6]	Suggest project classification model to address certain challenges on large-scale projects
[47]	Proposes effective talent management, internal and external enablers, and a regulatory framework to acknowledge labour market to address skilled labour shortages
[38]	Proposes improved lean strategies to redress wastage
[45]	Proposes awareness and application of supply chain management to redress identified number of bottlenecks
[39]	Recommends proper tax planning and in-house tax tasks relative to tax compliance costs
[30]	Proposes a performance prediction model to improve performance level of emerging contractors

Findings relative to RQ2 (Table 4)

Agile approaches in projects have been credited for being iterative alongside road mapping strategies which have been endorsed in terms of technology and innovation [7, 15]. Therefore, an innovated agile method that encompasses varied RM strategies is vital.

4 Conclusions

According to the findings, there are a number of varied strategies identified in managing risks in construction projects despite their paucities. Various alternatives have been employed based on individual preferences. Generally, there are still a number of impediments in managing projects within the SACI because of rampant risks. The findings indicate a dire need for research and innovation relative to agile methods in order to redress this predicament. Resistance to change and insufficient training are some of the drawbacks in revolutionising the industry as highlighted by some researchers. However,

Table 4. Findings relative to RQ2

Researcher(s)	Findings relative to RQ2
[7]	Indicate resistance to changes relative to the adoption of innovative agile project management and lean product development strategies
[15]	Present a positive impact of continuous information monitoring and adoption of a roadmap in innovation strategy decisions
[40]	Highlights lack of research relative to operational risk management framework
[25]	Highlights a dire need for managing construction risks and further research
[28]	Recommends statistical methodology for inventory management and stock control

there are a number of suggestions relative to improving project delivery, which include a need to adopt agile methods. The evident RM gaps essential for improving project performance indicate the need for agile and innovative approaches despite limited relevant research output. The need to adopt agile methods in construction is emphasised by readers similar to the software development sector. Therefore, an ARMP framework is essential for the SACI relative to accomplishing value-adding projects delivery. Further studies will benefit RM professionals exposed to these challenges in terms of how to adopt innovative solutions although they were not engaged in this probe. As a result, a thorough study is required to justify these assertions after this conceptual inquiry.

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Utilization of Delphi Method for Risk Management of Public-Private Partnership Construction Project Research in Ghana

Timothy Adu Gyamfi[1,2](✉), Clinton Aigbavboa[1], and Wellington Didibhuku Thwala[3]

[1] Faculty of Engineering and Built Environment, University of Johannesburg, Johannesburg, South Africa
agttimo78@gmail.com, caigbavboa@uj.ac.za
[2] Faculty of Built and Natural Environment, Koforidua Technical University, Koforidua, Ghana
[3] College of Engineering, Science and Technology, University of South Africa, Pretoria, South Africa
Thwaladw@unisa.ac.za

Abstract. Delphi method is designed to ensure consensus by a group of communicators responding to research inquiries. Organizations, institutions, government agencies, research, and policy development agencies uses Delphi method as research methodology. This technique entails the use of a questionnaire survey in two or more iterations, giving panel members the opportunity in the second round to review the findings from the first round and make changes to the first-round assessment if they deem fit, or to maintain their previous response. The use of Delphi surveys is beneficial for the development of report guidelines, prediction, and policy marking. The Delphi approach is used in this study to comprehend and forecast issues concerning risk management of Public-Private Partnership (PPP) projects in Ghana's construction industry. The application of this technique to this study is grounded on evidence that the approach has not been widely used in Public-Private Partnership risk management in construction, despite numerous experimental studies in this area. The study reveals that to employed Delphi technique for PPP and risk management in construction industry in Ghana experts are required to meet five minimum criterial and chosen sample size of 15. The methodology technique espoused for the study was a literature review from peer-reviewed journals articles. Finally, the authors maintain that the Delphi method is deliberated since it has the potential to address professionals' disagreement related to issues under scrutiny.

Keywords: Construction industry · Delphi technique · Ghana · Public-private partnership · Risk management

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1 Introduction

The Delphi technique is an organized method of communication, purposely established as a logical, interactional prediction technique that hinges on a panel of experts Sackman [1] and Linstone and Turoff [2]. It is grounded on the assumption that predictions from an organized group of individuals are mostly correct [3]. The Delphi method is grounded on the principle that combined intelligence enhances individual decisions and attains the collective opinion of panels of professionals [4]. The argument of Tilakasiri [5], was that the Delphi method is suggested for the development of principles, ideas, frameworks and/or models. The Delphi method was used in the current studies to develop a model for Public-Private Partnership (PPP) risk management. The technique was applied to ascertain the foremost attributes or factors that establish Public-Private Partnership risk management (PPPRM) execution outcomes. It was also used to study the degree of impact the main and sub-attributes have on PPPRM execution outcomes in Ghana.

The argument by Keeney et al. [6], was that the typical Delphi procedures generally comprise three rounds of the survey. The views of groups of professionals are solicited in Round 1 on issues under investigation by utilizing open-ended questions. Round 2 compares the group median score achieved in round 1 to the individual ranking made in round one. The third round is to ask a professional group as a final chance to reevaluate the rankings based on the results obtained in round 2. The rounds of the study may persist until agreement among professional panelists is reached on most or all of the items. Questions are utilized for each round of the survey, and the views of experts are computed and evaluated with percentages, median and interquartile ranges. In some cases, disagreement and counter-opinions of diverse answers are also offered during the feedback aspect of the Delphi method [7]. Grisham [8] stated that professionals' answers are evaluated to ascertain central and extreme tendencies and their validity. Miller [9] and Hasson et al. [10] highlighted that the Delphi technique is a qualitative method that explores to determine consensus in professionals' views via rounds of survey. The Delphi technique is a suitable tool for examination when a research study intends to explore or assess policies to direct similar public and private entities in the future [11]. It is advantageous to solicit views of professionals who are far apart. Moreover, it is stronger in predicting and acknowledging problems in research studies and is more likely to be able to identify problems in a study [7, 12]. The application of the Delphi method as a technique of inquiry in scientific study is gradually extending to different study areas [13]. Many studies acknowledge its application in medical fields [14–17], communication science, actuarial science and economics Society of Actuaries (SOA) [18], engineering and quasi-engineering disciplines [12, 19], built environment research [20, 21], and business and management studies [22, 23], and many others.

However, this current study gathered professionals across various locations in Ghana. It is imperative for the current study to employ the Delphi technique of enquiry to sort the opinion of professionals. Besides, little is known of the application of the Delphi technique of enquiry in PPP risk management studies in the Ghanaian construction industry. Hence, the utilization of the Delphi method for PPP risk management in the Ghanaian construction industry will be an innovative approach in obtaining qualitative data. The objective of this study is examining the utilization of Delphi method to forecast and comprehend situation on PPP risk management in construction industry in Ghana.

This was to establish the criteria and variables that effect successful execution of PPP risk management model in construction industry in Ghana.

2 Research Methodology

The study discusses how the Delphi method is utilized in the enquiry. The study is primarily of review of literature that is founded on published and unpublished existing literature with the goal of ensuring how Delphi method can be employed to forecast and understand situation concerning PPP risk management implementation in construction industry in Ghana. This was carried out through the deliberation of when to apply Delphi technique, components of the Delphi technique, and designing, constructing and implementing the Delphi study. This technique was espoused to surmount the misperception concerning the latent variable that impacts on successful execution of PPP risk management of Construction projects in Ghana.

2.1 Application of Delphi Technique, When?

As argued by Chan et al. [24], the Delphi method is employed to predict the possibility of an event occurring. Aigbavboa [7] posited that Delphi helps in recognising topics that are vital in the future. It is advantageous to utilize Delphi to reduce difficult and complicated knowledge so that it will be easier to decide. The Delphi is applied when confidentiality of professionals needs to be conserved [12, 24]. Also, where expects are far apart from each other, it is vital to utilize Delphi technique to gather their views, where assembling them would not be economically viable in terms of time-wise [7]. The Delphi method is the best when a larger number of people across various jurisdictions and areas of expertise are involved anonymously [25]. Besides, as opined by Aigbavboa [7], utilization depends on issues of research. This study utilizes the Delphi method as a qualitative research technique to solicit professionals' ideas in the development of an all-inclusive PPP risk management model.

2.2 Components of the Delphi Technique

According to Loo [11] and Aigbavboa [7], when conducting a Delphi study, five (5) main components are involved, and the current study adopted these: there should be a group of professionals chosen cautiously as a representative of a broader range of views on the subject under examination [5, 7, 11]; the professionals on the Delphi group should continue to be anonymous to each other during the study; the researcher should design a planned questionnaire to seek professionals' views on the subject under examination and provide feedback to the panel during the procedure; the outcome is reported and it includes information such as Delphi findings, the predictions, policy, and programme (thus their strengths and weaknesses); and probable suggestion to management and probable action to be taken [7, 11]. Additionally, Hasson et al. [26] contended that the application of the Delphi method in a study should be directed by the following: research problem, understanding the Delphi process, careful selection of experts, informing/invitation to experts: data analysis, and presentation and interpretation.

3 Designing, Constructing and Implementing the Delphi Study

Existing studies suggest that Delphi should be conducted chronologically. Instances of such studies include Chan et al. [24], Loo [11], Aigbavboa [7] and a recent study by Ameyaw et al. [12]. In the view of Loo [11], the Organization of Delphi includes definition of problems, selection of panels, determination of panel size and carrying out Delphi rounds. This chronological manner has been mostly employed in Delphi studies throughout different fields of enquiry. An instance is a doctoral study on residential satisfaction conducted by Aigbavboa [7]. Ameyaw et al. [12] opined that the chronological manner of conducting the Delphi survey includes panelist's selection, number of professionals in a group and number of rounds, and an anonymous feedback process. Also, according to Delbecq et al. [27], the recommended methods for the Delphi survey consist of development of a Delphi questionnaire, selection of a panel of professionals, sample size, Delphi round one questionnaire, round one questionnaire analysis, and round two and three questionnaires. The current study utilised the following Delphi process: review of literature, development of questionnaire, piloting of questionnaire, final questionnaire development, selection of knowledgeable professionals, sample size determination, distribution of round one questionnaire, analysis of round one data, development of round two questionnaire as feedback to round one, analysis of round two data, determination of consensus, reporting of Delphi findings when consensus was attained. It could be inferred that the method for the design, construction and implementation of the Delphi survey among many scholars is not different. Figure 1 illustrates the Delphi process flow chart.

Phase 1 – Delphi Question Development: The development of questionnaires is paramount for the entire Delphi survey. For Delphi survey to accomplish its objectives, some essential questions need to be considered, such as Why this study is being carryout? What do you need to know that you do not know now? How will the Delphi findings impact on the study? and these questions serve as the foundation for the construction of the Delphi questions in this current study.

Phase 2 – Delphi Expert Panel Selection: The role played by the Delphi experts' group is among the contributing factors to successful Delphi study Hasson et al. [10]. As opined by Chan et al. [24] and Ameyaw et al. [12], the selection of Delphi professionals must be done cautiously and objectively. The study by Hallowell [28] posited that to qualify as a Delphi panel member, one is required to have unique expertise/skills, such as appointments for a particular job, working experience, professional qualifications and evidence of publications. The criteria one could use in prequalifying experts for a Delphi survey vary among researchers. Adler and Ziglio [29] postulated four criteria in prequalifying a professional for a Delphi survey: expertise and skill of the subject being surveyed, capacity and willingness to participate, sufficient time to participate in the study, and effective communicative skills. Each professional in the current Delphi study was required to meet a minimum of five of the following requirements: experience on PPP projects in industry, academicians who are knowledgeable in the subject area, Higher National Diploma (HND) as a minimum education background, academicians who have published articles in peer review journals, a member of professional bodies, have good communication skills, and have abundant time to take part in the Delphi Study. The professional should have demonstrated a high level of theoretical and/or practical skill in the subject being investigated over years, among other requirements. The employment of a minimum of five criteria is well-thought-out rather than at least two criteria recommended by Chan et al. [24] and Rogers and Lopez [30]. In addition, Hasson et al. [10] and Aigbavboa [7] maintained that the assertion that one professional group is representative of legitimate experts' view has been disapproved mostly as inflated and is scientifically shaky. The members of the panel for the Delphi survey for this current study were determined from set out criteria such as academicians, procurement officers, development officers, and procurement board members. The academicians and researchers were from the institute of higher learning in Ghana. These personnel are involved in teaching and research in PPP and risk management related courses. The procurement officers involved in procurement of projects at national level. These individuals include Public Investment Division (PID) members who are in charge of PPP project delivery in Ghanaian institutions, members of building construction Procurement and tender reviewers. The development officers were from universities in Ghana. These individuals are work directors at various universities, thus both traditional and technical universities, and they are involved in the development of infrastructure and consultancy services on various campuses, including the oversight of PPP building projects. The procurement board members were from Metropolitan, Municipal, and District Assembly's (MMDAs). These members are experts in construction at MMDAs level who are assembled to oversee PPP infrastructure delivery within their operational jurisdiction. Panel members who qualify to participated in the Delphi survey may associate with one or more professional bodies in the construction industry in Ghana, such as the Ghana Institution of Engineers (GhIE), the Ghana Institution of Surveyors (GhIS), Institution of Engineering and Technology (IET), and the Ghana Institute of Construction (GIOC). All chosen professionals might meet a minimum of five criteria set out by the study. The selection of panel members for the survey can be done by sending invitation to those who meet the set criteria via e-mail and personal delivery of the objectives of the survey. Eventually, those who would respond to the invitation are required to fill bio data to enable researchers to verify their qualification to participate based on the set criteria. Upon the verification, the chosen professionals qualify to participate in a Delphi study.

Phase 3 – Determining the Panel Size: It must be highlighted that no single accepted optimum size for the Delphi group can produce consensus amongst scholars Chan et al. [24], Aigbavboa [7], and Ameyaw et al. [12]. In view of that, many scholars have expressed divergent views in the literature. For example, as stipulated by Andranovich [31], a homogeneous panel thus a panel that shares the same views of size 10 to 15 will be ideal; however, if differing opinions exist amongst the panel of professionals (heterogeneous professionals' panel), it will be necessary to increase the panel size to ensure consensus [7, 32]. Furthermore, Phillips [33] stated that the optimal group size for a Delphi survey is between 7 to 12; whereas the opinion of Miller [9] was that after the first 30 respondents, any other respondents do not engender any different information. Similarly, Dunn [34] recommended a group size of 10 to 30 for the Delphi survey, with formal and informal participants who are more sympathetic to the issue under consideration. Therefore, it can be inferred that two diverse opinions are held in literature regarding the size of the panel for the Delphi survey. A similar opinion was shared by Ameyaw et al. [12]. One school of thought opines that the accuracy and credibility of Delphi study mainly depends on large panel size [35]. Those who agree with this school of thought employs large group size for Delphi research. The opposing viewpoint is that there is no significant relationship between group size and the accuracy and credibility of the Delphi study [36].

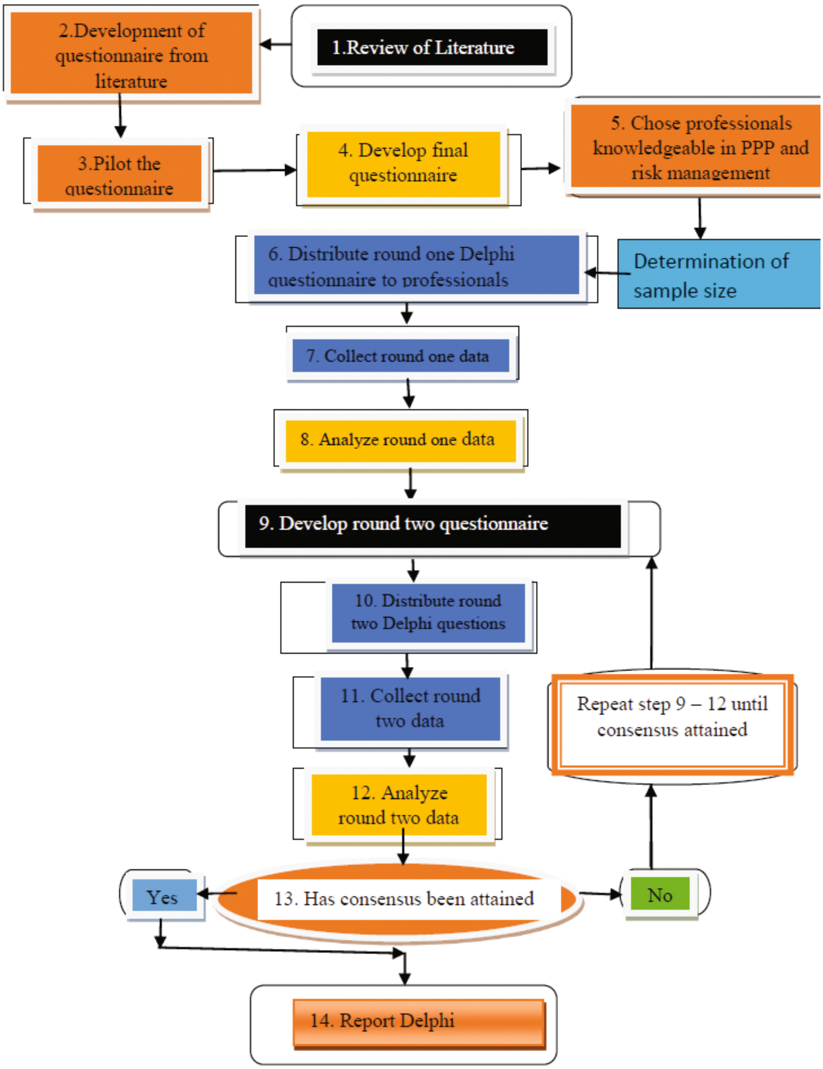

Fig. 1. Flow chart for Delphi process

The size of the group is established for a number of reasons, such as the nature of the issue being examined, resources available in terms of time and money, and the number of expert availability [10, 37, 38]. A study by Ameyaw et al. [12] investigated 67 qualitative studies that employed the Delphi technique. It was discovered that most of the studies (41/67) utilized panel size between 8 to 20, whereas a smaller number of studies utilized panel size above 20. Hence, this current study employs the small panel size of 15 to ascertain the factors of this research.

Phase 4 – Conducting the Delphi Iterations: As posited by Ameyaw et al. [12], there is no identifiable guide on the optimum number of iterations in a Delphi survey. Many studies recommend at least three or four iterations of questions and feedback to achieve agreement [7, 11], whereas Dalkey et al. [39] stated that Delphi outcomes can be accurate after round two. Yet, as it was observed by Xia et al. [40], generally after the second round, the number of professionals began to drop. Also, Crisp et al. [41] proposed that the Delphi procedure should come to conclusion when there is an occurrence of data stability. The Delphi iterations utilized in this study encompassed three rounds, with the goal that carefully selected professionals will assist to attain consensus on the impact of factors of PPP risk management in the construction industry in Ghana. The Delphi questionnaire can be distributed via e-mail or personally to all experts involved, to answer the question with their experiences and expertise. The experts' answers from round one of the surveys are analyzed and the outcome served as a means to establish rounds two and three. Frequencies are utilized to measure the extent of consensus attained in view of participants in relation to factors that ascertain the PPP risk management model. The second round of the Delphi questionnaire are meant to give the professional panelists the chance to reevaluate their responses on the attributes that establish PPP risk management in the construction industry in Ghana. The third round, which happened to be the last, anticipated to inform the professional groups about the outcomes from the analysis conducted in round two; and seek their final opinions (confirmation) on factors to which agreement had not been attained, at the end of round two. The outcomes of the third round Delphi study seek to produce a number of main attributes and sub attributes for a given research enquires. The identified attribute formed the basis for the conceptual model for a given study.

4 Conclusion

The Delphi approach is discussed as a globally accepted and trustworthy research method, in which professional members respond to a series of questions in three iterations to reach agreement in recognising the criteria and indicators that impact successful risk management execution for PPP construction projects in Ghana. The method was used as the primary means of determining the criteria and indicators that influence the successful implementation of risk management in PPP construction projects because it is intended to eliminate potential bias associated with professional meetings, as opposed to other decision-making methodologies. As a result, based on the assertion of the outlined protocol, it is recommended that the use of Delphi methods as tools for PPP risk management in construction projects employ well-formulated questionnaires, as questionnaires are essential to the Delphi method. Once again, it is critical that the professional panelist understand the context in which the questions were designed. Similarly, stringent measures should be taken when selecting an expert to avoid compromising the procedure.

In addition, panel size must be determined based on a diverse range of backgrounds to ensure all-inclusive knowledge and know-how.

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Conceptual Design of a Sustainable Rainwater Harvesting and Treatment System

Chidozie Charles Nnaji[1,2](✉) and David Ezekoye[1]

[1] Department of Civil Engineering, University of Nigeria, Nsukka, Nigeria
chidozie.nnaji@unn.edu.ng
[2] Faculty of Engineering and Built Environment, University of Johannesburg, Johannesburg, South Africa

Abstract. In Nigeria, corrugated sheets make up more than 60% of rooftop catchments, indicating the tremendous potential of rainwater harvesting and treatment as a dependable source of drinking water. Rain Water Harvesting and Treatment is a sustainable approach that should be incorporated in urban water cycle management. It has the potential to reduce the external water demand in urban areas, alleviate water stress, lessen non-point source pollution, decrease the volume of treatable urban runoff, stop flooding, and aid in the mitigation of climate change. However due to the fears, concerns and misconceptions of people concerning rainwater and its cleanliness, it has become imperative to design a treatment system that ensure rainwater after contact with contaminants in the atmosphere and on catchment areas is still suitable and most preferred for drinking purposes. The Rainwater treatment system used in this study comprises of an Aluminum catchment, a first flush and conveyance system, storage system, a treatment system, a Rain gauge, an Electronic water level indicator and a nozzle controller. This treatment system which is made up of ceramic disinfector pellets of various particle sizes such that as rainwater goes through the pellets it serves as a filter and also a disinfector to ensure the Rainwater comes out drinkable. This system is cost effective, it is easy to install and maintain and can be operated with little or no training and as such it is suitable for use in rural areas.

Keywords: Rainwater harvesting · Roof · Contamination · Water supply · Treatment

1 Introduction

Rainwater harvesting and treatment is a water conservation strategy that is particularly helpful in regions where other water resources are limited or challenging to access. This approach could be crucial in the future management of water resources in the rural areas of Nigeria and may offer a feasible solution to the problem of urban water stress. In addition to reducing the demand for primary water supply, rainwater source control can also provide a chance to reduce energy consumption and associated emissions (and wastewater to be treated) [1].

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The need for water is growing as a result of growing population, changing lifestyles, and the effect of climate change is becoming more vivid by the day. Water is more scarce and demand is typically higher in arid climates where many people live and work. An effective RWH&T system will significantly reduce the dependency on the mains water supply. Reducing the amount of mains water supplied will therefore result in less water being drawn from lakes, rivers, and aquifers, leaving more water available to improve the ecosystem and support the aquatic environment [2].

RWH&T systems can lessen the chance of floods and pollution by releasing less rainwater into drains, sewers, and ultimately rivers. When there is a high flow of water, they can help to slow it down and relieve the strain on the drainage systems. Rainwater harvesting is frequently used in sustainable drainage systems (SUDS). SUDS increase the retention and control of surface/storm water, which lowers the danger of flooding [3].

2 Literature Review

Since corrugated sheets make up more than 60% of rooftop catchments in Nigeria, RWH has a significant potential for being a dependable source of potable water. The community streams in Akufo, a hamlet in Ibadan, Nigeria, where rainwater exploitation was explored as a water source, were extremely filthy and sick; as a result, rainwater was viewed as a practical option in the construction of a community water supply network [4].

Moreover, [5] has researched the difficulties with RWH in Nigeria and determined that storage facilities were inadequate. In six rural villages in Nigeria, samples of rainwater were taken from thatch, aluminum, asbestos, corrugated iron roofing sheets, and open surfaces from catchment roofs. The potability of these samples was evaluated. In the rural areas, they discovered rainwater characteristics that were less than ideal, as the majority of the physicochemical and biological traits of the rainwater samples fell below the WHO criterion.

Therefore, this study is aimed at developing (designing and constructing) a sustainable, cost effective and portable rainwater harvesting and treatment system/technology that guarantees domestic water supply in the rural areas and urban areas of Nigeria with a view to reducing the water shortage problem.

3 Materials and Methods

3.1 Rain Water Harvesting and Treatment System Components

The RWH&T System collects roof runoff, provides water quality treatment and uses enough head to send the water to the secondary storage/distribution system.

The RWH&T system is comprised of five key components:

Catchment Surface – The roof of the mode RWH&T system provides the surface area for rainwater collection.

Conveyance System – This consists of gutters, downspouts, and piping that transport water from the roof to the primary storage, through the ceramic disinfector, and finally to secondary storage.

First Flush Device - This mechanism prevents the "initial flush" of rain from entering the storage tank. It is a quality control mechanism designed to keep pollutants that have accumulated on the roof from entering the system.

Water Storage – For the purpose of this design two storage tanks will be used above ground. The first storage, acting as the primary storage will be used to store the rainwater from the roof and it will be fitted with a water level indicator. The second storage acting as the secondary storage will be used to store the treated water.

Ceramic Disinfector – The filtration and treatment system is made up of clay mixed with rice husk and grog and infused with silver nitrate. The Ceramic disinfector pellets are installed in the disinfector compartment, just after the primary storage.

Recording Rain Gauge - The Tipping bucket rain gauge is used to automatically record the amount of rainfall received in the proposed area for a given time period (Fig. 1).

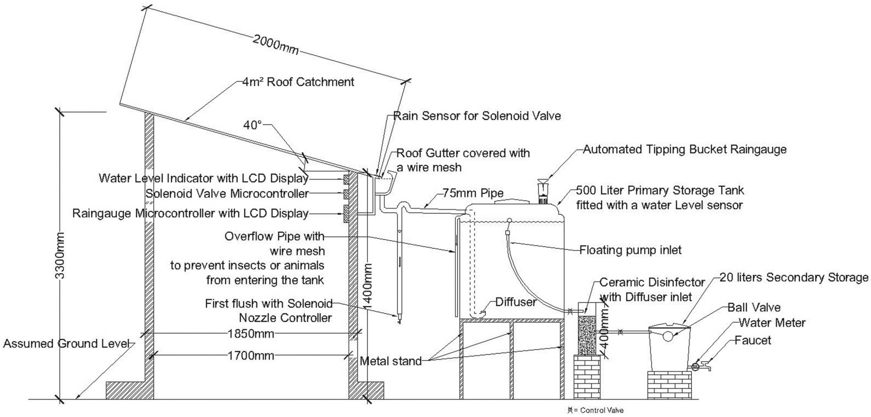

Fig. 1. Cross section through the RWH&T model system

3.2 The Catchment Surface

For the purpose of this design, the model catchment was constructed with aluminum roofing sheets. A Catchment area of 4 m^2 was used for this design model. This catchment was designed to meet the daily water demands for a family of 1 person for a year. According to [6] annual rainfall in the South Eastern part of Nigeria ranges from 1400 to 2700 mm. Hence, the catchment was designed with the maximum value of annual rainfall. The Catchment was designed to have a slope of 2:1, pitch of 7:12 and a slope factor of 1.1577.

The Runoff Coefficient (RC) is a dimensionless number that calculates the amount of rainfall that actually turns into runoff after accounting for spillage, leakage, surface wetting, and evaporation losses [7]. The RC is therefore helpful for estimating the potential water that may run off a surface and be transferred to a rainwater storage system (Table 1).

3.3 Interception and Conveyance System

This is the network of pipes, gutters, and downspouts that is used to transfer water from the roof to the primary storage, through the ceramic disinfector and then the secondary cistern. A PVC gutter covered with a screen was used to channel rainwater from the roof to the primary cistern. In order for the Interception and Conveyance System to function effectively, it was essential to be able to intercept the maximum quantity of water from the catchment, minimize transmission losses from the gutter to the cistern, and get rid of standing water, which may easily turn into a mosquito breeding ground.

Table 1. Runoff coefficients for different roof materials

Roof	Runoff coefficient (RC)	References
Roofs (in general)	0.7–0.95	[8]
Sloping roofs		
Concrete/asphalt	0.9	[9]
Metal	0.95	[9]
	0.81–0.84	[10]
Aluminum	0.7	[11]
Flat roofs		
Bituminous	0.7	[11]
Gravel	0.8–0.85	[9]
Level cement	s0.81	[10]

3.4 First Flush Device

The First flush system in this study was completely automated with a nozzle controller. It was designed to temporarily store and then automatically expel the first water that flowed off the roof following each rainstorm occurrence. Since the catchment surface may gather bird droppings, garbage, and other contaminants, the "initial flush" of water was directed to an area outside of the storage system.

A first-flush diverter is a necessary component of a RWH system for drinkable water. The first flush can be separated primarily using one of four techniques: manual, fixed volume, fixed mass, and flow rate. But for the purpose of this design, a fixed volume first flush device controlled by a solenoid nozzle sensor was used. The first flush was bent upwards along the pipe length to ensure the raw water does not escape into the primary tank. The size and length of the downpipe utilized were used to calculate how much water was directed to the first flush device. The first 1mm of rain on your roof is a “rule of thumb” on how much of the initial water to divert. Therefore:

i. Since the roof area is 4 m^2.
ii. One liter of water is produced by 1 mm of rain on 1 m^2 of roof.
iii. So, the first flush for the roof catchment should be 4 L + 10% factor of safety = 4.4 L = 0.0044 m^3
iv. Therefore, for a 3 in. pipe, the depth of the pipe should be 0.96 m (Fig. 2).

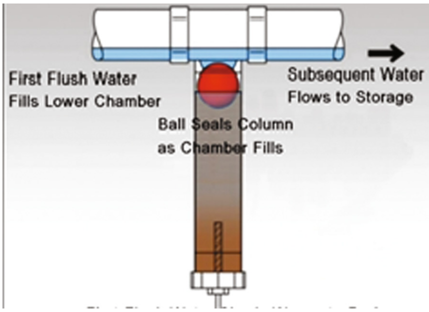

Fig. 2. Cross section through a fixed volume first flush device

3.5 Water Storage/Cistern

The most crucial and expensive part of the rain harvesting system is the storage cistern. For the sake of this design, Polyvinyl Chloride (PVC), a non-corrosive cistern material designed for longevity, was utilized since it will not rust or experience corrosion during its service life as will metal and concrete. PVC storage tanks are portable and simple to handle. They are often produced as a single unit. They do not have any sealants used to bind any component of the cistern together, nor do they have any joints or seams where pieces of the cistern have been welded together. Additionally, PVC storage tanks can be recycled once their useful lives are over.

The rainwater cistern used for this study was carefully placed and covered to prevent leaves, dust, insects, vermin, and other agricultural or industrial contaminants from contaminating the water. Diffusers/Strainers were installed at the inlet and outlet of the primary storage tank so as to screen the incoming and outgoing water. When given some time to sit inside the cistern, relatively clean water will typically get cleaner. When the water is reasonably clean, bacteria that enter the cistern will quickly die off. Algae growth was avoided by using a black cistern and keeping the cistern sited in a shady spot so as to keep the water cool. Additionally, a water level sensor was employed to provide a real-time reading of the water level in the main storage tank.

3.6 Cistern Design

The main calculation carried out was to accurately size the water tank to provide enough storage space. Several interconnected aspects that were considered together led to the storage capacity. They consist of:

i. The amount of rainfall available for use, as well as local rainfall data and meteorological patterns.
ii. The roof size.
iii. Runoff coefficient (value varies from 0.5 to 0.9 depending on the type of roof and slope).
iv. The number of users, consumption rates, or the daily water needs of the household.

All but the first of these factors can be controlled to some extent. The method of capturing rainwater, i.e. whether the system will give a full or partial supply, also influences the components and the sizes of the system. The tank is sized using a number of different techniques. The sophistication and complexity of these techniques varies. Others require computer software and expert engineers who are familiar with the software, while some can be easily completed by relatively novice, first-time operators. The following factors will play a significant role in determining the method used to design system components:

i. The complexity and scale of the system and its parts.
ii. the accessibility of the equipment needed to use a specific method (e.g. computers).
iii. The expertise and the level of education of the operator/designer.

It is also important to size the reservoir correctly in regions with low rainfall or variable rainfall distribution. There will be a surplus of water during some months of the year and a deficiency at other times. If there is insufficient water available all year to meet the demand, then enough catchment and storage will be needed to get through the dry spells. This will be done carefully to prevent unforeseen expense because storage is pricey. However, the following is a condensed method.

Supply Side Approach

i. Number of expected users: 1 person
ii. Consumption per day: 50 lpcd
iii. Total Demand: 50 L per day
iv. For a year the total water demand = $50 \times 365 = 18{,}250$ L per year
v. Supply:
vi. Roof area: 4 m^2
vii. Runoff coefficient (aluminum roof): 0.7
viii. Average annual rainfall: 2700 mm per year = 2.7 m per year
ix. Water available annually (assuming all is collected) = $4\ m^2 \times 2.7\ m \times 0.9 = 9.27\ m^3$
x. Daily available water = 9.27/365 = 0.0267 m^3/day or 26.7 L per day. This amount of water is only about 50% of the basic water demand of 50 lpcd. Hence, the roof area needs to be increased to meet the basic water demand. The minimum roof

area per capita (person) required to harvest enough water to meet basic demand is 7.51 m^2 per capita. The implicit assumption is that there is uniform distribution of rainfall all year round, which is far from reality. If that was the case, a minimum storage of 50 L would have been adequate. Since this is not the case, a storage system is needed.

Demand Side Approach

The demand side approach will be utilized to calculate the maximum storage needed based on consumption rates and building occupancy.

i. Consumption per capita per day, lpcd – 50 L
ii. Number of persons, n = 1
iii. Longest average dry period – Assume a period of 15days
iv. Annual consumption = lpcd × n × 365 = 18,250 L.

Storage requirement, T = (18,250 × 15)/365 = 750 L. This storage should be enough to hold water for the length of dry days specified but will not be able to serve during the dry season which lasts for about four months. Besides, there will be water spill any day the rainfall amount exceeds 0.74 cm. An optimization approach with cost-benefit analysis is the most preferred method for the purpose of sustainability and cost minimization.

3.7 Ceramic Disinfector

For the purpose of this design, ceramic pellets were employed for filtration and water treatment. The ceramic pellets were manufactured with a mixture of good plastic clay, sawdust, grog, silver nitrate and water. The Ceramic disinfector compartment was located just after the primary storage. First, the dry clay sample was obtained from the Ceramic Studio, Department of Fine and Applied Arts, Faculty of Arts, University of Nigeria, and passed through a 22-mesh sieve. Grog was also utilized to increase the flow rate of water through the final filter and avoid shrinking of the ceramic disinfector during drying and firing. When clay bricks that were broken or rejected after primary production are ground, grog—which is clay that has already been fired—is produced. The ceramic disinfector was manufactured by combining 5.89 kg (73.7%) plastic clay, 1.90 kg (23.8%) rice husk, 196.8 g (2.46%) of grog and 0.11 g (0.001045%) of $AgNO_3$. Silver nitrate is a known bactericide. Once the clay, rice husk, and grog were thoroughly combined and thoroughly mixed with the hands, silver nitrate was prepared by combining it with a small amount of water and adding to the mixture. Water was then added gradually until the mixture had a consistent paste. Rubber gloves were worn during this mixture to avoid the black coloration of the hands by $AgNO_3$. Mixing silver nanoparticles into the clay mixture prior to firing has been found to increase silver retention in the ceramic disc filter and may result in a longer lifespan when compared to filters made using the silver microparticle approach, which release silver at high levels immediately during early use [12]. The amount of silver in the ceramic also affects how well the filter works.

After reading multiple articles where ceramic filters were made with various ratios of clay, sawdust, and grog, this combination of materials were chosen. Higher clay content fired ceramic filters displayed a comparatively low value of hydraulic conductivity and, as a result, an intolerably low flow rate, whereas higher rice husk content fired ceramic filters were brittle and readily shattered.

After mixing, the mix was then separated into 90 small portions, molded by hand, left to air dry for more than 24 h and then fired in the Kiln at a temperature of 900 °C for another 4 days. The rice husk in the filter is burned during this process, creating a porous, water-permeable ceramic substance.

Firing the Clay mixture at such high temperatures will allow for:

(1) the complete dehydration of the clay and
(2) the vitrification (chemical alteration) of the clay to create the final disinfector component.

After firing, the ceramic disinfectors were then cooled, crushed and sieved with sieve numbers 12 and 6. A normal filter lifespan is two to three years; to preserve the specified flow rate, it will be frequently cleaned with a brush. Next, the ceramic disinfector pellets will be inserted into the disinfector compartment which is inclined at 90° to enable flow by gravity, also one-way valves will be installed just before and after the ceramic disinfector to ensure there is no backflow.

3.8 Recording Rain Gauge

One of the major problems associated with water supply in developing countries is lack of adequate data for planning and implementation. Since the annual rainfall used here is a generalized value for Southeastern Nigeria, there is need to determine the actual amount of rainfall in the proposed location of the setup in order to validate the assumptions made. Hence, a tipping bucket rain gauge was built from scratch using locally sourced materials, electronic components and sensors, it was used to automatically record the amount of rainfall received in the proposed area for a given time period. It provides a continuous reading of rainfall depth and time (Table 2). To avoid interference from the surrounding the rain gauge was kept twice the distance away from the height of the nearest obstruction. It was placed 250mm off the top of the tank to prevent splash back. The tipping bucket rain gauge was designed and used alongside the RWH&T system so as to produce a unit hydrograph.

4 Results and Discussion

The rainfall recording of the rain gauge was compared with the standard gauge at the Department of Geography and the result is presented in Fig. 3. Although there are differences in the results of the two instruments, analysis of variance reveals that there is no appreciable difference between the recorded rainfall values of the standard gauge and the one produced in this study [$F\ (2.3) < F_{cr}\ (3.9)$]. However, the total volume of rainfall recorded by the test gauge over the period of comparison was about twice that recorded by the standard gauge. Hence, there is need for further validation before deployment of the unit.

Table 2. Component of the recording rain gauge

S/N	Materials	Function
1	Arduino Uno	It is an open-source electronic hardware board designed to read input and turn it into output. This is accomplished by instructing the board by delivering a set of instructions (a program) to the microcontroller on the board. Programs are designed using the Arduino programming language and the Arduino software or IDE (Integrated Development Environment). In the rain gauge it reads each bucket tip and converts the tips to rainfall amount (in millimeters) according to the calibration employed
2	16 × 2 LCD display	For displaying rainfall reading
3	Plastic box	–
4	LED's (red 2, yellow 2, green 2)	Switch, current and battery indicators
5	RTC module	Real Time Clock module is a time electronic system that timestamps all recorded data so that we know the exact day, hour, minute and second each data record took place
6	Bread board	Plastic board with tiny holes for holding electronic components to build an electronic circuit
7	Hot glue gun	Alternative to soldering iron
8	Data logger shield	Electronic system that receives and saves data (rainfall data in this case) on an SD card
9	Memory card 4Gb	For storage of rain data later to be retrieved via computer
10	PCB	Printed Circuit Board electrically connects electronic components and holds them fast to the board
11	Resistor – 220 Ω	To control electric current
12	Screw	–
13	Toggle switch - 1 no	For breaking or connecting circuit
14	Variable resistor - 10 kΩ	Current control
15	Connecting wires	For connecting electronic components

5 Conclusion

Following the need to design a sustainable rainwater harvesting and treatment system that is durable, affordable, efficient and easy to maintain this system was fabricated. It is self-sufficient and it requires little or no training to operate this system. It is the future

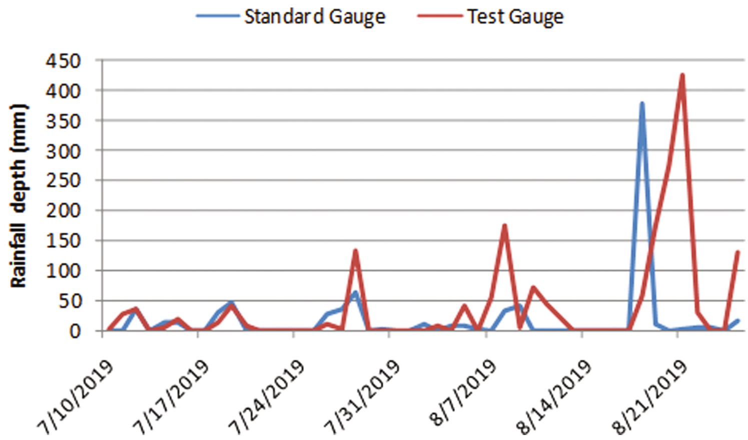

Fig. 3. Rainfall comparison chart between standard RG and designed TBRG

of water conservation in both Rural and Urban areas. The rainwater that will be treated by this system is expected to meet WHO's drinking standard and be as clean as nature originally intended it to be. The incorporation of a locally fabricated rain gauge is an innovative idea which requires fine-tuning and further validation before deployment.

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Compressive Strength and Water Absorption Capacity of Clay Bricks in South Africa

Bonga Khuzwayo(✉)

Department of Civil Engineering and Geomatics, Durban University of Technology, Durban, South Africa
bongak@dut.ac.za

Abstract. Some masonry unit manufacturers and suppliers make available to the public the compressive strength and water absorption capacity of burnt clay masonry units, as designers frequently request them. For this study, the compressive strength and water absorption capacity of several commonly used burnt clay bricks in South Africa were determined. The clay brick samples came from all over South Africa, but predominantly Durban (KwaZulu Natal). There were 37 different types. Seventeen were solid and twenty were perforated bricks. An analysis of the relationship between the compressive strength and water absorption capacity of solid clay bricks revealed that compressive strength increases as water absorption capacity decreases. This finding corroborates prior research indicating that a decrease in compressive strength results in an increase in water absorption. Correlation analysis between the capacity of perforated clay bricks to absorb water and their compressive strength revealed no significant relationship between the two. This is unsurprising, given that the compressive strength of perforated bricks decreases proportionately to the reduction in solid cross-sectional area. The study discovered that the type of brick affects the water absorption capacity after examining the effect of size (perforated versus solid) possibly, because they were unmatched low or high porosity burnt clay masonry units.

Keywords: Clay units · Water absorption · Compressive strength

1 Introduction

Many construction projects use clay masonry walls for various purposes. In addition to compression strength, they may be required to provide stability, fire resistance, weather resistance, thermal insulation, and sound insulation [1]. Good quality masonry is a durable building material [2]. Sadly, low-quality materials, poor building and design practices, inadequate knowledge and training, and poor workmanship plague the industry today. These flaws cause premature depreciation of building assets, discouraging financial institutions from refinancing them. Some building merchants disclaim responsibility for performance or standard compliance. The fact that some manufacturers choose to produce a substandard product with no quality assurance disadvantages the diligent manufacturers. Lack of standard enforcement exposes the public to potentially substandard

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building materials and uncertainty. Poor knowledge and training lead to poor practices. In addition to the above, poor masonry walling and mortar joints necessitate investigation to determine structural soundness [3]. Due to a lack of skilled labor and frustration with a partially regulated industry, developers are turning to alternative building systems like lightweight steel frame buildings and expanded polystyrene components. Others have poor thermal inertia, corrosion issues, and premature deterioration. Employers lose jobs as the industry shifts from labor-intensive construction methods to faster systems that require less workers. This goes against the South African government's plans to use labor-intensive construction methods [4]. Material testing is required to ensure high quality and regulatory compliance. Material testing has many advantages for companies selling reliable products and clients investing in long-lasting structures. The process determines whether a material is suitable for a given application, certifies it to a National Standard or specification, or shows it meets other stringent criteria before use. Material testing is compatible with ongoing product validation. Because the process is critical to ensuring the material's safety and reliability, as well as minimizing potential damages and costs, it is used in both the design and manufacturing processes. As for any construction material, especially those that are commonly used, such as burnt clay bricks in the South African Construction Industry, and can be procured easily in either poor or good quality, or even unknown quality, it is essential to continuously evaluate its quality for public knowledge and advocate for necessary improvements. The aim of this study is to determine the compressive strength and water absorption capacity of several commonly used clay bricks in South Africa in order to make recommendations for improvements to the masonry industry. The objective is to figure out how compressive strength and water absorption capacity relate to one another, as these are the two most commonly requested properties by engineers for design purposes.

2 Characteristics and Properties of Clay Bricks

According to Karaman et al. [5], the compressive strength and water absorption are two significant physical properties of clay bricks that are excellent predictors of the brick's resistance to face cracking. According to Agbede and Joel [6], bricks are classified according to their average or minimum compressive strength as well as their water absorption percentage. Water absorption is a parameter that indicates available space expressed as a percentage of the dry brick mass. When a brick's density reduced, its strength and heat conductance reduces, while water absorption increases. With an increase in firing temperature (700–1100 °C), the strength of bricks increases and water absorption decreases. According to Maheri and Sherafati [7], the amount of water absorbed by the brick has an effect on the bond strength because it determines the amount of water transmitted from the mortar to the brick. This regulates the extent to which the mortar hydrates and the amount of hydration products transported and deposited in the masonry pores. According to Ukwatta and Mohajerani [8], bricks' water absorption properties are critical in determining their durability and according to Eliche-Quesada et al. [9], water absorption is a key factor affecting the durability of bricks and is an indirect measure of open porosity. The increased water absorption values result in significant volume changes, which eventually result in the formation of cracks in the clay bricks. Reduced water absorption values, on the other hand, are undesirable because rainwater will quickly absorb through the mortar joints and enter the building, rather than absorbed by the bricks partially. As a result, the mortar joints would be less durable [10]. As a result, water absorption should be closely monitored, with acceptable values not exceeding 17% for severe weathering resistance bricks, less than 22% for moderate weathering resistance bricks, and no limit specified for negligible weathering resistance bricks (ASTM Standard C 62-01 2001). Open porosity plays a role by increasing the absorption capacities of clay bricks [11]. Riaz et al. [12] determined that the inclusion of Brick Kiln Dust (BKD) marginally reduces the mechanical strength, which in turn increases water absorption capacity. There is a close relationship between water absorption and apparent porosity of bricks. The more porosity, the more water absorption [13].

Brick Development Association [14] recommends a minimum compressive strength of bricks 3.5 MPa, and water absorption should not exceed 20% and according to Gencel et al. [15] the Brazilian standard, NBR 6480, recommends that the water absorption value not to be more than 22%. The porosity is a critical parameter that affects a variety of brick characteristics and its increase result in an increase in water absorption capacity, while bulk density and compressive strength decrease. Jahagirdar et al. [16] noted that a large number of voids emerge within the bricks' bodies. As a result, the brick structure becomes porous, resulting in decreased compressive strength and increased water absorption. A study by Eliche-Quesada et al. [9] determined that the incorporation of urban sewage sludge, brewing industry sludge, and bagasse in the body clay increased the number of open pores, as indicated by the water absorption data and the scanning electron microscope micrographs, thus decreasing the compressive strength and slightly increasing the thermal insulation properties of the bricks. Lingling et al. [17] found that the fired bricks with high volume ratio of fly ash were of high compressive strength and low water absorption. Nelson and Malumbela [18] compared the compressive strength of concrete and burnt clay masonry bricks from large-scale manufacturers who either had their products certified by the Botswana Bureau of Standards (BBS) or indicated their strength. In the study's nine product sets, only three met BBS standards, and four of the six that did not were two classes below the manufacturer's claims. The findings concluded that users of masonry units in Botswana receive inferior products, jeopardizing public safety. There are two types of clay bricks: solid and perforated. The axial load to bed joint (normal loading) decreases as a percentage of solid cross-sectional area when comparing solid and perforated bricks. In practice, the increased quantity of clay body usually compensates for this [19].

When flexural strength of solid bricks compares to that of perforated bricks, there is no evidence of a reduction in the strength of masonry with a perforation percentage of up to 25%. Due to the keying effect of mortar in the perforations, slight increases enhances vertically spanning masonry. This may shift the mode of failure of bricks from shearing to snapping, particularly in the presence of large central perforations [19]. Comparing solid bricks and perforated bricks for shear strength, the pro-rata reduction in unit strength between the two types of bricks is evident at the failure line. This could have an effect on the shear strength of masonry resulting in a reduction in the strength of the bonded connection. Additionally, heavily perforated units may reduce the performance of reinforced masonry beams and shear walls. However, this is insignificant in terms of domestic loading levels [19]. Rain penetration is comparable to solid bricks when compared to perforated bricks. The use of raked joints increases the risk of rain penetration in all masonry structures exposed to moderate or severe weather [19]. As a result, the thermal resistance of the brick leaf went up by up to 100% for bricks with 25% perforations and by up to 200% for bricks with 35% perforations. This still only meets about 20% of the resistance requirements for a typical cavity wall. Large holes and slots are inefficient, especially if they cross from face to face. Numerous staggered holes or slots provide the best performance [19]. When comparing the durability of solid bricks and perforated bricks, there is no evidence of a significant difference in frost resistance or efflorescence damage to the bricks themselves, or sulphate attack on mortar in walls, between 'equivalent' solid and perforated bodies [19]. Because perforated bricks are lighter, it is easier to move and lay them on the ground than solid bricks. Units with a high perforation count are more delicate and require careful handling to avoid excessive wastage [19]. Objective of the study: The study investigates the compressive strength and water absorption capacity of some of the most frequently used clay bricks in South Africa with the intention to assess and make informed suggestions to improve the masonry construction industry.

3 Method and Results

Procuring clay units from the manufacturers or suppliers: The clay specimens were purchased from the manufacturers and suppliers across SA, but predominantly Durban (in KwaZulu Natal). Some specimens were obtained as far as Cape Town and Pretoria. Manufacturers and suppliers were identified through internet search and by physically visiting industrial hubs with crowded hardware shops. Upon identifying suitable specimens, 10 specimens of each type were purchased, provided the first author had not purchased the same from another supplier. Identical specimens were purchased if they came from a different quarry or had a different colour compared to the specimens already procured. A receipt (proof of payment) was obtained for every specimen purchased to complete this study. A total of 37 different types of specimens were attained ranging from emerging to established entrepreneurs/manufacturers/suppliers. 17 clay bricks were of solid type and the other 20 were perforated (systematically). Water absorption test method to SANS 227: Clause 6.9 of SANS 227 [20] requires three (3) apparatus to conduct the water absorption test, namely: a forced-draught drying oven capable of maintaining a temperature of at least 105 °C; a lidded heating tank with a grid at the bottom to allow circulation of water all around the units; and a balance capable of measuring the mass of units to an accuracy of 0.1%. The procedure calls for drying of units in an oven at a temperature of at least 105 °C until a constant mass (m_1) is achieved. The specimens are then immersed in clean water for 24-h (commonly known as the immersion test), maintaining a room temperature between 22 and 25 °C. At completion, the specimens are removed, excess water is wiped off with a damp cloth and immediately measured for the mass (m_2) again. After the 24-h immersion test, the specimens are placed on a grid inside a tank. The water temperature is raised to boiling over a period of 1 h and maintained at a boiling point for 5 h (commonly known as the 5 h boiling test). The tank is then switched off and the water in the tank with specimens is allowed to cool naturally between the 16–19 h. The specimens are then removed, wiped with a damp cloth and measured for the mass (m_3). The water absorption capability is calculated in accordance with clause 6.9.4. In consideration of the requirements for apparatus used, area of bed-face, preparation of test specimen, procedure and calculation of the ultimate stress the sample can take, the compressive strength of clay bricks was tested in accordance to clause 6.6 of SANS 227. Correlation and regression analysis were launched to investigate the relationship between the compressive strength and water absorption capacity of clay units as well as the type (solid or perforated) effect.

4 Analysis and Discussion

Correlation analysis of solid clay bricks: The correlation coefficient (r) yielded − 0.536, and this is an inverse relationship with a high degree of strength. This means that as compressive strength increases, the capacity to absorb water decreases, and vice versa. Table 1 summarizes the results of solid clay bricks.

The findings corroborate prior research in the literature, which increases designers' awareness of the compressive strength and water absorption relationship in general. When a brick's density reduces, its strength decreases, but its water absorption increases [6]. Jahagirdar et al. [16] found that as the brick becomes more porous, the compressive strength decreases and the water absorption increases. According to Eliche-Quesada et al. [9], increasing the number of open pores results in a decrease in compressive strength, as indicated by water absorption data and scanning electron microscope micrographs. In other study by Lingling et al. [17], fired bricks containing a high volume ratio of fly ash had a high compressive strength and a low water absorption rate. The graph in Fig. 1 depicts compressive strength (N/mm^2) on the horizontal axis and moisture content on the vertical axis (%). Clay bricks typically contain a high proportion of microcracks, some of which are well visible to the naked eye. As a result, it is unsurprising to see scatted data. Nonetheless, the relationship is discernible.

Correlation analysis of perforated clay bricks: For perforated clay bricks, the correlation coefficient (r) yielded − 0.142 and this inverse relationship is not strong. Therefore, there is no significant relationship between water absorption capacity and compressive strength ($p = 0.586$). It does not come as a surprise because compressive strength for perforated bricks under normal loading (axial load to bed joint) decreases as a percentage of solid cross-sectional area reduction (Building Research Establishment 1983). We would later discover that the type of clay brick (perforated or solid) has an effect on the capacity of the brick to absorb water. According to this study, perforated clay bricks appear to absorb slightly less water than equivalent solid bodies. Table 2 provides a summary of the data.

Figure 2 depicts the compressive strength (MPa) and moisture content (%) graphically, indicating that there is no significant relationship between the two.

Effect Size: Although Building Research Establishment [19] reported that, there is no evidence that solid and perforated bricks with equivalent low porosity bodies perform differently. The study found that the type of brick has an effect on the water absorption capacity as indicated by Partial Eta Square of 0.114. This is possible because the solid

Table 1. Moisture content and compressive strength of solid clay bricks.

Sample number	Description	Solid (S)	Moisture content (%)	Compressive strength (MPa)
A11–A20	*Low Burnt	S	23	3
Z1–Z10	*Light Burnt	S	29	4.5
A1–A10	*Hard Burnt	S	22	6
Z11–Z20	*Hard Burnt	S	23	6.2
P11–P20	Brick NFX Foundation	S	15	9.9
P21–P30	Perforated Plaster Brick	S	11	12.3
G1–G10	Brick Clay Stock	S	18	12.7
L1–L10	Brick Solid Plaster NFP/NFX YD	S	20	13
G11–G20	Brick Verona	S	14	13.7
U1–U10	Brick Clay Stock/Rock Plaster	S	13	17
W1–W10	Plaster Brick Rok	S	11	18.2
E1–E10	Ocon Brick Clay Stock	S	20	20.4
G21–G30	Rock Plaster	S	13	20.4
P1–P10	Heritage Travertine Blend	S	8	22.8
X1–X10	Gold Rustic	S	18	28.9
V1–V10	Brick Clay Rok NFP 7 MPa Cabrico	S	17	31
V1–V10	Brick Clay NFX 14 MPa Cabrico	S	12	43.9

and perforated bricks examined do not have comparable low or high porosity bodies. The type of brick has a small or minimal effect on the Compressive Strength as indicated by Partial Eta Square of 0.018. With respect to the compressive strength, whilst in theory the strength of bricks will tend to fall with increasing percentage perforation, in practice this is compensated by an increase in density of the clay body as a result of the de-airing process. As reported by Building Research Establishment [19], vertical perforations have less effect on strength than voids introduced as random pores. All perforated bricks used in this study had similar perforation pattern for each type of specimen.

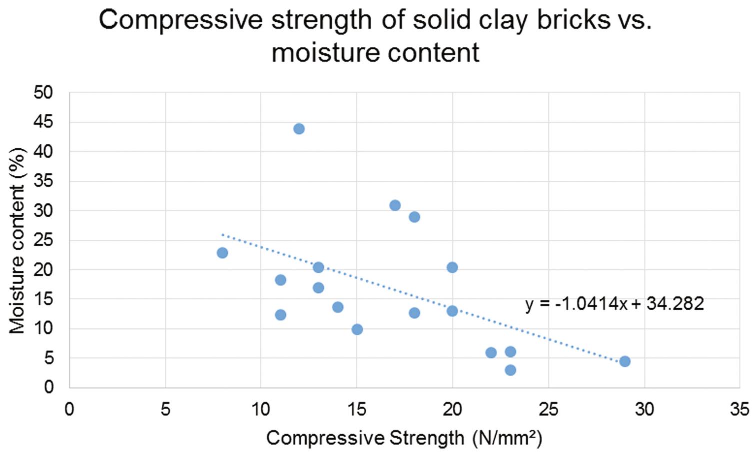

Fig. 1. Compressive strength and moisture content of solid clay bricks.

5 Conclusion and Recommendation

In this study, we investigate the compressive strength and water absorption capacity of clay bricks in Durban (KwaZulu Natal), South Africa. No two clay brick, solid or perforated, are exactly alike. The correlation between compressive strength and water absorption capacity of solid clay bricks revealed a relationship between the two. This finding supports prior research linking compressive strength loss to water absorption. Because clay bricks lose compressive strength as they become more porous, they can absorb more water. The water absorption capacity and compressive strength of perforated clay bricks did not correlate significantly. This is not surprising, as perforated brick compressive strength decreases with solid cross-sectional area. The study discovered that the type of brick has an effect on the water absorption capacity. This could be because the study used clay bricks with varying porosities. Notably, the Building Research Establishment [19] found no evidence for comparable low porosity clay bodies. The study used perforated bricks with a similar perforation pattern for each specimen type, so the type of brick had little or no effect on the compressive strength. The study's practical implications call for regular compression and water absorption testing of units. A high-water absorption capacity could lead to durability issues with low strength burnt clay masonry units. The type of clay units with regard to the composition of the materials and the testing procedure serves as the limitation for the study.

Table 2. Moisture content and compressive strength of perforated clay bricks.

Sample number	Description	Perforated (P)	Moisture content (%)	Compressive strength (MPa)
C1–C10	Brick Face Catchcarth	P	14	6.7
T1–T10	Foundation Coro Maxi 90 NFX	P	13	8
D1–D10	Plaster Coromaxi 90 NFP	P	14	8.4
T21–T30	Plaster Coromaxi 90 NFX	P	13	8.9
U1–U10	Brick Cameo Rosso Light	P	20	10.2
Y21–Y30	Brick Firelight Satin-RP001	P	11	10.4
Y11–Y20	Brick Common Clay Stock	P	18	12.5
X21–X30	Choc	P	12	13.3
V1–V10	Brick Rok NFP 7 MPa Corobrick (with holes)	P	17	13.8
W1–W10	Brick Rof NFP Plaster Perforated (600pp)	P	13	14
E11–E20	Cameo 1 Face Brick	P	21	14.4
P11–P20	Stock - NFP Plaster Bricks	P	20	14.9
X11–X20	Nala Travertine	P	11	15.2
T11–T20	Opal Satin	P	11	15.7
E21–E30	Bergendal Satin Bond	P	14	16.2
C11–C20	Brick Face Roman Barley	P	11	18.2
Y1–Y10	Brick Clinker Nanxing Yard	P	15	18.8
D11–D20	Coro Mega	P	11	19.3
P21–P30	Red Rustic (SAB)	P	14	21.4
P1–P10	Blue Rock Face	P	11	24.4

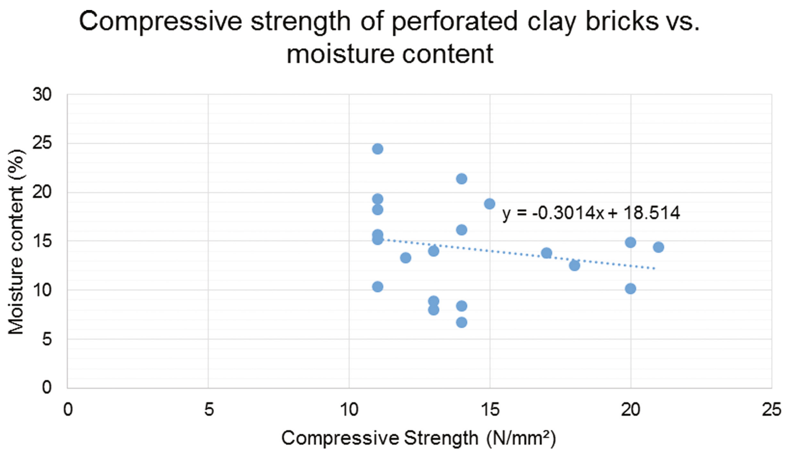

Fig. 2. Compressive strength and moisture content of perforated clay bricks.

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Enabling Legislative Coherence in the Eswatini Construction Industry: A Conceptual Framework

Thandiwe Hlatshwayo, Fidelis Emuze(✉), and John Smallwood

Nelson Mandela University, Gqeberha, South Africa
femuze@cut.ac.za

Abstract. This is a conceptual paper from a doctoral study. The literature-based paper is related to the coherence of the legislative framework, designed for the regulation of the construction industry of Eswatini. The construction industry has been criticized for ineffective regulation The argument for improved regulation in the construction industry is based on the sentiment that if the industry is left unchecked, the sector would suffer gross inefficiencies, and lack of regulation will stifle innovation and development. Consequently, the construction industry would become less productive as the lead-time for projects would increase, the cost of construction would increase, and construction customers would be unsatisfied. This conceptual paper attempts to propose how to structure its regulatory framework to promote regulatory coherence. The issue is that the construction industry is complex and therefore requires that the regulatory framework be context-specific to align with the level of development. The conceptual paper will thus discuss 'coherence' to map out how to build a tailor-made regulatory framework to address regulatory issues in Eswatini and similar developing countries.

Keywords: Coherence · Construction · Regulations · Eswatini

1 Introduction

Effective regulation is necessary to address the issues of poor construction commonly cited in many developing countries, including Eswatini. Of the many complex characteristics of the construction industry, the key problem for regulation is that the sector is resource-and-capital intensive and involves many stakeholders during the long-life cycle of construction projects. This necessitates the identification and streamlining of issue-specific regulations to ensure maximum output and sustainability of the industry. Masurkar and Attar [1] emphasised that the quality of construction activities requires regulation over a continuum of processes such as design, detailing, drafting, material selection, quality workmanship, proper inspections, formwork, and factors such as geotechnical failures, technical failures, maintenance failures, ignorance, carelessness, negligence, and greed. Doloi et al. [2] asserted that these numerous construction problems have prompted many governments to resolve the regulation challenges by creating extensive national regulatory agencies to manage the construction industry. However, this approach

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is marred by its own challenges, as the agencies find it difficult to establish relevant and nationally acceptable regulations and standards for regulating their local construction industries. According to the highlights of the Organisation for Economic Co-operation and Development (OECD) [3], the realisation of coherent regulatory framework within multi-sectoral industries remains a challenge in most developing countries.

The lack of coherent policy development for the construction industry, which is the focus of the paper has led to unconducive business environment for the sustainable development of the industry. A coherent regulatory framework is necessary for effective and efficient regulation of the industry. This will remove barriers in doing business and in attracting foreign direct investment for the economic development of the industry and the country. In Eswatini, the construction regulatory framework is at an elementary stage as only the construction regulatory authority is in place being the Eswatini Construction Industry Council (CIC). And there are noted challenges in developing and finalising a coherent regulatory framework with the relevant stakeholders within the construction industry. In essence, this article presents a study that investigated the lack of a coherent regulatory framework within the construction industry of Eswatini.

2 Statement of the Problem

Despite the establishment of the CIC in 2013, the entity is still struggling to finalise the main legal framework for regulating the construction industry in Eswatini. To date, the stakeholders do not fully support or understand the role of the CIC in promoting the construction industry including the expected development outcomes. The main problem for Eswatini's construction sector is that the Government of Eswatini established the CIC without first identifying the key and unique problems of the construction industry in Eswatini as well as the legislative framework that would be necessary to address the unique problems of the industry in the context of the conditions in Eswatini. The CIC Act 2013 that established the construction industry regulator has not been supported with specific regulations that will provide guidelines on how to effectively regulate the specific components and processes of the construction industry that warrant regulation. The CIC produced a draft of the regulation in 2016, but to date, the endorsement remains pending. In effect, the lack of specific industry regulations over and above the CIC Act 2013 is impending effective regulation of the industry and limiting the development expected from having a regulator in the industry. The lack of legislative coherence is therefore hindering the performance of the construction industry in Eswatini.

To address the issue of ineffective regulation within Eswatini's construction industry, this research will assess the theories related to best practice on how to regulate specific construction problems. The purpose of this analysis is to examine the key systematic and fundamental issues of the construction industry in Eswatini that necessitate regulation and specific industry problems in the context of Eswatini. The investigation will define the composition and processes of the construction industry in Eswatini and identify the specific components of the industry that need prioritised regulation to improve the construction sector. The recommendations on best practices on how to regulate specific issues of the industry will be used as a starting point for developing the construction industry guidelines that are much needed by the industry to improve performance.

Having said the above, the statement of the problem can be summarised as follows:

(i) The CIC was established in 2013 and to date, the Council is still struggling with the enactment of a coherent regulatory framework.
(ii) The lack of coherence in the legislative framework of the Eswatini construction industry hinders the performance of the sector resulting in the country not deriving the maximum benefits from the industry.
(iii) With the fragmented and complex nature of the construction industry, a "one-size-fits-all" approach will not create a coherent regulatory framework. Eswatini is no exception to this critic.
(iv) To date Eswatini has not enacted regulations for the construction industry.

The Primary Research Question and Secondary Questions

Noting that the construction industry in Eswatini remains without approved industry regulations to regulate the processes of the industry, the main research problem is investigating the structure and components of the regulatory framework needed by the construction industry in Eswatini to ensure the effective delivery of its developmental mandate. The primary research question for the study elicits responses to how the Government of Eswatini needs to structure its regulatory framework in the construction industry and what type of regulatory framework would promote regulatory coherence in the construction industry in Eswatini to systematically address the pertinent issues that affect all stakeholders in the construction industry.

2.1 The Challenges Faced by the Eswatini Construction Industry

The Government of the Kingdom of Eswatini enacted the Construction Industry Act No 14 of 2013 which provides for the establishment of the Construction Industry Council and outlines its functions. The Council is now operational and implementation of the provisions of the legislation is underway. This means that the promulgations of construction regulations are still in the process. The construction industry is one of the key players in the economy of the country and the challenge is that it remains without a coherent legislative framework for the regulation of the industry. The Mission of the Council is, "To regulate, develop and promote the construction industry for the benefit of all stakeholders through transformation for sustainable growth, monitoring industry performance, research and empowerment, thus improving the socio-economic status of the country" [4].

The status quo within the construction industry is a serious cause for concern as it tends to create an unconducive business environment for the relevant stakeholders for the sustainable development of the industry. The CIC identified ineffective and inefficient regulation as a key factor impeding the performance of the construction sector in Eswatini [5]. One of the critical reasons for the delay in the endorsement of the regulations is the poor relationship between the regulator (CIC) and the stakeholders of the construction industry [5]. To improve the performance, and enhance the competitiveness of the construction sector, it is necessary to define empirically the key priority problems being faced by the sector that are impeding performance and to define a suitable regulatory framework that would best address the needs of the industry. No such study has been conducted in the Eswatini context and so the knowledge generated would provide the steps the CIC could follow to transform the construction industry to perform at a much higher level of production and productivity.

Effective regulation is necessary to address the issues of poor construction commonly cited in many developing countries, including Eswatini. Of the many complex characteristics of the construction industry, the key problem for regulation is that the sector is resource-and-capital intensive and involves many stakeholders during the long-life cycle of construction projects. This necessitates the identification and streamlining of issue-specific regulations to ensure maximum output and sustainability of the industry. Masurkar and Attar [1] emphasised that the quality of construction activities requires regulation over a continuum of processes such as design, detailing, drafting, material selection, quality workmanship, proper inspections, formwork, and factors such as geotechnical failures, technical failures, maintenance failures, ignorance, carelessness, negligence, and greed. Similarly, Doloi et al. [2] asserted that these numerous construction problems have prompted many governments to resolve the regulation challenges by creating extensive national regulatory agencies to manage the construction industry. However, this approach is marred by its own challenges, as the agencies find it difficult to establish relevant and nationally acceptable regulations and standards for regulating their local construction industries.

2.2 Methodology

This is a conceptual paper based on the review of literature related to the coherence of the legislative framework with particular attention to the construction industry of Eswatini. Therefore, the conceptual framework is not *sui-generis*, it is a preliminary stage for a doctoral study. This study is a critical review of relevant information related to the theory of coherent legislative framework. This paper is a review of related reviews, commentaries and results from empirical sources.

2.3 The Concept of Coherence in Regulatory Systems

The phenomenon that underpins this article is coherence in the regulatory framework, with particular attention to the legislative framework of the construction industry of Eswatini. Coherence has been referred to as a "property" that emerges when the linkages between both similar and distinct classes of legal concepts (norms, principles, values, or 'units of analysis') align conceptually with minimal friction or logical inconsistency [6]. Figure 1 displays the various components of the phenomenon of coherence in policy making. Coherence is a broad and well-established concept. According to Luhmann [7], regulatory coherence is also a theory of law examining how normatively founded political decisions charged with social control are institutionalised. It has been recognised that regulatory systems are not created in a vacuum; rather they are embedded with legal systems [8]. In the Australian case *of Miller v Miller*,[1] it was held that lack of coherence involves some kind of "incongruity" or "inconsistency" between legal rules. Therefore,

[1] (2011) 242 CLR 473.

the law must be narratively, normatively, and systematically coherent on all its levels to be truly coherent [7]. On the flipside of definitions, Raz has opined that what is incoherent is unintelligible because it is self-contradictory, fragmented, and disjointed. What is coherent is intelligible, makes sense, and is well-expressed, with all its bits hanging together [11]. Ruhl [15] opined that it has long been recognised that regulation may be conceptualised as a system-like construct of interdependent parts.

The normative dimension of coherence deals with theoretical and policy considerations determining the design of the regulatory systems [13]. The positive dimension is less abstract and deals with the implementation of normative policy choices by translating them into positive legal norms [8]. There must exist coherence between the legal system and the society it leads to, otherwise, incoherence between the two (2) leads to a loss of faith in law and law's legitimacy [9]. While the attribute of coherence remains the same for both legal and regulatory coherence-that is, frictionless, aligned relationships - legal coherence focuses on the relationships between facts, rules, and decisions while regulatory coherence focuses on the relationships between the components and process of regulatory systems [8]. Feaver [9] argues that coherence draws attention to the unique characteristic of regulation. According to Forster and Stokke [10], regulatory coherence enables policymakers to avoid basic problems arising from poor regulatory design including policy incoherence, systematic fragmentation and ultimately, regulatory failure.

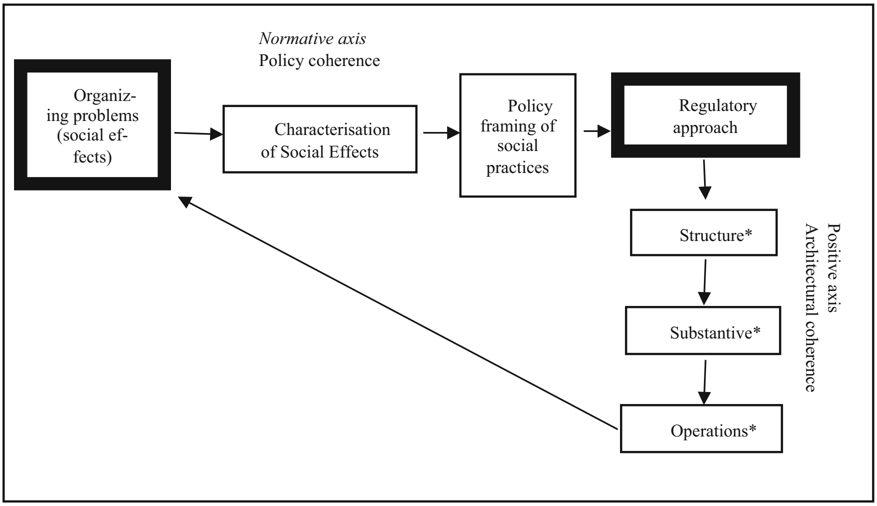

Fig. 1. A model of regulatory coherence based on Feaver and Durrant (2008).

2.4 Designing Effective Regulation and the Significance of Coherence in Legislative Framework

Generally, most industries with their relevant stakeholders have designed coherence legislative framework to ensure a sound and conducive business environment within their respective industries [12]. Whilst others in developing countries are still in the process of developing the legislative frameworks to regulate the relevant industries. Some countries remain without effective regulatory mechanism for their respective industries. Eswatini is no exception as already alluded to above in particular in its construction industry. Therefore, there is an urgent need for those countries without a coherent legislative framework for their industries to design and develop a coherent regulatory regime to fully partake in the global economy [12].

Regulation that is ineffective in meeting its objectives can be just as harmful to government, businesses, and consumers through unintended consequences, as no regulation or over-regulation [8]. Put differently regulation that is not coherent and fails to achieve its objectives is a recipe for disaster or failure for all stakeholders which is the same as not having proper regulation in place. Reference [6] states that the question of whether to regulate is usually viewed as a political decision that involves identifying and determining if a social problem is sufficiently important to warrant a coordinated response. In addition to being political, decisions about regulating human behaviour are usually highly ideological decisions. Conversely, the rationalist approach asserts that an objectively determined, pre-existing problem should be identified and analysed using deductive reasoning consistent with the scientific method leading to a consensus-based rationally generated solution [8].

Ideally the above is the conventional approach towards effective regulation of any industry which presupposes that the need for regulation must exist, be determined and analysed in line with the relevant scientific approach and consultation with all relevant stakeholders in order to achieve a consensus-rationally based effective regulations for the respective industries. In essence the above is necessary in designing a coherence legislative framework for effective regulation of a particular industry. According to the OECD Summary of National and Expert Views[2] [12], the designing of effective regulation will offer both an analytical and self-assessment tool which aims to prompt policymakers to introspect their legislative frameworks, policy settings and processes as well as the need to undertake holistic and coherent actions towards developing a coherent legislative framework that will consider the business, economic, social, and environmental interests. Secondly, the design [13] will inform the decision making and support policymakers and the construction industry stakeholders to design a coherent legislative framework that will systematically consider the following:

(a) The different stakeholders' diversity, roles, and responsibilities as well as the diverse contribution of public and private for the sustainable development of the construction industry.
(b) The policy inter-linkages across economic, social, and environmental spheres, including the identification of synergies, contradictions and trade-offs as well as aligning the policies to domestic and international policies.

[2] Approaches to Assessing Policy Coherence for Development: A Summary of National and Expert Views, (SG/PCD(2009)3.

(c) The non-policy drivers, which involves the enablers that can contribute and the disablers that can hamper the development of the construction industry at national, regional, and global stage.
(d) The effectiveness of the legislative framework.

3 Conclusion

Indeed, the construction industry is one of the oldest and most dynamic sectors facilitating improvement in human life through infra-structure development. Yet it remains one of the challenging industries for governments in terms of instituting coherent regulatory regimes to facilitate productivity by addressing interests of all stakeholders involved. Based on the literature above, the importance of coherence in legislative framework cannot be overlooked. The construction industry being one of the dynamic, complex and fragmented sectors, a coherent legislative framework could enhance efficiency and effectiveness. The Eswatini construction industry and other developing countries could derive multiplier benefits from the establishment of a coherent legislative framework that will effectively cater for the needs of the construction industry. The Sustainable Development Goals (SDGs) cannot be implemented independently from each other. They are intertwined, multi-dimensional concepts, which cut across the 2030 Agenda, and as a result, coherence is essential to achieve the SDGs [16].

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Use of Bamboo Ash as Partial Replacement in Cement Mortar

Olusoji Dapo Adetola[1], Imoleayo Abraham Awodele[2], Modupe Cecilia Mewomo[2](✉), Nathaniel Ayinde Olatunde[3], and Bosede Olajumoke Adebayo[3]

[1] 3 Bolodeoku Close off Kadiri Street, Ogba, Lagos, Nigeria
[2] Department of Construction Management and Quantity Surveying, Durban University of Technology, Durban 4001, South Africa
ModupeM@dut.ac.za
[3] Department of Quantity Surveying, Federal University Oye-Ekiti, Oye-Ekiti, Ekiti State, Nigeria

Abstract. The present high cost of construction materials in the country calls for alternative materials which will also be suitable for construction work. In this study, normal cement mortar was compared with partially replaced bamboo ash-cement mortar which contained varying percentage of bamboo ash contents. The percentage of bamboo ash by mass of the total finer aggregates was varied in steps of 5% up to a maximum of 20% to normal cement mortar. The standard mix which was 1:6 with 0.65 water/cement ratios was investigated. The test result showed that the percentage of bamboo ash cement mortar between 0 and 15% is suitable for construction works. Compressive strength of not less than 7.6 N/mm^2 were obtainable at 28 days period for the mix with bamboo ash of 0–15%. The density of bamboo ash cement mortar and its compressive strength show that bamboo ash cement mortar is good and reliable for any construction work. Test results show that strength increases with the increase of bamboo ash up to an optimum value, beyond which, strength values start decreasing with further addition of bamboo ash. The use of partially replace bamboo ash in cement mortar helps in meeting the demand and requirement of cement used in the construction process by stakeholders and the public which does not have additional cost to procure rather lowering the cost when compared to ordinary portland cement which in turn help to reduce over dependent on cement in order to produce more housing units to meet infrastructural projects and create employment opportunities.

Keywords: Bamboo · Cement mortar · Replacement · Construction material

1 Introduction

Cement has been adjudged one of the most manufactured and consumed construction materials and as such building and construction industry has experienced increase in demand in recent times [1, 2]. Cement mortar on the other hand, is a building compound created by mixing fine sand, cement, and specified amount of water to make a bonding paste used in construction works. The mortar can be used for several applications such

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as plastering over bricks, means of adhering bricks or other forms of masonry. Bamboo occur naturally and grows abundantly in most of the tropical countries. It consists of cellulose fibers imbedded in a lignin matrix [3]. Cellulose fibers are aligned along the length of the bamboo providing maximum tensile flexural strength and rigidity in that direction. Over 1200 bamboo species have been identified globally. Bamboo has a very long history with humankind [3, 4]. Bamboo chips are used to record history in ancient China. Bamboo is also one of the oldest building materials used by mankind [5]. It has been used widely for household products, construction processes and extended to industrial applications due to advances in processing technology and increased market demand.

Many empirical research has been undertaking considering bamboo leaf waste for concrete and cement. However, there a still few works reporting bamboo as a replacement of cement, due to the diversity of existing species. Mujedu et al. [6] studied the physical and mechanical properties of bamboo ash cement mortar that had been partially replaced. The study concluded that, although having a total SiO_2, Al_2O_3, and Fe_2O_3 concentration of 37.68%, bamboo ash is a poor pozzolan. However, for the manufacturing of masonry mortar for construction projects, 10% bamboo ash replacement was deemed optimal. Asha et al. [7] investigated the impact of bamboo leaf ash (BLA) as a cement substitute on the compressive strength and durability of concrete. They discovered that when the percentage of BLA in the concrete increases, the compressive strength of the concrete drops, but that acid and chloride resistance improves when 10% of the cement is replaced with BLA. As a result, they concluded that BLA concrete should be utilized for civil engineering projects where durability is more important than strength.

Characteristics of bamboo leaf ash blended cement paste and mortar were examined by Umoh and Odesola [8]. They determined that the physical qualities of the pastes met the criteria of relevant standards, however the compressive strength of the mortar cubes improved with curing age and that the mix containing 15% BLA by mass competes favorably with the reference mix at 28 days and higher. Sara et al. [9] investigated the feasibility of using bamboo culm ash (BCA) as a concrete addition. They discovered that as the amount of BCA in the concrete increases, the compressive strength of the concrete drops, but the initial and final setting times both rise. As a result, they determined that BCA may be used in cases where delaying the concrete's curing time is more important than its strength.

Partially replaced bamboo-ash cement mortar is a new building material which has recently received the attention of researchers and cement manufacturing industries in Nigeria and the world at large. Due to high cost of construction materials in Nigeria and other developing countries where construction is widely caried out, the high and steadily increasing cost of cement has made construction very expensive [10]. To be able to meet the demand and requirement of cement used in the construction process by stakeholders and the public, there is need for a cheaper substitute. The substitute will be needed in the industry to lower the cost of cement and reduce over dependent on cement in order to produce more housing units to meet infrastructural projects and to reduce overall cost of construction. The present work aims to present the use of bamboo ash as partial replacement in cement mortar, as an alternative building material. Normal cement mortar was compared with partially replaced bamboo ash-cement mortar which contained varying percentage of bamboo ash contents.

2 Materials and Method

The experimental location for this study was Building Department of the University of Lagos, Akoka Yaba, Lagos State, Nigeria. This section outlines the experimental procedure of test perfomed and equipments used in carrying out the various tests. The materials used were Ordinary Portland Cement which conformed to the specification BS 8110, natural sharp sand, finely sieved bamboo-ash, electronic weighing balance, pestle, set of sieves, and clean portable water. The soil samples were oven-dried at 110 °C for 10 min and weighed. A manual sieve analysis was done by using 500 g each of sand. Each of the soil samples was passed through a batch of BS test sieves by shaking for 5 min.

The dried sand sample was placed on the largest size test sieve at the top of the arranged test sieves. The arranged test sieves were shaken and held firmly with the aid of the lock attached to the two metal poles of the shaker. The shaking continued rotationally for 15 min, and some of the particles passed through the hole of each test sieve and some were retained on each test sieve, this ensured that only individual particles were retained in each seive size. The mass of dry soil retained on each sieve was recorded, and the percentage of the total sample passing each of the sieves was calculated. The bamboo leaf burnt in an open space was allowed to cool and placed in the arranged test sieves and process for another 15 min, the ash retained on sieve 75 mm which is the finer ashes which can be partially replaced with cement was used (Fig. 1).

(a) **(b)**

Fig. 1. (a) Burning process. (b) Sensitive weighing balance and oven

2.1 Procedure for Sieve Analysis of Bamboo-Ash

Obtain exactly 350 g of air-dry representative bamboo ash sample and recorded the mass on the data sheet. Determine the mass of each sieve and recorded the value on the data sheet appropriately. Then, the stack sieves was placed and the weighed test soil was poured into the top most sieves. Clipped the sieves and continously shaked for 5 to 10 min. Remove the stack of sieves from the set and carefully separate the sieves. Weigh the sieves and recorded the total mass of sieve + soil retained on the data sheet. Obtain the mass retained on each sieve by subtracting the sieve mass from the sieve mass + retained soil. Recorded this value on the data sheet. Then sum the column of masses including that in the pan. Compute the percent mass retained on each sieve, cumulative percent retained and percent passing as follows: % Mass retained = mass retained/total mass × 100%; Sum % retained = summation of % retained; Recorded the values at appropriate columns on the data sheet. A semi-logarithmic plot of particle size versus percentage passing will be generated based on the calculation.

2.2 Sieve Analysis for Sand

Obtain exactly 500 g of air-dry representative sand sample and recorded the mass on the data sheet. Also determine the mass of each sieve and record the value on the data sheet appropriately. Place the stack of sieves and pour the weighed test soil into the topmost sieves. Clipped the sieves and continously shake for 5 to 10 min. Then remove the stack of sieves from the set and carefully separate the sieves. Weigh the sieves and record the total mass of sieve + soil retained on the data sheet. Obtain the mass retained on each sieve by subtracting the sieve mass from the sieve mass + retained soil. Record the value on the data sheet. Sum the column of masses including that in the pan. Compute the percent mass retained on each sieve, cumulative percent retained and percent passing as follows: % Mass retained = mass retained/total mass × 100%; Sum % retained = summation of % retained. Record the values at appropriate columns on the data sheet. A semi-logarithmic plot of particle size versus percentage passing immediately will be made after the particle size distribution, the materials i.e. cement fine aggregate was batched in the correct mix proportion of 1:6 being the proportion by mass of cement:fine aggregate.

The mixing of the bamboo ash was first carried out on a dry, clean, and hard surface using shovel. Cement and bamboo ash were first mixes properly for 2 min followed by the addition of sharp sand which were thoroughly mixed together, and mixing continued for another two minutes without water, thereafter water was slowly added, and mixing was continued until a uniform mix was obtained. The mortar which contained bamboo ash took longer time to produce a uniform mix than the normal mortar. This is due to the fact that bamboo ash when wet becomes soft and gel like and thus becomes very resistant of fine aggregate mixing. After mixing of both the normal mortar and partially replaced bamboo ash cement mortar, a test was carried out and was recorded for the two types of mortar. The sampling of each of the layers partially replaced bamboo ash cement mortar of varied percentage of sand was given 25 strokes using the tamping rod. Also, the normal mortar was placed like the partially replaced bamboo ash cement mortar. Each one was equally given 25 strokes of tamping rod. Immediately after sampling, the test specimens were covered with a polyethylene sheet to avoid escape of moisture. 24 h after sampling, the test specimens were stripped. The specimens were moved to the soil laboratory for assessment and pouring of water under normal laboratory condition. All the test specimens were kept immersed under water throughout the test for various ages of 7, 14, 21 and 28 days. At various ages compression machine was used on them for determination of their various compressive strengths (Fig. 2).

(a) (b)

Fig. 2. (a) Soundness test in progress. (b) Batching and mixing of bamboo as cement mortar

2.3 Pozzolanic Activity Index Test/Compressive Strength Test

This is done to determine the compressive strength of a pozzolanic mix and apparatus used are: Flat glass tube, 75 mm × 75 mm × 75 mm mould, spatulas (big and small), digital weighing balance measuring cans, measuring cylinder, scoop, and trowel, head-pan, tampering bar, lubricant oil. The procedure adopted is ratio of cement to fine aggregates is 1:6, 2.083 kg of cement was weighed and placed on the glass plate and 12.498 kg sand was weighed and mixed appropriately. Trial mixes were used to get the required water to produce a specific flow. It was mixed until a specific flow was observed, the mix was put in the mould in three layers using scoop and for each layer for 25 blows were applied. The bamboo ash-cement mortal was smoothed in the surface with the use of hand trowel and allowed to harden for 24 h. The cube was de-molded and cured for 7, 14, 21 and 28 days. The cubes were dried before crushing and the compressive strength for each of the stated days were recorded. This is the control experiment and was repeated for 5, 10, 15 and 20% replacement of cement with bamboo ash. 12 cubes were made from each of the percentages and the average of their crushing strength were obtained making 48 cubes altogether.

3 Results and Discussion

The compressive strength for various percentages of partially replaced bamboo ash cement mortar and normal mortar are shown in Table 1. The test result shows that the compressive strength of normal mortar is greater than partially replaced bamboo ash cement mortar. For the mix proportion of 1:6 at water/cement ratio of 0.62, the 5% partially replaced bamboo ash cement mortar has an average strength of 3.70 N/mm^2 at 7 days, 8.4 N/mm^2 at 14 days, 10.8 N/mm^2 at 21 days and 11.7 N/mm^2 at 28 days respectively. The 10% partially replaced bamboo ash cement mortar has an average strength of 3.3 N/mm^2 at 7 days, 9.2 N/mm^2 at 14 days, 8.8 N/mm^2 at 21 days and 11.0 N/mm^2 at 28 days. The same process was followed for the rest as shown in Table 1.

Table 1. Compressive strength of partially replaced bamboo ash cement mortar

Ages (days)	Percentages in				
	20%	15%	10%	5%	0%
7	1.9	2.4	3.3	3.7	6.6
14	4.1	5.8	9.2	3.7	10
21	5.7	7.3	8.88	10.8	12.4
28	5.87	7.8	11	11.7	14.6

3.1 Sieve Analysis

Sieve analysis results of bamboo ash and fine aggregate (Sand). The results of the particles size grading of bamboo ash and sand are presented in Tables 1 and 2 and Fig. 3 are showing the graphical representations of the tests.

Table 2. Result of sieve analysis of bamboo ash

Sieve size (mm)	Weight retained	% retained	Weight retained	% passing
1.18	2.12	0.61	0.61	99.39
0.71	5.1	1.46	2.07	97.93
0.6	14.77	4.22	6.29	93.71
0.5	28.41	8.12	14.41	85.59
0.425	43.43	12.41	26.82	73.18
0.3	63.14	18.04	44.86	55.14
0.15	72.25	20.64	65.5	34.5
0.075	84.9	24.26	89.76	10.24
Passing 200	31.41	8.97	98.73	1.27

Here the table showed various sizes of test sieves used and the weight of bamboo ash retained on each test sieve and also showed the pecentage of sample passing each sieve. E.g. for 1.18 mm sieve, a weight of 2.12 g was retained and total % passing was 99.39 and this was done for subsequent one as the sample passes through the various sieves. A graph of % passing against the sieve size was done as indicated below.

Cement mortar:Mix Ratio (1:6)

Mould is (75 mm $\times$ 75 mm $\times$ 75 mm) 4 numbers. Volumes of each mould that was used for 7 days, 14 days, 21 days, and 28 days. $0.075 \times 0.075 \times 0.075 \times 4 = 0.00169\ m^3$. For Cement; $1440\ kg/m^3 = {}^{M}/_{V}$. Then, $M = 1440 \times 0.00169 \times 1/7$. Mass $= 0.347$ kg (dry).

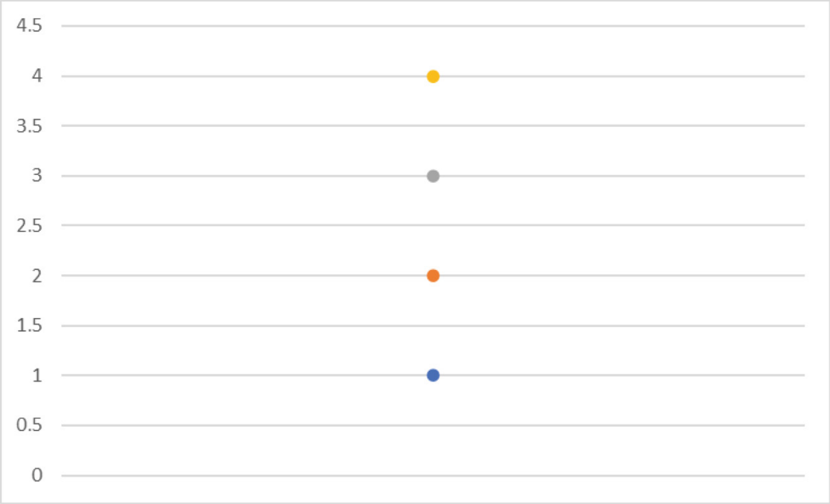

Fig. 3. A sieve analysis for bamboo ash calculations for weight batching

Wet mix = 0.347 kg × 1.5 = 0.5207 kg that is 520.7 g when converted to gram.

For Sand; 0.00169 × 6/7 × 1.5 = 0.00217 m^3 = 2.848 kg = 2848 g of sharp sand.

For 5% bamboo ash; 520.7 × 5/100 = 26.04 g.

For 10% bamboo ash; 520.7 × 10/100 = 52.07 g.

For 15% bamboo ash; 520.7 × 15/100 = 78.11 g.

For 20% bamboo ash; 520.7 × 20/100 = 104.14 g.

Table 3. Various mix ratios for different percentage

Percentage (%) Bamboo ash	Cement content (g)	Bamboo ash content (g)	Sand content (g)
0	520.7	–	2848
5	494.66	26.04	2848
10	468.63	52.07	2848
15	442.59	78.11	2848
20	416.56	104.14	2848

Table 3 shows various mixes of cement and bamboo ash for various percentage. It was obtained by the calculation done above; using the standard batching ratio for cement mortar.

Table 4. Various slump values for different percentages of bamboo ash replacement

Per (%) Replacement	Cube (nr)	Cem/wt (g)	Ash/wt (g)	Water (g)	Water/cem ratio	Slum value (mm)
0	3	115.73	–	71.75	0.62	25
5	3	109.94	5.79	79.85	0.69	30
10	3	104.16	11.57	83.33	0.72	27
15	3	98.37	17.36	93.74	0.81	26

Table 4 shows the slump value using the slump instrument by measuring the difference in height after filling the cone object with cement mortar and thorough compaction. These values are recorded as the slump values.

4 Discussion of Findings and Conclusion

The aim of this study was to present the use of bamboo ash as partial replacement in cement mortar as an alternative building material. Normal cement mortar was compared with partially replaced bamboo ash-cement mortar which contained varying percentage of bamboo ash contents. Based on the results, the followed conclusions can be drawn:

It can be seen that the higher the bamboo ash, the lower the strength. It shows that the mortar attains higher strength at twenty-eight days than at seven days of curing. Compressive strength of normal mortar was slightly above 14 N/mm^2 at twenty-eight days for mix proportion of 1:6 with 0.62 water/cement ratio. The compressive strength of both 15% and 20% bamboo ash-cement mortar at twenty-eight days was between 40–53% of the compressive strength of the normal mortar at twenty-eight days, both having equal mix proportion of 1:6 with 0.62 water/cement ratio of normal cement mortar and 0.81 w/c of 15% bamboo ash. The compressive strength of bamboo ash-cement mortar up to 15–10% at seven days was about 16.4–22.6% of the compressive strength at twenty-eight days, whereas at fourteen days, the compressive strength was between 40–63% of the twenty-eight days strength respectively. This means that the bamboo ash cement mortar can be used and will achieve a reasonable strength at fourteen days. Bamboo ash-cement mortar may require slightly more water than the normal mortar to obtain a mix which will be workable and yield reasonable strength. As much as fifteen percent bamboo ash can replaces cement content and still retains the required strength. Like the normal cement mortar, bamboo ash –cement mortar is equally dense and structurally sound up to 15%. Bamboo ash-cement mortar up to 15% is equally good and workable at 28 days.

This study revealed clearly that bamboo ash is an effective pozzolan which can contribute to mechanical properties of mortar and as such can partially replace cement in mortar. Bamboo ash replacement of cement is effective for improving the resistance of mortar to sulfate attack. The sulfate resistance of bamboo ash mortar increases with increasing the bamboo ash replacement level up to 20%. It can be concluded that the use of bamboo ash leads to enhanced resistance to segregation of fresh mortar.

5 Recommendation

The results of the experiments and the empirical findings will help to develop the research and practice of using bamboo ash as a partial replacement material in cement mortar. Bamboo, an agricultural waste, is widely available in Nigeria and is recommended for building construction due to its appropriateness and cost savings over the traditional Portland cement used for building and other constructions. This will result in a decrease in the use of Portland cement as well as a decrease in the cost of constructing a project.

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Valuation Problems in Developing Countries: A Theoretical Framework

Irene Cheloti(✉) and Manya Mooya

Department of Construction Economics and Management, Faculty of Engineering and the Built Environment, University of Cape Town, Cape Town, South Africa
irene.cheloti@gmail.com

Abstract. Property valuation problems, such as valuation inaccuracies/variations, client influence and inappropriate use of heuristics negatively affect the valuation profession in Kenya and other developing nations. Although most empirical studies under the rubric of behavioural issues in valuation mainly attribute these problems to cognitive limitations from human psychology, a few studies demonstrate that these problems exist partly because of weaknesses in the standard theory of market value and indicate the importance of anchoring valuation research in economics. This paper examines the theoretical explanation for valuation problems in Kenya and similar developing countries, intending to introduce a more appropriate theoretical framework, one that better explains these problems. This study reviewed the extant theoretical and empirical literature and established that the standard theory of market value is overly abstract, unrealistic and incapable of explaining valuation problems across the world, especially in developing countries. Based on these findings, the study argues for the need for an alternative theoretical framework, one that is more realistic and capable of adequately explaining valuation problems in practice. The study proposes the New Institutional Economics (NIE) as an alternative theoretical framework for property valuation and concludes that valuation problems in practice are better explained within the theoretical lens of this framework.

Keywords: Valuation problems · Developing countries · Standard theory of market value · New Institutional Economics (NIE)

1 Introduction

Property valuation problems such as valuation inaccuracies/variations, client influence, and inappropriate use of heuristics negatively impact the valuation profession globally. These problems have been shown to be more pronounced in developing countries. While developing countries represent immature property markets with poor information, developed countries exhibit a more structured and mature property market that is more active with greater market transparency [8, 21]. The persistence of valuation problems in developing countries has mainly been attributed to the current strategies that address these problems in the context of improving valuer conduct, with little emphasis on market-related issues such as poor information and problems related to the normative basis of the standard valuation theory [10].

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Previous research in valuation is premised on neoclassical economics (underpinning the standard theory of market value) and theories from human psychology [3, 25, 27]. Emerging researchers [8, 19, 23, 25] have criticised the validity of neoclassical economics in explaining contemporary valuation problems in practice. Further, the researchers criticise theories from human psychology that neglect economic theories underlying valuation theory. This study departs from previous studies that predominantly adopted neoclassical economics and theories from human psychology and seeks an alternative theoretical framework that better explains events in the property market. The study proposes the New Institutional Economics (NIE) theory, which is more realistic and capable of explaining valuation problems globally.

This paper is arranged into six sections. The second section describes the research methods, while the third section discusses valuation problems in practice. The fourth section discusses the neoclassical economics theory focusing on its relationship with the standard theory of market value and the property market while indicating the need for an alternative theoretical framework. The penultimate section presents the New Institutional Economics (NIE) theory, focusing on transaction costs and institutions and their application in property markets. The paper ends with a discussion of the appropriate theoretical framework for property valuation in developing countries.

2 Research Methods

A systematic review of the scholarly literature was adopted for the study. Literature was retrieved from online databases and search engines, including the University of Cape Town online library, Google Scholar, Taylor and Francis, Emerald, etc. Specifically, the review covers issues around valuation problems in practice, neoclassical economic theory, the standard valuation theory, and the proposed theoretical framework, i.e., the NIE. In essence, the review focuses on the lack of capacity of the standard theory of market value in explaining valuation problems in practice and proposes a theoretical framework to adequately explain the valuation practice in Kenya and other developing nations.

3 Valuation Problems in Practice

Scholars have been paying increased attention to behavioural issues in valuation, such as valuation inaccuracies/variations, client influence, and anchoring heuristic [3, 25]. Studies worldwide have demonstrated that valuers are unable to estimate market value as conventionally defined with reasonable accuracy [1, 4, 5]. According to Mooya [25], valuation inaccuracies are not unusual in practice.

Client influence is common within the valuation profession globally [3, 20]. Valuers are constantly under pressure from banks to provide favourable valuations that influence their lending criteria [29]. This practice negatively impacts the credibility of the valuation. The use of heuristics is yet another global valuation problem. Heuristics refers to rules of thumb that help in decision-making when faced with complex situations or incomplete information [15]. Studies such as Diaz and Hansz [12] and Iroham, Ogunba and Oloyede [17] have confirmed the existence of anchoring heuristics. Osmond [27] argues that valuers typically adopt heuristics due to limited information contributing to inaccurate valuations.

Previous valuation research is mainly premised on human psychology theories [3, 27], with a few studies anchored in neoclassical economics underpinning the standard valuation theory. Researchers such as Beale [8], Lawson [23], and Mooya [25] have criticised human psychology theories for neglecting economic theories that underlie valuation theory. They believe that studies in valuation should remain grounded in the economics discipline. While most studies have accepted the standard theory of market value, emerging research questions whether valuation problems in practice can be explained from within this theory [8, 19, 23, 25].

Beale [8] claimed that anomalies arising from the profession's practices in Jamaica are partially due to gaps between theory and practice; however, she focused on implementing practical procedural guidelines without a working valuation theory. Lawson [23] suggests that price theory is an appropriate proxy for valuation theory but fails to discuss how valuation problems can be solved from within price theory. Kinnard [19] recognises a growing dissatisfaction with neoclassical economics theory but failed to provide an alternative theoretical framework. Mooya [25] criticised the existing theoretical framework and developed an alternative theory of market value but failed to focus on valuation problems specific to developing countries.

From the preceding literature, there is minimal emphasis on theoretical explanations of valuation problems from economic principles that underlie valuation theory. Further, there is little focus on the gap between the standard theory of market value and reality. The present study attempts to fill these gaps in the literature by proposing a better theoretical framework to explain events in the property market.

4 Neoclassical Economics Theory

Neoclassical economics is based on the notion that perfect competition causes efficient resource allocation that regulates economic activities and establishes equilibrium through demand and supply [2]. The key assumptions of neoclassical economics theory include rational choice, full information, homogenous product, and equilibrium [2]. As discussed below, these assumptions are embedded in the standard valuation theory and differ from actual property markets.

4.1 Neoclassical Economics Theory and the Standard Theory of Market Value

The assumption of rational choice is based on the concept of 'the rational economic man,' who operates within the confines of rational choice theory as a self-interested individual who strives to maximise his/her utility [2]. Therefore, agents will always behave in a manner that maximises benefits and minimises costs [25]. For instance, sellers will always want to obtain the highest price possible, whereas buyers will want to pay the lowest price possible [25].

The assumption of rational choice is embedded in the standard theory of market value. For instance, valuation methods are based on the principle of substitution that assumes a rational decision-maker. The market approach assumes that a rational purchaser will not pay more for a property than the price of a comparable substitute property [25]. Similarly, the cost approach presupposes that a rational purchaser will not pay more for a property than the cost of constructing an equally desirable substitute less applicable depreciation [25]. Since valuation methods replicate the thought processes of typical property purchasers [25], valuers are expected to be rational and objective in arriving at market value estimates.

A prerequisite to the rational choice doctrine is the assumption of full information [2]. Neoclassical economics holds that complete information is required to make rational choices [22]. This assumption ensures that trade is not constrained by transaction costs arising mainly from imperfect information, thereby enabling markets to adjust efficiently and solely to price signals [25]. Therefore, neoclassical economics disregards transaction costs and institutions that emerge to reduce these costs [26].

Just like rational choice, the assumption of full information is embedded in the standard theory of market value. Accordingly, the market approach, whose underpinning principles are present in all the valuation methods, works best in environments with full information [25]. The investment approach requires that valuers have information on market rents, expenses, and discount rates. Similarly, the cost approach expects valuers to have information on construction costs, depreciation rates, and land comparable [25].

Closely related to full information is the assumption of homogeneity. Neoclassical economics theory assumes property homogeneity [25]. This assumption eases information problems about attributes of the subject property hence reducing transaction costs [25]. In applying valuation methods, valuers are required to adopt comparable information (market approach), comparable sales and rents (investment approach), and comparable construction costs as well as land comparable (cost approach). These methods presuppose homogenous properties as the information required entails property information that closely compares to the subject property.

The assumption of rational, fully informed agents, trading in homogenous properties, results in equilibrium tendencies in markets [25]. The central proposition of this assumption is that demand and supply forces drive the system to a state where economic forces are balanced, i.e., the point where the supply of a product matches its demand [2]. This assumption is rooted in the standard theory of market value, where sufficient competition is required to bring about equilibrium conditions [25]. For example, the market approach requires sufficient competition to generate clear patterns of prices [25]. The investment approach is more complex as it requires both prices and rents to be at equilibrium [25]. Similarly, the cost approach requires sufficient competition to generate clear patterns of costs [25].

The assumptions of rational agents, full information, homogenous properties, and equilibrium create the neoclassical notion of a perfect market embedded in the standard theory of market value grounded in neoclassical economics.

4.2 Neoclassical Economics Theory and the Property Market

The neoclassical assumption of rational choice has been widely criticised, with researchers arguing that actual property markets do not portray rational individuals but individuals with bounded rationality [25]. Kinnard [19] believes that investors do not look for the most profitable use or the best possible alternative; instead, they select one that meets the previously established standards or criteria. Kinnard [19] believes that the neoclassical assumption of a rational being is unrealistic as market participants have limited rationality which is the actual nature of human beings. In practice, valuers replicate the thought processes of typical property purchasers with bounded rationality.

Contrary to the neoclassical assumption of full information, property markets are characterised by incomplete information [21]. Property markets portray few uninformed buyers and sellers due to poor information [6]. Mooya [25] believes that information problems arise because property market transactions are complex and often shrouded in secrecy, real property is heterogeneous, and information is costly. Consequently, valuers are faced with the difficulty of assessing market value in an environment that exhibits limited information [10]. Accordingly, they experience high transaction costs hence the emergence of institutions to manage these costs.

The assumption of property homogeneity that is meant to ease information problems is unrealistic due to the globally heterogeneous nature of the property market [2]. Property heterogeneity is closely related to inadequate information, making the assessment of market value difficult.

Unlike neoclassical economics that presupposes equilibrium, the aforementioned peculiar features of the property market result in the non-existence of equilibrium forces [2]. Mooya [25] believes that the assumption of general equilibrium does not hold as property markets exhibit multiple equilibria.

While the theoretical foundations of neoclassical economics, such as the scarcity of resources, the concepts of supply and demand, and the role of price in resource allocation, are essential in property studies, neoclassical economics may not present the best theoretical framework for the analysis of property markets [2]. As discussed, the neoclassical analysis of property markets focuses on rational individuals with full information, homogenous properties, and equilibrium tendencies in markets portraying a perfect market. Conversely, property markets are subject to imperfections mainly stemming from property heterogeneity and illiquidity, lack of information and bounded rationality, resulting in multiple equilibria [2, 25]. This imperfection presents a gap between the ideal neoclassical and actual property markets. This gap is more pronounced in developing countries characterised by immature property markets with limited information [10].

While developed economies experience mature property markets with a lot of information, developing nations are characterised with immature markets with limited information [8, 21]. In essence, property markets in developing countries are far from attaining the characteristics of the neoclassical perfect market while developed countries are closer to the perfect market. Mooya [25] believes that the standard theory of market value is not universal; it is inadequate and unable to explain valuation problems in practice, more so in developing countries.

4.3 The Call for an Alternative Theoretical Framework for Property Valuation

The failure of the standard theory of market value in explaining the valuation function and the search for a better explanation of valuation problems in practice has led to a shift towards behavioural studies in property valuation. Behavioural research in valuation has its roots in human problem solving theories from cognitive psychology developed by Newell and Simon (1972) and Simon (1978) [12, 28] and Brunswik (1956) lens model of perceptual theory [3]. These theories assume that human beings resort to heuristic behaviour as a shortcut when faced with uncertainty. However, these theories from cognitive psychology do not offer economic explanations of such behaviour. Mooya [25] observes the lack of economic footing in the present psychological based real estate researches and calls for a more pragmatic theoretical approach. The basis of the property market is economics as property prices are determined by market behaviour hence the need for new directions in research to remain grounded in economic theory [8, 25].

As discussed, both the standard valuation theory and theories from cognitive psychology are inadequate in explaining valuation problems in practice hence the need for an alternative theoretical approach to address valuation problems [8, 23]. In an attempt to offer a better explanation of the valuation practice, Mooya [25] developed an alternative theory of market value, one which views market value as a social convention and emphasises its role as a transaction cost minimising device (see Mooya [25] for more details). However, this theory has not been tested, applied, or subjected to any empirical validation. This paper proposes the NIE theory as a better theoretical framework to explain events in the property market.

5 The New Institutional Economics (NIE) Theory

NIE is a theoretical paradigm that attempts to introduce more realism in economic analysis while retaining the solid theoretical foundations of neoclassical economics such as the scarcity of resources, the concepts of supply and demand, and the role of price in resource allocation [25, 26]. It extends neo-classical theory by modifying rationality and adding transaction costs and institutions as critical constraints [26]. NIE discards the neoclassical constructs of rational, fully informed agents, transacting in perfectly competitive markets with homogenous products that have made it an institution-free theory [2]. It instead focuses on agents with bounded rationality, limited information, heterogeneous product, and multiple equilibria, translating to high transaction costs hence the emergence of institutions [2, 16, 30].

In NIE, actors pursue their interests by making choices within constraints, i.e., they make choices that further their interests [16]. NIE distinguishes itself from neoclassical assumptions of rationality by attending to cognitive costs of decision making, i.e., individuals are boundedly rational, and information is often costly, contributing to high transaction costs [16]. Further, NIE takes cognizance of human agents' behavioural attributes, i.e., opportunism and human cognitive limitation, which results in problems of uncertainties, hence the corresponding institutions that seek to mitigate these problems by creating order, structuring human exchange interactions, and reducing transaction costs [2].

NIE also disregards the neoclassical assumption of full information and focuses on limited information, which is the actual nature of the social world [30]. The NIE School holds that information available to individuals is incomplete, and their mental capacity to process this information is limited [16].

Additionally, unlike the neoclassical construct of homogeneous properties, NIE assumes the existence of heterogeneous properties [30]. Heterogeneity presupposes inadequate information that translates to high transaction costs. NIE further holds that there is not one determinate equilibrium but multiple equilibria [26], which, as discussed previously, is consistent with property markets. NIE's assumptions of bounded rationality, limited information, heterogeneous properties, transaction costs, institutions, and multiple equilibria, presuppose the existence of imperfect markets, which is the actual nature of property markets.

Conclusively, NIE constitutes a modification of the neoclassical paradigm by introducing transaction costs and institutions [2, 9]. Eggertsson [13] regards the introduction of transaction costs and institutions as NIE's most useful theoretical contribution.

5.1 Transaction Costs and the Property Market

The starting point for the NIE theory is that uncertainty is ubiquitous, and transaction costs are inevitable in society [2, 13, 25]. In property markets, transaction costs are incurred to increase the information available and reduce uncertainty [2, 9]. They comprise monetary and non-monetary costs, including the effort and time taken to access property information [9, 25].

Real property presents unique characteristics, including its indivisibility and heterogeneous nature, contributing to widely varying physical characteristics and ownership structure [2]. These property market characteristics contribute to information problems and high transaction costs [9, 16]. Additionally, real estate is infrequently traded over relatively long holding periods mainly because the property market is characterised by few buyers and sellers [2, 25]. Further, its private and opaque nature results in limited disclosure obligations between parties, contributing to insufficient information [2]. Agboola [2] argues that these qualities reduce the liquidity of real estate, influencing the time taken to acquire and dispose assets. Therefore, compared to other products, real property contributes to high transaction costs mainly because of the imperfect information and prolonged periods required to close a given transaction.

Due to its illiquidity nature, real property is an asset-specific investment prompting the use of specialist market actors such as estate agents, valuers, and property managers to provide crucial market knowledge to facilitate property investment [2]. Although intermediaries provide essential information necessary to reduce risks and facilitate transactions, this information is brokered at a cost [2]. These costs, i.e., professional fees, contribute to high transaction costs. Other than professional fees, participants in property markets incur additional transaction costs, including transfer costs, i.e., statutory fees and taxes [2].

5.2 Institutions and the Property Market

The unique attributes of real property prompt the evolution of institutions, i.e., formal documented rules of land rights, which reduce uncertainty about what can and cannot be done with a piece of land and by whom, and informal institutions, i.e., norms, networks, and conventions [2]. For instance, landed property has rights and duties that reduce uncertainties surrounding a particular property [9]. Therefore, institutions are formed to reduce uncertainty in human exchange, supply information, and reduce transaction costs [26].

The property market exists within a broad institutional context defined by the prevailing political, economic, social, and legal systems which inform market structures and processes [18]. Each country's property market is conditioned by the institutional framework of administrative and regulatory burdens, the legal protection of investors, and the attendant transaction costs of these institutions [2]. Institutions can facilitate the attainment of collective ends that transaction costs might otherwise prevent [16]. In valuation practice, institutions may include property rights, local and international valuation standards, valuation regulations and policies, constitutions, and by-laws.

Differences in the institutional environments of the property market, i.e., laws, regulations, conventions, norms, networks, and business culture, lead to variations in investment experiences across markets [2]. Complex institutional structures (elaborately defined and effectively enforced property rights, formal contracts, property laws, and regulations) have been devised in developed nations to constrain participants, reduce uncertainty and prevent transaction costs [7]. In contrast, developing countries lack proper institutional structures with less than arm's length transactions translating to high transaction costs [7].

6 The Appropriate Theoretical Framework for Property Valuation: Discussions and Recommendations

Mooya [25] believes that to be useful as a tool of prediction and explanation, a good theory must accurately reflect the facts of the real world, it must not only explain the past but help to predict the future, it must offer practical guidance in solving daily problems, it must be internally consistent (i.e., should fit together logically), it must be economical in that it employs few unproven assumptions but explains as much as possible, it must be falsifiable (i.e., should have the capacity to be proven wrong) and finally, a good theory must stimulate the production of new knowledge. Therefore, a good theory of valuation should make realistic predictions and explanations about events in the property market [8].

Following the above criterion and based on our previous discussion, the neoclassical economics theory may not present a better theoretical framework for a representative study of the property market. On the other hand, NIE is a better theoretical approach to understand and explain events in the property market for the following reasons:

1. Unlike the neoclassical economics that assumes rational agents, NIE presupposes agents with bounded rationality, which is in line with the property market;
2. While neoclassical economics assumes complete information, NIE assumes limited and unreliable information, which coincides with the actual property market;
3. NIE disregards the neoclassical assumption of homogenous properties and adopts heterogeneous properties that is in line with the actual property market;
4. NIE abandons the neoclassical assumption of equilibrium and embraces multiple equilibria, which is consistent with the property market;

5. While neoclassical economics abandons transaction costs, NIE introduces transaction costs that are inescapable features of property markets;
6. Unlike neoclassical economics that disregards institutions, NIE's key contribution is that of institutions that emerge to reduce transaction costs, which aligns with the property market in practice.

In summary, while neoclassical economics assumes a perfect market that is inconsistent with the property market, the NIE presumes an imperfect market that is consistent with actual property markets.

These views are supported in the literature. For instance, researchers such as Beale [8], Kinnard [19], Lawson [23], and Mooya [25] have demonstrated a gap between neoclassical economics theory and reality. Coase [11] argues that the neoclassical economics theory is little concerned with what happens in the social world. It is mainly criticised for its lack of institutional foundation and its decreasing relevance in explaining real-world phenomena [14]. The approach fails to consider the social character of the property market and treats institutions and transaction costs as exogenous variables in analysing property markets [2]. Neoclassical economics is concerned with a frictionless world in which institutions do not exist, and all change occurs through perfectly operating markets without transaction costs [14]. Given the real world with positive transaction costs, neoclassical economics does not adequately explain events in the property market [2]. Agboola [2] argues that NIE provides a more practical approach to assessing the workings of the property market. Similarly, Menard [24] observes NIE as an alternative approach to neoclassical economics. NIE attempts to overcome the deficit of the mainstream by providing a framework to cover the latter's weak links while retaining its strong theoretical foundations [14, 30].

By demonstrating the incapability of the standard theory of valuation in explaining events in the property market and applying the principles of NIE to explain valuation problems in practice, this study builds on the existing body of knowledge by enhancing the theoretical platform for analysing valuation problems in practice. Therefore, the present study contributes to theoretical development.

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Addressing the Challenges in the Construction Industry Using a Systems Thinking Approach; A Case Study in Ghana

Joe Frederick Cobbinah[1], Kwamina Ewur Banson[2](✉), and Clinton Ohis Aigbavboa[1]

[1] Department of Engineering Management, University of Johannesburg, Johannesburg, South Africa

[2] Socio Economics and Commercialisation Center (SECC), Ghana Atomic Energy Commission (GAEC), Biotechnology and Nuclear Agriculture Research Institute (BNARI), Legon-Accra, Ghana

kwamina.banson@gaec.gov.gh

Abstract. Every construction project is exclusive and functions in a complex environs which needs its own sets of managerial procedures to complete the project in the predetermined duration, scope, cost, and quality desired. The construction process is viewed by many authors as a complex and risky business to undertake. Traditional project management view the construction process as linear, orderly and predictable which can be planned, organized, and managed top down like any other industry. The regular failures to finish construction projects timely and within estimated budgets assume thinking that the process may not be as orderly and predictable in the manner as perceived. The aim of this paper was to assess the possible application of systems thinking approach in the construction industry using causal loop diagram as an example. The application of systems thinking has the potential to alleviate several deficiencies that perhaps a more traditional project management approach has struggled to deal with. The result of the Bayesian Belief Network (BBN) model indicates that with systemic interventions of establishing funding source and reliable norms, chances of efficiency in the construction industry will increase from 42.6% to 67.6% high. It suggests a paradigm change from the traditional way of doing things by looking at a project from a holistic point of view.

Keywords: Challenges · Construction project · Project management · Systems thinking

1 Introduction

Each construction project is exclusive and functions in a complex environs which needs its own sets of managerial procedures. According to Wagner [1]. The challenges confronting the industry can be grouped under three main headings: Multiple – stages of design, procurement, and construction; Changing – frequent design changes, client requirements and performance priorities (time/cost issues); and Delays – in discovering

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rework. To address these challenges and inefficiencies confronting the industry, there is a need for project managers to move from traditional management approach and tools used in the past to a systemic method that deals with the original cause of the challenge. This new approach will provide a new tool for project managers to examine and understand the complex relationships of the project organization and the environment in which they operate [2]. The aim of this paper was to assess the possible application of systems thinking methods to address the challenges in the construction industry using some of it tools such as the causal loop diagrams and the Bayesian Belief Network Models.

1.1 The Traditional Project Management Concept

Traditional project management view the construction process as linear, orderly and predictable which can be planned, organized, and managed top down just like any other management discipline [3]. However, frequent failure of the industry to meet client requirement in terms of scope, time, quality and cost clearly show that the process is not ordered and predictable in its nature as perceived by players in the field. Clearly, the use of linear schedules tools by project managers to effectively planned and manages construction activities have contributed significantly to the poor performance and success of the industry. To deal with these challenges requires a paradigm shift.

1.2 Performance of the Construction Industry

The construction industry just like any other industry requires modern management techniques and tools to increase productivity and function effectively. The industry lacks behind other industry in terms of achieving its objectives on time, within budget and quality desired. Despite the improvement in project management methodologies to correct this unwanted situation over the years, many projects continue to fail. The emergence of tools including value engineering, value management, quality assurance, and wireless communication technologies in production management besides the well-known project management tool: critical path method (CPM) and numerous cost management interventions have only added marginal improvements [4]. The Critical Path Method which is the last and probably the best innovation of project management tools evolved during the early 1950s.

The Problems militating against performance and efficiency in the construction industry are numerous as outlined by the following professionals and research bodies. These bodies view the problems from different angles. Leśniak et al. [5] attribute the problem to lack of understanding of the effect of running projects in a multidimensional and multidisciplinary project environment. According to Shoar and Banaitis [6], the problem was placed on the lack of committed leadership, client's satisfaction and commitment to the workforce executing the project. Furthermore, Sanni-Anibire et al. [7], attribute the lack of performance to the nature and type of project to be executed. Many scholars and authors posit that there is the need to refine the existing project management practices which are deeply rooted in the scientific theory to design, execution, and control which forms a theoretical framework underpinning project management. However, the opinions of scholars and practitioners does not support the view that improvement lies in refining existing tools and methods. Scholars such as Brunet [8], among others, in their assessment of the current project management practices, tend to question the conceptual framework on which project management was built. These authors critically examined the state of conventional project management tools and approaches, only to highlight the weakness and its lack of relevant and comprehensive theoretical capability to bring improvement to project management practices, thus suggesting a paradigm shift to cope with project complexity especially in the contemporary world.

According to Derakhshan et al. [9], the method to construction management practices as embedded in project management literature and courses is of less value in the advent of rapidly technological change and modern construction projects complexity. This situation highlights the need to look for an alternative approach to project management theories that are closer to contemporary reality so as to address the weaknesses in the traditional project management practices. Furthermore, Bjorvatn and Wald [10] during their assessment of project management theory, stated: "the fundamental theory for management of project is obsolete and cannot solve the problem of complexity in a modern project". The industry is in search of new models that can depict contemporary reality; project management should also reconsider the theoretical framework that underpins project management practices to accommodate new challenges.

2 The Need for Systems Thinking Approach

The construction industry in Africa and Ghana, in particular, significantly contributes to the prosperity and development of the economy as in other parts of the world [11]. However, the performance of the industry in developing countries is abysmal in terms of meeting the expectations of clients and society as a whole and Ghana is not an exception [12]. The contribution of major construction activities in developing countries account for about 10% of their GDP, 50% of wealth invested in fixed assets and 80% of the total capital assets [13]. Furthermore, the industry is second to agriculture in terms of employment [14]. Notwithstanding the crucial role construction plays in developing countries development, the industry is characterized by cost and time overruns. Most projects do not realize their projected benefits and some are even terminate before their accomplishment. Undoubtedly, the building industry lags behind other industries in developing countries and in particularly their developed nation's counterparts. The sustainability of the construction industry in developing countries requires a new approach of doing things, to enhance capacity building, evolve, improve and raise the effectiveness of the industry in a more holistic way of thinking from reductionism way of thing. The traditional project management approach is based on the reductionist approach to deal with complex situations by breaking the entire system into its interactive parts. The concept is based on logical thinking that a complex system is the sum of its component parts, and therefore can be reduced to individual constituents for analysis. However, this approach according to Banson et al. [15], does not take the system as a whole into consideration, and could lead to consequences not accounted for. In addition, reducing complex systems to its constituent's part for analysis is a fundamental mistake. As opined by Banson et al. [16], the outcome from this approach is often far from contemporary realities and when adopted by management and decision makers in their analysis could result in unintentional consequences that will require expensive alleviation.

In contrast, systems' thinking is an approach which focuses on modeling features found in actual systems. The key concept of systems thinking in management is the emphasis on *holism*, which means that the parts cannot be fully understood without the examination of the entire system. It uses a set of tools and the art of interrelated thinking to deal with ambiguity in complex systems and the incorporation of mental models into systems structures. Systems thinking approach focus on procedures, feedback loops or mechanisms and interdisciplinary perspective to address multi-dimensional and multi-disciplinary project environments. It suggests a paradigm shift from the traditional way of thinking by looking at a project from a holistic point of view. This helps to reveal the fundamental causes and challenges in projects during the design and implementation stages. Systems' thinking offers comprehensions into the behavioural patterns and structure of organizations and the environment in which they operate. According to Highsmith [17] managing an operation with systems thinking can help improve performance, reduce uncertainty, anticipate delays and prevent unintended consequences. Even though, systems thinking approach according to Kim [18], has been criticized by critics as representing the view of technocratic to solving business problems, too fundamental and depends on models which threaten its validity in management training. However, its significant advantages were established by Sherwood [19] when they use systems thinking models to highlight and addressed problems in integrated project. It clearly demonstrates how to transform tough ideas into beneficial management tools for change. This has highlighted the weakness in traditional methodologies to dealing with today's complex management difficulties which only treat the symptoms.

3 Research Methods

The framework of the Evolutional Learning Laboratory (ELLab) of systems thinking was used to analyse the current events or symptoms, patterns of behaviour and the structure influencing the construction industry in Ghana to develop stakeholders' mental model using causal loop diagram (CLD). The first step involved a comprehensive review of literature and data collection through the question to find key drivers disturbing construction projects. Step two integrated the various key variables identified during the survey into a structure models using a software called Vensim [20]. Exploring and interpreting the archetypal models for patterns, interrelatedness is step three. It also involve analyzing feedback, and existing reinforcing and balancing loops. The aims of this step is to develop an understanding of selected variables, their interdependency and roles, and levels of impact in the whole system. Step three was done by interpreting and exploring the model for patterns, interconnected components, and analyzed feedback, reinforcing and balancing existing loops. Leverage points are identify as a result of interpreting the identified models for systemic intervention. Leverage points identified in the CLD are points of power, where a minor alteration can produce a major alteration in the whole system [21]. The identified leverage points are then selected as the main objectives for systemic interventions using the BBN. The BBNs are constructed to include the opinions and suggested mediations by the stakeholders.

Given the increasing complexity, changes and unpredictability of the construction projects, economic actors, and businesses should take into considerations all factors that might impact its relationships in the industry [22]. The theory of stakeholders in business ethics and organisational management that addresses values and morals in dealing with an organisations is detailed by Bosch and Nguyen [23] was adopted.

3.1 The Causal Loop Diagram

To integrate and interpret the mental models of stakeholders, the *Causal loop diagram (CLD)* is used as a tool. To develop an understanding of a system likeness, mental models are use. Mental models explains and shows how the behaviour of a system variables are interrelated. It consists of variables connected by causal arrows with Nodes and edges which take signs (‘positive and ‘negative and delays’) to describe the causal linkages. The rest of the nodes are the causal linkages creating the problem. From a systems viewpoint, these signs are used to show the behaviour of a cause and effect. *CLDs* transform the complex features into a simple and easy to comprehend format by means of Vensim software tool. A CLD is formed by identifying and determining the variables relating with other variables within the whole system.

4 Results and Discussions

4.1 The Mental Model of the Construction Industry

Figure 1 presents the CLD of the complex construction industry and its impact on sustainable construction among the stakeholders in Ghana. This model provides an explanation of both direct and indirect feedback loops between the design and construction management activities and its impacts on timely and successful completion of projects. This will allow contractors and stakeholders to identify business prospects that improve efficiency and back the growth of sustainable construction activities. The models can be used as development toolkits in the construction industry by decision and policy makers.

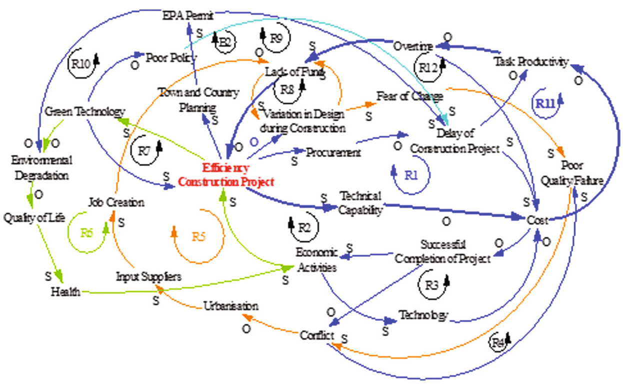

Fig. 1. CLD of the construction industry

Describing the causal linkages of Fig. 1, variables linked by causative arrows with signs such as “S” (same) and “O” (opposite) are used. The circles of cause and effect as described by the Feedback loops takes on life of their own. Figure 1 demonstrates feedback loops within the management of construction projects revealing the pros and cons of project sustainability. The feedback loops in Fig. 1 signifies that a particular change kicks off a set of changes that cascade through other elements that will either intensify ("reinforce" (R)) or step down against ("damp", "balance" (B)) the initial variation.

The illustration shows that, the possibility for constructors to achieve sustainable construction project outcome is dependent on timely procurements of materials and equipment from nominated suppliers/suppliers. The good of timely procurement is therefore in opposite direction to delays in construction which enhances task productivity, which reduces overtime and cost leading to successful completion of the project as shown in Fig. 1. Abandonment or failures of projects are not without cost, they are costly in two ways, and the first is the cost of fixing the cause of failure and the price of solving conflicts. This leads to overtime which depletes funds and finally pushes back against the efficiency of construction projects as shown by 'R11' in Fig. 1.

To ensure efficiently in the construction industry, the town and country planning agents in collaboration with the EPA ensure that design and environments meet standardization. This mostly leads to delay and clients and some contractors begin work without a permit. This agent, therefore, tries to enforce regulations by trying to stop the work that has commenced and hence creates delays and cost within the system as shown in Fig. 1, 'B2' leading to unsuccessful completion of the project which hinders economic activities and affects efficiency.

Efficiency in the construction industry is also affected by variation in the design during construction which sometimes leads to poor acceptances by clients as a result of fear (high cost). Conversely, this leads to poor or failure of project arousing conflicts which affects urbanization and economic activities (input supply). If the capacity to supply input is eroded, several things go bad and leads to unemployment which affects cash flow and funds availability as shown in Fig. 1, 'R5'.

4.2 Bayesian Belief Network (BBN) Modelling

Deliberations with some key stakeholders were involved in the identification of leverage points from Fig. 1 and also participated in the creation of the BBN models. Increasing efficiency in the construction industry was suggested as a leverage point. Together with some key experts and literature review, the BBNs were built to include the opinions and proposed solutions of the construction industry. Unescapably and admissible, the use of public funds are seriously scrutinized and moneys and interventions must demonstrate value both afore and after project inception, therefore the creation of BBN models are to aid in investment decisions.

4.3 Bayesian Belief Network (BBN) Modelling for Increasing Efficiency for Construction Projects

It is obvious from the arguments above that improving construction productivity is one of the key leverage points to overcome the challenges in the construction industry.

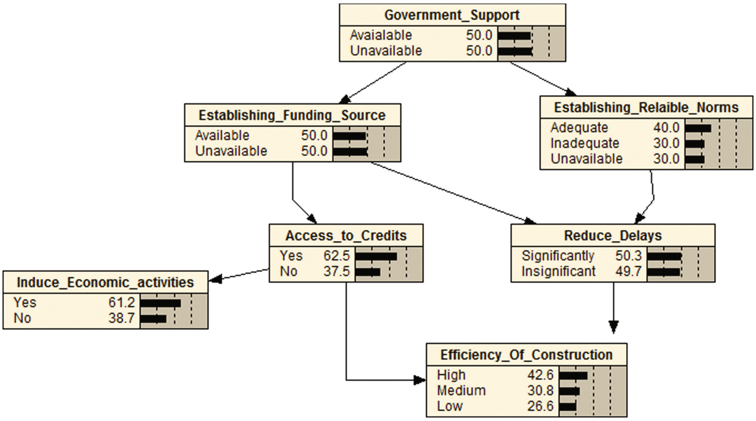

Fig. 2. BBN for increasing efficiency of construction service (without intervention)

Subsequently, several Bayesian Belief Network (BBN) models as (Figs. 2 and 3) were established to determine the interventions for enhancing efficiency in the build industry in Ghana.

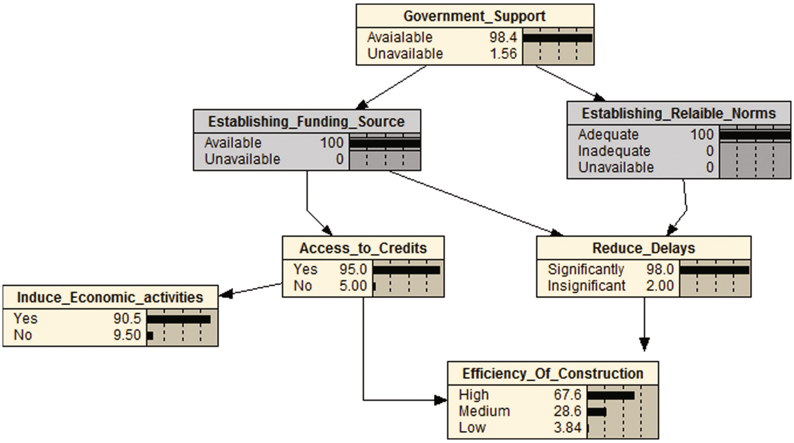

Fig. 3. BBN for increasing efficiency of construction service (with intervention: establishing funding source and reliable norms)

The BBN model of Fig. 2 shows that the present state of efficiency in the construction industry as 42.6% probability high with the probability of significant delays of 50.3%. Also, the chances that economic activities will be induced are 61.2% with 62.5% chances of getting access to credits. The systems BBN model of Fig. 2 was used as a decision support tool to observe the likely consequences of alternative interventions by studying what will occur to the system when a specific policy or combination of tactics is applied. They included establishing funding source and reliable norms for construction. Figure 3 shows increased levels of efficiency with spiral positive effects on other components of the systems. The BBN model (Fig. 3) indicates that with the systemic interventions of establishing funding source and reliable norms will increase the chances of efficiency in the construction industry from 42.6% to 67.6% high. With the probability of reducing delays significant from 50.3% to 98%. Also, the chances that economic activities will be induced is improved from 61.2% to 90.5% with 95% chances of increasing access to credits from 62.5%.

4.4 Implication of the Findings

To identify the fundamental causes or sources of management challenges in the construction industry, systems thinking is the approach to adopt. It highlights the possible consequences of policy decisions that may affect successful outcome of construction projects.

5 Conclusion

As confirmed in the above CLD, systemic methodologies will undoubtedly help construction industry to evolve from traditional to systemic approaches and provide systemic solutions and interventions which will ensure efficiency in the industry. To solve today's problems, decision or policy makers must overcome the erroneous perceptions of systems and interconnected thinking that created the current predicament of "keep on doing what we did in the past". Governments, managers, policymakers, scientist and contractors can benefit from this approach which will help them to foresee the consequences of the actions and decisions they make, as well as help to avoid any unpredicted consequences of policies as a result of "silo mentality" and "organizational myopia".

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Flexural Bond Strength Analysis of Dry vs. Water Saturated Burnt Clay Brick Prisms: Pilot Study

Bonga Khuzwayo(✉)

Department of Civil Engineering and Geomatics, Durban University of Technology, Durban, South Africa
bongak@dut.ac.za

Abstract. To improve the bond strength between burnt clay bricks and mortar, SANS 227 recommends moistening or wetting the clay bricks prior to construction or laying of mortar beds. One may argue that the informal construction sector generally fails to comply with this recommendation, as there are many uninformed and un-skilled building applicators and operators. The study examined the effect of substandard practices by contrasting dry versus water saturated burnt clay bricks. Between 2017 and 2020, 122 clay brick prisms were constructed. Prisms were constructed comprising six courses in stack bond fashion and were subject to two-point flexure load testing at 28 days in order to assess the flexural bond strength. This pilot study reports up to a 21-fold difference in flexural bond strength between dry and water-saturated bricks. The findings of the study affirm the importance of moisture on the flexural bond strength in clay masonry construction and flexure design and suggest further investigation on full-scale models to ascertain the ramifications of inadequate preparation work on masonry.

Keywords: Dry clay bricks · Water saturated clay bricks · Wetted clay bricks · Flexural bond strength · Burnt clay bricks

1 Introduction

Studies have suggested the employment of burnt clay units around 10,000 years or so [1], demonstrating both engineering and architectural feats in terms of endurance, aesthetics and widespread use. Amongst some of the advantages of employing masonry units include excellent thermal mass. This property is especially beneficial in smoothening high and low temperature variations such as the alternation of day and night for the comfort of occupants dwelling in such units made from clay masonry [2]. The use of burnt clay masonry is expected to increase as South Africa faces a substantial shortage of low-cost homes for millions of people [3, 4]. The rapid population growth, combined with urbanization, is the key cause of housing problems in most developing countries. Those most vulnerable are the financially disadvantaged, who cannot afford monthly mortgage bond repayments [5] and rely on locally manufactured construction materials such as clay bricks to build their homes. To add to the challenge, the construction

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industry is widespread for skilled and unskilled, professional and unprofessional labour [6]. There is also lack of the necessary skills and expertise for both effective and efficient management of the industry, including masonry industry [7].

Street traders face numerous problems, including deprivation, unemployment, infrastructure shortages, lack of information about essential regulations and survival issues [8]. Quarrying activities contribute to the development of other informal business activities, such as small-scale trading of construction materials supporting the local community as an alternative means of living and transforming rural into urban activities [9]. It has been widely accepted that informal economic activities contribute to the economic growth, while also influencing/affecting the built environment [10]. Invariably, the increase in illegal small-scale activities comes from the growing national unemployment and personal hardship [11]. This has contributed to the rapid and unmonitored commercialization of building materials such as clay bricks. The informal economy is evident in various settings that involve lucrative operational activities in pavements, pedestrian malls and transportation interchanges. This market is a very difficult to label [12]. Some of these manufacturers do not evaluate the quality of production and are unaware of the standards' requirements when manufacturing construction materials [13] including clay bricks. The inability of manufacturers to comply with standards compromises the quality of construction materials and recommended production procedures, allowing the sale at a reduced price [14] and becomes preferable to public to save money in two ways: (1) unknowing the consequences of the choices they make or (2) desperate desire to save money at any cost.

While there exists approved laboratories to test building materials, at a cost, however, certain manufacturers chose to produce inferior products without the quality assurance. This disadvantages the diligent manufacturers. This affects various construction materials, including but not limited to: building sand, cement, brick force, clay bricks, concrete blocks, concrete lintels, hoop irons, plaster sand and wall ties. Although masonry is the oldest building material, the standardization of this material has always been behind concrete, structural steel and other building materials due to the wide variety of masonry elements and construction methods, etc. [15]. Poor workmanship may lead to poor-quality masonry walls, which could require testing to decide whether the structure is sound or not [16]. Factors such as lack of expertise and experience in the labour force, language differences between contractors and staff, insufficient resources and costs [17], are determined as what could lead to inferior masonry structures. Othuman Mydin et al. [18] also acknowledge that poor workmanship is a major factor in building flaws or accidents, and affects many buildings. Ali and Wen [16] also noted that the most significant contributor to low quality workmanship is the lack of work experience and expertise. Mitigation requires ensuring sufficient job preparation and education. Kamanga and Steyn [19] stressed the shortage of skilled workforce in South Africa is a generic problem. The success of the construction industry has been slowed by a lack of skills, which further affect building standards and materials and efficiency as well as improving social and economic infrastructure [20, 21]. The lack of these main elements, which includes preparation, transferring skills and possessing organisational knowledge leads to poor workmanship, substandard work performance and project failure [22]. According to Ali and Wen [16], labourers lacking experience and expertise are the key cause of poor workmanship. Adequate education and training are required for the proper use of construction materials such as clay bricks.

The construction sector is in need of quality/adequate training especially in construction materials and methods [23–25]. Governments have persistently been encouraged to provide or promote training that suits community needs [26–28]. It is evident that the construction industry desperately needs training on using construction materials such as clay masonry in order to ensure safe and durable structures. Some scholars [20, 29] warned that insufficient skills and expertise shortages hamper the growth of SA's engineering market, which has an impact on improving social and economic infrastructure, building standards and efficiency. Jordaan and Barry' [30] study revealed that South Africa has a shortage of qualified artisans due to frustration with the remuneration that causes them to leave the industry. Kamanga and Steyn [19] also reiterated the concern of the lack of qualified technical staff in the industry. In South African context, it is becoming clear that the construction should look into or begin accommodating unskilled and uninformed labour since they are an indelible component of the industry. This has been seen in Tanzania where informal construction firms provide work to both private customers and other contractors when opportunities occur [31]. Good quality and adequate training of how to use the materials correctly is necessary to achieve this. In South African context, SANS 227 recommends moistening burnt clay bricks prior to construction to improve the flexural bond strength between the bricks and mortar. In the informal construction industry, however, many uninformed and unskilled building applicators fail to comply with this recommendation. Hence, the objective of the study is to evaluate the flexural bond strength of prisms and report the difference between dry and water-saturated clay brick prisms.

2 Bond and Flexural Strength

Specifying and complying with technical standards such as water absorption capacity in masonry design and construction has influence for both bond performance and in turn, flexure for both planes of failure parallel and perpendicular to joints. Figure 1 demonstrates the influence of moisture absorption on various types of mortar class [32]. In essence, masonry units with inherently low water absorption capacity perform superior than 'thirsty' or high water absorption demand units. This, therefore, demonstrates the importance of pre-soaking or wetting of burnt clay bricks prior to laying of mortar beds. Moist curing of clay brick walls after construction of mortar beds also improves flexural strength [33] resulting in direct gain of tensile bond strength. Recently, Luso and Lourenço [34] demonstrated that the bond strength relates to several factors including: the coarseness of the substrate, the petrographic features of the masonry unit, the moisture content of the substrate, and the grout-mortar applied. Testing of brick prisms for flexural strength by Sarangpani et al. (2005) presented three types of flexural failure: (1) Failure at the brick-mortar interface indicating bond failure, (2) Failure of brick in flexure with the brick-mortar interface intact and (3) combination of above. Erratic climatic conditions such as high winds and rainfall may expose patent construction flaws in construction and may arguably manifest through collapse of say retaining and gable walls which serve important purpose in protecting occupants and property. Extreme weather trends and events are still expected [35] and this will test the endurance of our infrastructure in masonry walls and retaining walls. Complying with industry standards ensures minimum performance in infrastructure development. SANS 227 advises moistening burnt clay bricks before laying on mortar beds as this enhances the unit bond and thereby prevents brick detrimentally absorbing all moisture from the mortar, which deprives mortar of moisture necessary for the hydration of cement. As indicated in Fig. 1, clay bricks with low water absorption yield high bond strength. Bricks with high-water absorption produce a low bond strength. Between high (left) and low (right), the relationship is nonlinear.

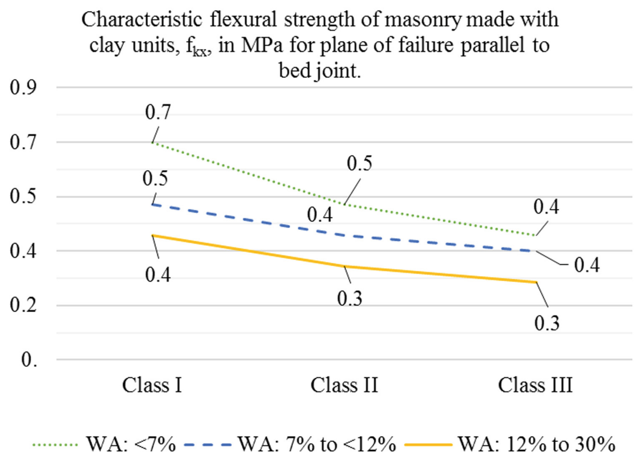

Fig. 1. Water absorption capacity versus flexural bond strength for various mortar classes.

3 Methodology

For the purposes of this study, locally available 14 MPa NFX (Non Facing Extra) hard burnt solid bricks were sourced from a small scale brick manufacturer to make evident the effect of substandard practices by contrasting dry versus water saturated burnt clay bricks. The bricks used were known to be excessively water thirsty based on previous industry experience and were confirmed to be 27% in accordance with clause 6.9 (water absorption test) of SANS 227 [36]. Three hundred and seventy two (372) bricks were subject to oven conditions at 105 °C until dry. Three hundred and sixty (360) clay bricks were soaked in water until fully saturated. In all, the study constructed 62 and 60 clay brick prisms between 2017 and 2020. The bricks comprised nominal dimensions of 220 mm in length, 103 mm in width and 75 mm in depth. Both dried and soaked bricks cooled for 24 h and 12 h to room temperature and dripped excess water naturally respectively. Prisms were constructed comprising six courses in stack bond fashion. A mixture of two parts sand to one part cement in volume was employed and water was applied to produce a workable mortar with a slump of 85 mm. Approximately 10 mm mortar bed thickness was used. The prisms constructed from pre-soaked bricks cured through sprinkling water for seven days. The dry bricks did not receive any curing. The various prisms were subject to two-point flexure load testing at 28 days in order to assess for flexural bond strength (Figs. 2, 3 and 4).

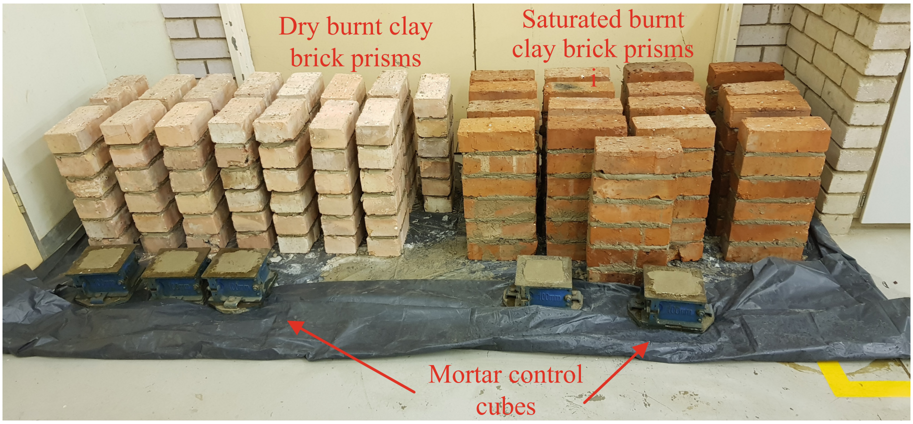

Fig. 2. Dry and 24 h soaked burnt clay bricks (last set for 2020).

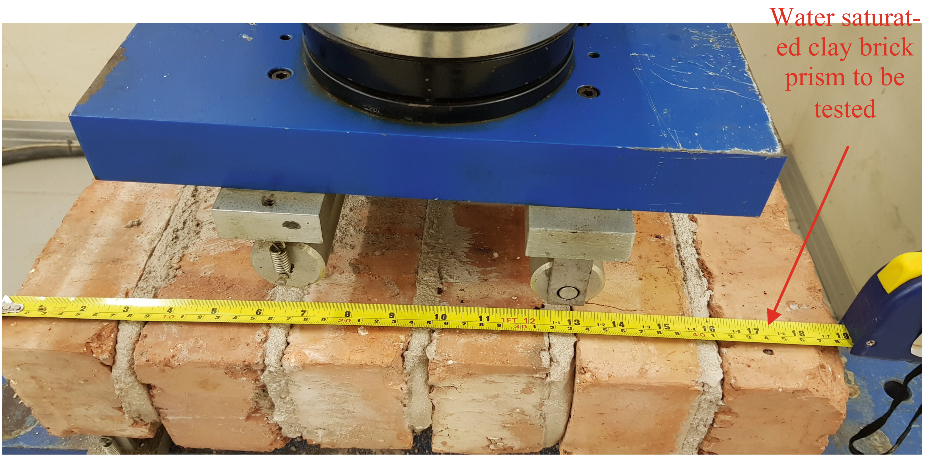

Fig. 3. Flexural bond test arrangement of water saturated burnt clay bricks prior to testing.

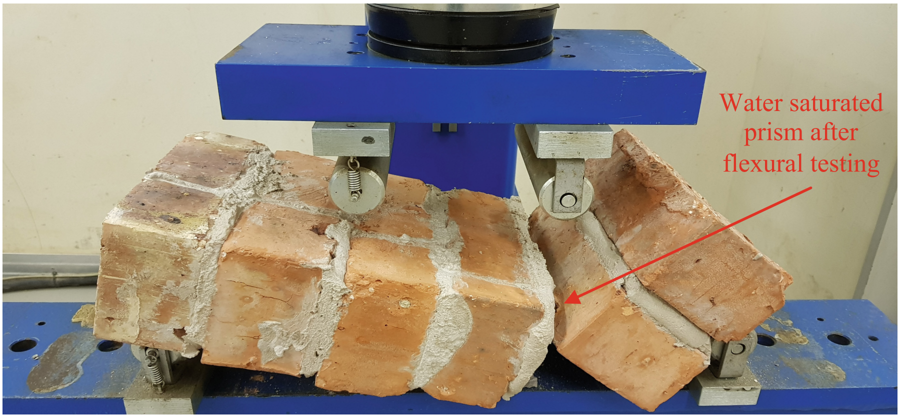

Fig. 4. Water saturated burnt clay brick prism after flexural bond testing.

4 Results and Discussion

In all specimens, failure occurred between the brick-mortar interfaces indicating bond failure. It is notable that prisms constructed from dry bricks performed dismally as indicated in Figs. 5 and 6. Collapse was observed either during manoeuvring and handling prior to load application or infliction of minimal of load. According to Maheri and Sherafati [37], the amount of water absorbed by the brick has an effect on the bond strength because it determines the amount of water transmitted from the mortar to the brick. This regulates the extent to which the mortar hydrates and the amount of hydration products transported and deposited in the masonry pores. The effect is visible. Not moistening and wetting clay bricks result in poor-quality mortar joints with respect to flexural bond strength.

Fig. 5. Dry laid burnt clay brick prism failure mode.

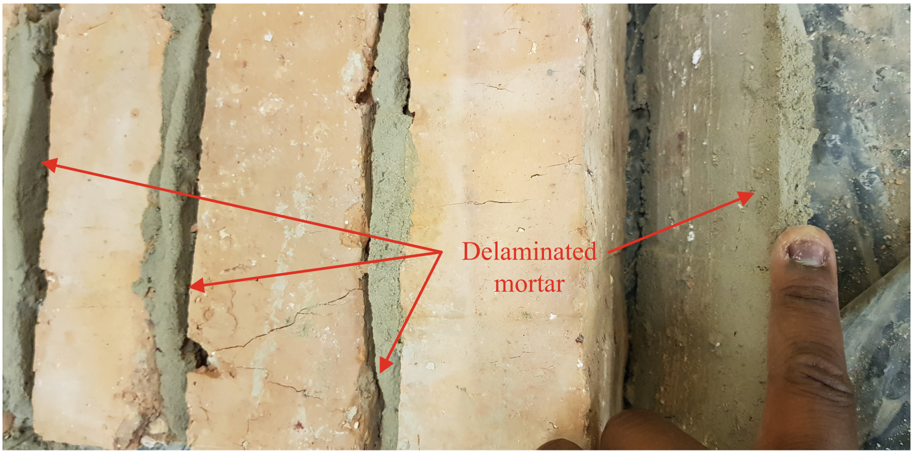

Fig. 6. Easy delaminated burnt clay prism.

The maximum stress supported by dry clay brick prisms was 0.03 MPa for both 2:1 and 3:1 mortar mix. This was due to self-weight with no additional significantly quantifiable stress from the beam press machine. The maximum (average) stress sustained by 24 h soaked clay brick prisms for 2:1 mortar mix was 0.33 MPa and 0.62 MPa for 3:1 mortar mix. A summary of the results are presented hereunder in Table 1. Luso and Lourenço [34] demonstrated that the bond strength correlates to the petrographic characteristics of the masonry structure, the moisture content of the substrate and the grout-mortar used. Moist curing of clay brick walls subsequently to construction of mortar beds also improves flexural strength [33], resulting in direct gain of tensile bond strength. The study executed curing. To achieving good quality mortar, the quality of each constituent is critical. The water retention and water content govern mortar bond strength. High water retention produces a high bond strength [38]. Mortar structure, mortar water retentiveness, brick surface texture, brick moisture content and brick surface absorption are factors influencing the interface bond [33]. Bond strength depends on the unit and mortar properties and the unit's moisture content when laying [39].

After excluding low-performing dry burnt clay brick prisms, Table 2 provides a summary of the average flexural bond strengths between 2017 and 2020.

5 Conclusion

Prisms constructed from 24-hour soaked clay bricks demonstrate between 11 (for 2:1 mix) and 21 (for 3:1 mix) fold superior flexural bond strength performance compared to prisms constructed from dry clay solid bricks. The notable loss of bond strength may be attributed to the weakness induced in the mortar beds as moisture is drawn by the thirsty dry bricks over time resulting in impediment to the hydration of the mortar and in turn, bond strength. Therefore, the importance of understanding and complying with technical specifications such as SANS227 to wet burnt bricks is emphasised in this study. Recommendations for further studies may extend to examine the effect of various wetting

Table 1. Summary of results for four batch of tests.

Year	Description	No. of prisms	Mix	Moisture absorption %	Bending stress (MPa)
2017	Dry	16	2:1	23	0.03[a]
	Wet	13	2:1	23	0.34
2018	Dry	17	3:1	24	0.03[a]
	Wet	17	3:1	24	0.59
2019	Dry	14	2:1	23	0.03[a]
	Wet	13	2:1	23	0.31
2020	Dry	15	3:1	22	0.03[a]
	Wet	17	3:1	22	0.65

[a] Stress at failure due to self-weight

Table 2. Final flexural bond stresses.

Description	Mix	Moisture absorption %	Bending stress (MPa)
Wet	2:1	23	0.33
Wet	3:1	23	0.62

durations and methods on the flexural bond strength of engineering units. The study's practical implications call for regular full-scale models to determine the ramifications of inadequate masonry preparation. The findings are limited to 14 MPa NFX (Non Facing Extra), hard burnt clay units with an excessively high-water absorption capacity of 27% prisms prepared and tested as specified in the study.

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Valuation Problems in Kenya: A Literature Review

Irene Cheloti(✉) and Manya Mooya

Department of Construction Economics and Management, Faculty of Engineering and the Built Environment, University of Cape Town, Cape Town, South Africa
irene.cheloti@gmail.com

Abstract. Property valuation problems, including valuation inaccuracies, client influence, and the use of heuristics, dominate valuation research internationally. These problems, mainly studied under behavioural valuation, have been observed to negatively affect the valuation profession worldwide. Although efforts have been undertaken to minimise valuation problems in Kenya, these problems persist. Accordingly, this paper explains why valuation problems exist and persist in practice. It discusses the problems of valuation practice in Kenya, which are expected to be similar to other developing countries; the various efforts undertaken to address the said problems; and the recommended measures to improve the valuation profession. This study reviewed extant literature on valuation problems in practice, the various strategies adopted by professional bodies and practitioners, and strategies recommended by researchers to deal with valuation problems. The study found that problems in valuation practice result from three main categories: valuer conduct/behaviour, market-related (valuation environment) problems, and problems related to the disjuncture between the normative basis of valuation and actual practice. Additionally, the study established that efforts to address these problems mainly focus on improving the conduct of the valuer while the other two factors are neglected. Consequently, this study concludes that practical valuation problems should be understood and explained in the context of the three main categories.

Keywords: Valuation problems · Developing countries · Valuer conduct · Market-related problems · Standard theory of valuation

1 Introduction

Property valuation is vital in the operation of property markets and the financial system as investment, development, and lending decisions rely heavily on the valuation function [8]. While the critical role of property valuation indicates the importance of accurate valuation outcomes, empirical studies under the topic of "behavioural valuation" found that property valuation problems such as valuation inaccuracies, inappropriate use of heuristics, and client influence exist within the valuation profession across the globe. These problems undermine valuers' professional credibility and reputation, negatively affecting the valuation profession worldwide.

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The extent and prevalence of valuation problems differ in developing and developed economies. Developed economies experience mature real estate markets with numerous well-informed buyers and sellers, numerous transaction activities, adequate market infrastructure, and sound land information management systems. However, developing nations are characterised by non-mature real estate markets, comprising market participants with poor information, few transaction activities, insufficient market infrastructure, and poor land information management systems [23]. Consequently, valuation problems are expected to be more conspicuous in developing nations than in developed nations [11].

Although professional bodies and researchers have established efforts to improve the valuation profession, property valuation problems in developing nations subsist. Research in developing nations duplicates those of their counterparts in developed nations, mainly focusing on behavioural valuation while suggesting measures to enhance the conduct of the valuer and improve the valuation profession. Little emphasis is placed on problems related to the valuation environment and problems related to the normative basis of the standard valuation theory. Given the valuation environment in developing countries, these nations' valuation problems arise from market-related problems, valuer conduct/incompetence, and problems related to the disjuncture between the normative basis of the standard valuation theory and reality.

Market-related problems result from the valuation environment in developing countries represented by poor information and other problems. While property markets are uncertain globally, the degree of uncertainty is expected to be greater in developing economies with developed economies experiencing low levels of uncertainty. According to Awuah et al. [7], the level of uncertainty is a major determinant of inaccuracies in valuation. Market-related problems in Kenya include poor information, high levels of corruption, and poor land information management systems [11]. These problems negatively impact the valuation industry leading to inaccuracies in valuation, clients' pressure and adoption of heuristics [11].

Valuer misconduct refers to valuers' unethical behaviour, including professional misconduct, negligence, or incompetence. These problems contribute to valuation inaccuracies and client influence. Lastly, problems related to the normative basis of the standard valuation theory refer to the disjuncture between the ideal environment as portrayed by the standard valuation theory and actual material conditions. For instance, while the standard valuation theory is embedded in neo-classical economics assuming a perfect market characterised by rational agents, full information, homogenous properties, and equilibrium, the actual property market is imperfect, characterised by agents with bounded rationality, limited information, heterogeneous properties, and multiple equilibria.

From a literature review perspective, the paper attempts to establish why valuation problems persist in Kenya while recommending appropriate measures to improve valuation practice. By deviating from previous studies and focusing not only on valuer conduct but on all three categories, the study provides better approaches to addressing property valuation problems in developing economies. This paper is organised into five sections. Section two focuses on research methods, while the third section introduces the reader to property valuation problems in practice. The penultimate section focuses on valuation problems in the Kenyan context, while the final section presents the study discussions and recommendations.

2 Research Methods

A systematic review of the scholarly literature was adopted for the study. This encompassed a review of existing publications, including textbooks, journals, and articles on valuation. Unpublished materials, i.e., scholarly journals, dissertations, research projects, and theses, relevant legislation, and regulations were also adopted. Additionally, newspaper articles and professional bodies' websites, were valuable.

The data was mainly obtained from online sources, including the University of Cape Town online library, Google Scholar, Taylor and Francis, Emerald, among others. Specifically, the review covers behavioural valuation and valuation problems in practice. In essence, the review focuses on why valuation problems persist, despite efforts undertaken by professional bodies and researchers to improve the practice of valuation. A holistic approach to addressing valuation problems in practice is recommended.

3 Property Valuation Problems in Practice

In this section, the study focuses on the main problems of valuation practice. These problems include valuation inaccuracies, client influence, and the use of heuristics.

3.1 Valuation Inaccuracies/Variations

Valuation accuracy refers to the ability of a valuation to correctly identify the target, i.e., the property's sale price or rent, while valuation inaccuracy is the converse [13]. Valuation variation is the ability to assess similar market values for two or more properties on the same basis at a particular point in time [7]. It measures valuation accuracy indicating differences between two or more valuations. For instance, high variations denote inaccuracies in valuation, while low variations signify valuation accuracy.

McGreal and Taltavull de La Paz [25] found that 94.26% of residential property valuations in Spain are either plus or minus 15% of the market value, suggesting a margin of error of 15%. They found that location and environmental factors are the key contributors to valuation variations in Spain.

According to Abidoye et al. [1], the main factors contributing to property valuation inaccuracies in Australia include inexperienced valuers; the selection and interpretation of comparable data; and the complexity of the subject property. Abidoye et al. [1] ranked the extent of client pressure as fourth, indicating that it is not the main factor contributing to valuation inaccuracies. Unavailability of data and lack of valuation standards were ranked twelfth and twentieth, respectively, indicating that these are not significant factors contributing to valuation inaccuracies [1]. This perhaps reflects the mature nature of the property market in Australia. The above studies focused on valuation inaccuracies in mature property markets (developed nations) and not developing countries that encounter information problems.

In developing countries, Awuah and Gyamfi-Yeboah [6] found high variations in valuation opinions among professional valuers in Ghana. They argue that valuation variations might be more pronounced in complex assignments. Similarly, Awuah et al. [7] found that valuation variation is relatively high in Sub-Saharan Africa compared to international evidence. The main factors contributing to valuation variations include poor information, unstandardised valuation methods, property complexities, and client influence [7].

The main factors contributing to valuation inaccuracies in Ethiopia include unavailability of data, inappropriate valuation techniques, lack of valuation standards, and unethical conduct of valuers [5]. In Nigeria, inadequate data, market imperfection, and client influence were seen as the main causes of mortgage valuation inaccuracies [2].

The above studies did not understand valuation problems in the form of the three main categorisations, i.e., market-related problems, valuer conduct, and problems related to the normative basis of the standard valuation theory. Further, strategies recommended to address valuation problems in the above studies are largely skewed towards improving the conduct of the valuer without much focus on addressing problems related to the other two categories.

While valuation inaccuracies is a global problem, it is more pronounced in developing economies, characterised by immature property markets with incomplete information [23]. However, developed nations demonstrate mature markets with a lot of information [23].

3.2 Client Influence

Client influence refers to situations where clients manipulate the valuation process for their benefit. This compromises the independence of the valuer, their objectivity and unbiased reporting leading to inaccuracies in valuation [31]. According to Mooya [26], clients usually have an interest in the reported value, more so in situations where their compensation depends on the valuation outcome.

Wilkinson et al. [34] established client pressure from the lending sector as a key problem affecting the valuation industry in Australia. Similarly, Klamer et al. [21] established that client influence is counterproductive to valuation practice in Netherlands. Kucharska-Stasiak et al. [22] attribute client influence to the valuation environment and the lack of compliance with the code of conduct in Poland.

Crosby et al. [12] found that property appraisals during the 2007 UK market downturn were influenced by clients affecting appraisal outcomes. Crosby et al. [12] believe that the UK is a mature and transparent commercial property market where professional bodies closely monitor appraiser's behaviour. They argue that client influence is exacerbated in immature property markets, where the valuation profession is less developed. Consequently, the findings of Crosby et al. [12] suggest that client influence may be conspicuous in less mature markets like those depicted in most developing countries, raising concerns about the quality of real estate appraisals in such markets. However, Crosby et al. [12] focused on a different environment, i.e., the downturn in the property market, and does not provide evidence on whether client influence would impact property markets in a normal environment.

In Africa, Ashaolu and Olaniran [4] found that client influence is a major problem in Nigeria as valuers succumb to this influence. They established major factors stimulating valuers to succumb to client influence to include collaboration between mortgagor and mortgagee's staff, client's disposition for inducement, survival instinct of the valuer, superior information power of the client, non-familiarity with the property location, lack of reliable data, and lack of confidence on reported values.

Mwasumbi [29] established that client influence affects mortgage valuations in Tanzania. Similarly, Oshiobugie et al. [32] found that client influence impacts mortgage valuations in Nigeria. Nwuba et al. [31] ranked the factors contributing to client influence in Nigeria from the most significant to the least significant to include corruption, fear to lose clients, greed, insufficient jobs, failure by regulatory bodies to sufficiently enforce disciplinary measures, valuers' unethical behaviour, inexperience of valuers, and the small size of most valuation firms. This finding indicates that valuers' behavioural characteristics are a major contributor to valuation inaccuracies in Nigeria.

Just like valuation inaccuracies, recommendations by the above studies to minimise client influence mainly emphasise enhancing valuer conduct without much focus on market-related problems and problems related to the normative basis of the standard valuation theory. Therefore, the studies did not understand client influence in the form of the three main categories. Client influence is expected to be more prominent in developing economies as opposed to developed economies due to the latter's poor information.

3.3 Use of Heuristics

Heuristics refers to rules of thumb that help people make decisions in complex situations or when faced with incomplete information [18]. Zrobek et al. [35] believe that the use of heuristics may sometimes lead to undesired results due to its generality and lack of precision.

According to Amidu et al. [3], property valuation is not a rational process. They believe that property complexity and unavailability of information necessitate the use of intuition/heuristics for effective decision-making in valuation. Also, Hansz [19] established the use of heuristics in the USA, where appraisers anchored on mortgage reference points contributing to inaccurate valuations.

Diaz [16] established that when working in familiar geographical areas in the USA, valuers were not influenced by previous valuation estimates. However, Diaz and Hansz [14] found that American appraisers working in unfamiliar geographical locations were influenced by previous valuations. Likewise, Diaz and Hansz [15] established that appraisers working in unfamiliar geographical areas in the USA were influenced by different reference points, such as the comparable and subject properties' uncompleted contract prices and previous valuations. Accordingly, these studies indicate that geographical unfamiliarity, characterised by poor information contributes to anchoring heuristic. Apparently, the use of heuristics is essential when assessing market value in environments with poor information.

Just like Diaz and Hansz [14] and Diaz and Hansz [15], Zrobek et al. [35] found that anchoring heuristic is pronounced in unfamiliar locations and less pronounced in familiar environments in Poland. Zrobek et al. [35] established that valuers were influenced by previous valuations and negotiated property transaction prices. This finding confirms that inadequate information provokes the use of anchoring heuristic while a lot of information reduces this type of heuristic.

Evidently, appropriate use of heuristics is useful in environments with poor information, while its inappropriate use leads to inaccurate valuations. The use of heuristics is expected to be more conspicuous in developing economies due to poor information in such areas. The above studies recommend measures to improve the valuation practice that mainly emphasise on the improvement of the conduct of the valuer (such as establishing local valuation standards while ensuring their strict enforcement) with little emphasis on market-related problems and problems related to the normative basis of the standard valuation theory.

4 Valuation Problems: The Kenyan Context

Just like in the rest of the world, problems of the valuation practice in Kenya include valuation inaccuracies [17], client influence [10], and the use of heuristics [18]. Additionally, valuers in Kenya face problems that are similar to other developing economies, such as poor information. For instance, the country does not have a central database of comparable information [17]. Other problems affecting the valuation profession in Kenya include corruption, non-enforceability of zoning regulations, poor land information management systems, and inadequate valuer training [27, 30]. These problems contribute to valuation inaccuracies.

Cheloti and Mooya [11] found market-related problems, i.e., limited and unreliable information as the leading cause of valuation inaccuracies in Kenya. Factors contributing to valuation inaccuracies in their order of importance include limited and unreliable information, corruption, poor land information management systems, and valuer misconduct [11]. This indicates that while market-related problems majorly contribute to inaccurate valuations in Kenya, valuer misconduct is not the leading cause of valuation inaccuracies in the country.

Land is an emotive subject in Kenya, with its information closely guarded, presenting challenges in obtaining comparable market rates [27]. Not only is comparable information in Kenya limited, but it is also unreliable [30]. According to Ndungu et al. [30], comparable sales data in Kenya rarely has sufficient information on market value determinants. Further, property values are usually under-declared at Kenya's land registry to pay low stamp duty. Additionally, the stamp duty determination exercise is non-transparent and is hampered by corruption [30]. Reliance on such figures as comparable information may lead to misleading valuations. Mwangi [27] reported corruption as the most significant factor affecting the valuation profession in Kenya. Procurement managers in government institutions and bank credit managers were reported to demand bribes from valuers and dictate valuation figures [27].

Further, Kenya is characterised by non-enforceability of planning regulations [30]. This leads to inconsistent developments, over-development of properties and change in users. Property values in such areas increase, reflecting the speculative Highest and Best Use (HBU) and inflated market values [30].

Additionally, owing to the manual record-keeping system, land records at the Kenya's Ministry of Lands & Physical Planning are either missing or outdated. Furthermore, some of these records are deliberately tampered with, making it difficult for valuers to access information [27]. Therefore, undertaking due diligence, which is a significant component of valuation work in Kenya, becomes challenging. Further, Mwangi [27] argues that valuer education and training in Kenya is inadequate and out of date.

The above market-related problems contribute to valuation inaccuracies and undermine valuers' professional credibility and reputation [9]. Criticisms of the accuracy of valuation advice in Kenya are common, with increasing complaints from clients and the general public.

Efforts to adopt good valuation practices have been underway in Kenya. For instance, the country subscribes to International Valuation Standards (IVS) [30]. Additionally, the Institution of Surveyors of Kenya (ISK) recently launched Kenya Valuation Standards (KVS), which is expected to streamline the valuation profession through enhanced valuer conduct and reduced valuation inaccuracies/variations [20]. Further, the ongoing review of the Valuers Act 1985 [33] is expected to empower the Valuers Registration Board (VRB) to regulate the valuation profession properly.

The above measures of improving valuation practice mainly focus on improving valuer conduct with minimal focus on market-related problems and problems related to the normative basis of the standard valuation theory. Some of the measures adopted by the government to improve access to information include the ongoing digitisation of land records with the Nairobi registry close to completion; and the ongoing development of the land value map under the Land Value Amendment Act [24].

Despite the above efforts, valuation problems in Kenya persist. Therefore, the current approach of explaining valuation problems and efforts to minimise these problems in the context of valuer conduct may not be sufficient. There is a need to redirect valuation research to a holistic approach, one that explains property valuation problems with reference to not only valuer conduct, but also market-related problems, and problems related to the normative basis of the standard valuation theory.

5 Valuation Problems in Practice: Discussions and Recommendations

Valuation problems in practice have been researched widely under behavioural valuation. These problems negatively impact the valuation profession globally. Most previous studies explain valuation problems with reference to valuer conduct while paying little attention to market-related problems and problems related to the normative basis of the standard valuation theory.

Unlike developing economies that portray non-mature property markets with poor information, developed economies exhibit mature property markets with a lot of information. In essence, market-related problems such as poor information are significantly reduced in developed countries. Despite the different market environments, previous research in developing nations duplicates those of developed nations, mainly explaining valuation problems concerning valuer conduct with minimal emphasis on the valuation environment in developing countries.

Accordingly, measures to improve the valuation profession mainly focus on enhancing the conduct of the valuer without much focus on minimising market-related problems and problems related to the normative basis of the standard valuation theory. Measures directed towards the improvement of valuer conduct in Kenya include establishing and enforcing valuation regulations and standards, training valuers, and effecting disciplinary measures in situations of gross misconduct [20, 33]. Ongoing efforts to minimise market-related problems by improving information availability include digitisation of land records and the development of the land value map [24, 28].

This study recommends a holistic approach of dealing with practical valuation problems based on the three categories, i.e., market-related problems, valuer conduct, and problems related to the normative basis of the standard theory of market value.

In addressing market-related problems, the country should develop an up-to-date central database of comparable information and fast-track the development of the land value map under the Land Value Amendment Act [24]. Further, the professional body, ISK, should spearhead the development and maintenance of a central database of comparable information. Secondly, there is a need for an up-to-date computerised land information system that guarantees the accuracy of information. The National Land Information Management System (NLIMS), a government initiative that involves the digitisation of land records, which is ongoing, should be fast-tracked. Finally, the outdated zoning regulations should be revised and aligned with the current approved trends while ensuring enforcement of the same.

In responding to problems related to the normative basis of the standard valuation theory, i.e., the gap between the normative/ideal environment as postulated by the standard valuation theory and reality, the study recommends that further research be directed towards exploring alternative theoretical frameworks. The alternative theory of market value developed by Mooya [26] and other alternative theoretical frameworks should be widely tested, applied or subjected to empirical validation in different contexts.

Finally, to address valuer misconduct, the study recommends better standards, regulations, and their enforcement to govern the valuation practice. This includes, among others, enforcing the KVS, fast-tracking the review of the Valuers Act 1985 [33], and promoting the professional conduct of valuers through enhanced standards and regulations, ethical code of conduct, and practical training of valuers.

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Barriers to Knowledge Management Capabilities of Quantity Surveying Firms in an Emerging Market

Victoria Adekola[1], Sunday Odediran[1](✉), Olubola Babalola[1], and Clinton Aigbavboa[2]

[1] Department of Quantity Surveying, Obafemi Awolowo University, P.M.B. 013, Ile-Ife 220282, Nigeria
sjodediran@oauife.edu.ng

[2] Faculty of Engineering and the Built Environment, University of Johannesburg, 37 Nind St., Doornfontein, Johannesburg 2094, South Africa
clinton.aigbavboa@uj.ac.za

Abstract. Managing knowledge to improve service delivery in business operation is becoming essential on daily basis. However, certain barriers limit the implementation of knowledge management capabilities of firms, hence this study. This paper examines sources of knowledge and barriers to knowledge management capabilities of quantity surveying firms in Oyo State, Nigeria with a view to enhancing quality service delivery. With a quantitative research approach, data were purposively collected using copies of questionnaire administered on 14 quantity surveying firms in Oyo State, Nigeria. Statistical tools use for data analysis include frequency distribution, mean score and analysis of variance. The results obtained show that these firms obtained knowledge through superior in the profession (M = 4.09), personal knowledge (M = 4.03), colleagues experience (M = 4.00), books (M = 3.97), conference and event (M = 3.97) and regular meeting attendance (M = 3.94). However, top ranked barriers hindering knowledge management capabilities of quantity surveying firms include difficulty in locating knowledge (M = 4.66), trying to solve large problems (M = 4.03), lack of cooperation amidst employees (M = 3.81), lack of effective communication amidst employees (M = 3.75), uniqueness of projects (M = 3.75) and lack of time (M = 3.71). The study concludes that cooperation and communication among employees are hindering knowledge management capabilities of quantity surveying firms.

Keywords: Knowledge · Management · Capabilities · Quantity surveying · Market

1 Introduction

Decades ago, professionals in the teaching line as well as practitioners have pointed out the advantages of knowledge. Nowadays, knowledge is the fundamental basis of competition [1]. It is however essential that knowledge has to be managed effectively to yield a meaningful product because knowledge alone cannot guarantee a strategic

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advantage. Having knowledge is not enough but the ability to manage the knowledge matters [1]. However, it is said that during the formative age, firms that come up with novel knowledge and effectively put it into use efficiently, will be successful at creating viable advantages. From a practical perspective, [1] supported this view by stating that, firms are noticing the importance of managing knowledge if they want to remain competitive while [2] advanced the statement by saying that firms that are managing their growth will enhance their chances of survival in the construction market. So, having realized all these, companies have come to terms that it's expedient to actively manage their knowledge and intellectual capital [3].

Knowledge management on its own is a process of systematic management of vital knowledge and the processes associated with it, which include creating, gathering, organizing, diffusion, use and exploitation [4]. It entails turning personal knowledge into corporate knowledge that can obviously be widely shared throughout the organisations. All organisations are entailed with information and knowledge. The problem is that it is invisible and most people in organisations simply do not know what their colleagues know. The organisations do not know what their employees know, nor do they have any way to find out or organize it [4]. According to [5], knowledge management is also a process of systematic management of vital knowledge and its associated process of creating, gathering, organizing, diffusion, use and exploitation. Knowledge management has turned into an increasingly important issue due to a swift change in market conditions, competition and technological developments, which have caused a great change in the way work is organized. The intellectual capital of individuals and teams are presented in a tangible form that facilitates the adding of value to the organization and ultimately its customers [6].

Knowledge management is particularly important for quantity surveyors, for at least three main reasons. Firstly, it is needed to increase the level of productivity [7, 8]. Hence, there is a need for quantity surveyors to improve the existing processes and management of their firms. Secondly, the project-based nature of the quantity surveying firm has made it particularly important to record and transfer lessons from one project to another [9]. Thirdly, quantity surveying firms today face various challenges and new solutions are necessary to meet the growing demands for new types of buildings and structures [10].

Significant number of these studies examined sources and classification of knowledge as well as the factors influencing knowledge management. However, there appears to be inadequacy in the available of studies on knowledge management in the Nigerian construction industry because most of the studies failed to examine the views of all professionals in the industry. Moreover, existing studies failed to cover all geographical locations especially in the Southwestern region in the country. Hence, this study will assess the sources as well as barriers to knowledge management capabilities of quantity surveying firms in Oyo State, Nigeria.

2 Review of Literature

This section of the paper presents review of literature on knowledge management, sources of knowledge, and barriers to knowledge management capabilities.

2.1 Knowledge Management

According to [11], knowledge management is a process, which enables organisations to learn, create, develop and apply necessary knowledge. Reference [12] also affirmed that knowledge management is often used to describe the processes through which an organization develops, organizes, and even shares knowledge to cope well and achieve its comparative advantage. The major aim of knowledge management strategies is to facilitate learning and the creation of new knowledge by teaching individuals where to find appropriate knowledge, where to use and apply it effectively and to share and disseminate it appropriately [13]. According to [14], knowledge management is the systematic and organised attempt to use knowledge within an organization to improve its performance. Knowledge management could also be defined as a discipline with the aim of improving the growth of knowledge or a means by which knowledge is communicated, and the way the acquired knowledge is preserved within a firm [6] to achieve a better exploitation of this very importance and essential resource.

The primary aim of knowledge management in any organization is to tap knowledge form all members of the organization and manage it to enable all members to share and access the resource without complications. With all these definitions, we are able to conclude that knowledge management has to with synthesis of different procedures, activities, processes, technologies and field of study needed to bring about a capable and sustainable environment enabling knowledge to be celebrated and exploited to create a value for the organization. Thus, and in generic terms, the aim of knowledge management practices entails to maximize organizational and individual knowledge by extracting tacit or implicit knowledge and convert or translate these into explicit knowledge, which can then be interpreted, represented, codified, stored, retrieved, shared and disseminated [15].

2.2 Sources of Knowledge

A research carried out by [4] on knowledge management practices among construction professionals in Nigeria revealed that knowledge for quantity surveying firms can be sourced through the following ways including personal experience, colleagues' experiences, internal courses, external courses, interaction with outside parties, research and development departments, company libraries, and other sources like internet, journals and books. The study also revealed that personal experience and colleagues experience is very important, internal and external sources is moderately important, interaction with outside party is important, company libraries and internet/journals is least important, while others as not important. Based on the data obtained, it was agreed that the listed sources of knowledge management is based on human and this means that the staff needs to acquire knowledge through personal experience, linkages with others and interactions. Thus, colleague's experience is still a very vital source that is readily available to the construction professionals as they rely much on interaction among themselves. It was also believed that personal knowledge management should be enhanced.

2.3 Barriers to Knowledge Management Capabilities

According to [4], there are many other barriers to the successful implementation of knowledge management within a construction enterprise which include lack of time, trying to solve large problems, converting knowledge, large number of small and medium enterprises (SMEs), multi-disciplinary teams, unique projects; lack of learning, lengthy time period, loss of faith and IT support. Reference [4] also highlighted influencing factors to include funding, lack of time and understanding of knowledge management, lack of proper technical expertise, lack of adequate and up to date data, lack of successful knowledge management model in the construction industry, lack of effective communication among construction professionals, difficulty in capital valuing intellectual, lack of cooperation among construction professionals, misunderstanding knowledge management with information management, government policies, difficulty generalizing & storing knowledge, unwillingness to change current operating system, difficulty in capturing knowledge, unwillingness of employee to share knowledge and difficulty in locating knowledge.

According to [16], a factor such as cultural barriers was given where a typical construction organization does not encourage the culture of sharing knowledge. Primarily, the culture of the organizations needs to be addressed if KM is to be of benefit. Each organization has its individual culture and a system needs to be set up to encourage a change in culture. Another factor is lack of time. Sharing of knowledge demands additional effort. This effort may be minimized by work practices and the introduction of better knowledge sharing tools. Construction projects always requires working to tight deadlines and anything that detracts from the main business is seen as of diminished importance.

Also trying to solve large problems tends to be a barrier as well. The various stages involve in KM are complex. It is easy to envisage the ultimate world of delivering knowledge to different members of the project team as at when required for different stages of the construction process. However, in reality, for a company embarking on knowledge management, it is best to undertake very small projects that are self-contained with little input from external parties. Another major barrier is converting knowledge. One substantial obstacle is how organizations capture knowledge on projects that cuts across organizational boundaries. The industry is full of individuals, skilled trade workers and professionals who have years of experience of doing specific tasks. Converting their tacit knowledge to explicit knowledge for the benefit of others is a problem, which is difficult to conduct within a reasonable period and at an acceptable cost.

Large number of SMEs can also stand as a barrier. The Nigerian construction industry consists of a large proportion of small to medium-sized enterprise (SMEs). These organisations have more pressing concerns than knowledge management and, in many cases, do not see the need nor do they have the commitment and resources to undertake knowledge management. Multi-disciplinary team also influences KM as some project team members may belong to different divisions or even different companies. Managing knowledge with such a team within a limited period is difficult. Each team member will be working towards the agenda set by their employer. The benefits of knowledge management may be seen as limited to the life of the individual project unless in long-term partnering type relationships.

Uniqueness of a project affects knowledge management capabilities. Despite efforts to encourage the Nigerian construction industry to view itself as a manufacturing enterprise, it still regards each project as a one-off. This reinforces the view that knowledge management on individual projects will be wasted as the next project may be quite different. Another barrier is lack of learning system and this is because of the view that the industry produces unique projects. There has also been a failure to learn from past mistakes. In many circles, the Nigerian construction industry is regarded as a national (rather than international) industry and there is no willingness to learn from internal and external sources.

Lengthy time period tends to influence knowledge management is a long-term goal without any short cuts. If it is to bring long-term benefit to the organization, it will take a considerable period to have systems up and running with sufficient time to be validated and for benefits to percolate to the organization's performance. Lastly according to [16], loss of confidence can be a barrier as well. With knowledge management systems available, employees may be tempted into thinking that the data required is always easily accessible. In fact, it will take considerable time to get a spread of working KM systems. This may lead to employees losing confidence in the system because it does not deliver immediately benefits in their own individual areas.

3 Research Methodology

The section focusses on the research designs, study population, the sample size and techniques, methods of data collection and the tools for data analysis necessary in achieving the research objectives. A quantitative method was employed in this study using questionnaire. The population for this study was practising consulting quantity surveying firms in Oyo State, Nigeria. According to the Quantity Surveyors Registration Board of Nigeria (QSRBN) (2017), there are 14 practising quantity surveying firms in Oyo State. This constituted the population for this study. This study employed total numeration technique in selecting the sample size due to limited number of practicing quantity surveying firms in the study area. Therefore, the sample size for this study was 14 practising quantity surveying firms in Oyo State. In order to increase the sample size and get a reasonable response, three copies of questionnaire were administered in each of the firms.

The questionnaire was carefully designed in such a way that each question will be stated clearly, precisely, simple and understandable. The questionnaire was administered to employees in the quantity surveying firms in the study area. In addition, the questionnaire survey was done in such a way that it provided the respondents with an ample time to scrutinize the questions in order to attempt it appropriately. The questionnaire was divided into sections. Section A addressed the background profile of the respondents and firms. Section B addressed the sources of knowledge and barriers to knowledge management capabilities of quantity surveying firms. In order to analyse the data collected through copies of questionnaire administered, IBM Statistical Package for Social Sciences (SPSS) software was used. However, descriptive and statistical tools such as frequency description, mean score and analysis of variance were employed in analyzing the data collected.

4 Results and Discussion of Findings

The section presents the data collected, analysis carried out, and results generated as well as a discussion of findings.

4.1 Background Profile of the Firms and the Respondents

This section presents the general profile of the firms and the respondents. The results in Table 1 show the general information about the firms and the respondents. It emerged that 21.9% of the respondents are MD/Principal Partner of their firms, 18.7% are Senior Employee while 59.4% are Junior Employee. For their professional memberships, it further showed that 59.4% of the total respondents are probationer members of the Nigerian Institute of Quantity Surveyors (NIQS) while 34.3% and 6.3% are corporate members (MNIQS) and fellow members (FNIQS) respectively. The table also shows the professional registration of the respondents and it emerged that 40.6% registered with Quantity Surveyors Registration Board of Nigeria (QSRBN) and 59.4% are not registered with QSRBN. The table also indicates the year of work experience of respondents. The results show that 62.5%, 12.5%, 9.4%, 6.3%, 3.1%, 6.3% had work experience between 0 and 5 years, 6 and 10years, 11 and 15years, 16 and 20 years, 21 and 25 years, above 25 years respectively.

Also presented in the table are the number of employees in each of the firms and the results reveals that 84.4% have between 0–5 numbers of employees while 15.6% have 6–10 numbers of employees. The table also established the highest academic qualification of all the respondents. A total of 12.5% are holders of Ordinary National Diploma (OND), while 31.3% hold Higher National Diploma. A total of 40.6% are holders of Bachelor of Science/Bachelor of Technology (B.Sc./B.Tech) while 6.3% and 3.1% hold Masters of Science/Master of Technology (M.Sc./M.Tech) and Doctor Philosophy (Ph.D.) respectively.

4.2 Sources of Knowledge

The responses and information gathered about the sources of knowledge employed by quantity surveying firms in the study Oyo State, Nigeria are presented in Table 2. The results obtained show the average mean and rank with respect to the designation of the respondents as well as the overall ranking of sources of knowledge among quantity surveying firms in the study area. From the table, the top five high ranked sources of knowledge management include through the superior in the profession (MS = 4.09), personal knowledge (MS = 4.03), colleagues experience (MS = 4.00), books (MS = 3.97) and conference and events (MS = 3.97). The least ranked five sources are interaction with outside party (MS = 3.47) external courses (MS = 3.47), internal courses (MS = 3.25), research and development (MS = 3.06) and company libraries (MS = 2.81). These sources were moderately ranked.

The respondent's view was tested using ANOVA, the result shows that only three out of 19 sources examined established that there is a significant difference in the way they perceived those sources of knowledge. These sources include interaction with outside parties ($P \leq 0.01$), external courses and internal courses ($P \leq 0.05$). However, the results from this study are justified by Oke et al. [4] who claimed that personal knowledge and colleague experiences are very important, internal and external courses are moderately important, interaction with outside party is moderately important while company library is least important.

Table 1. Background profile of the firms and the respondents

Profile of the respondents	Frequency	Percentage
Designation of the respondents		
MD/principal partner	7	21.9
Senior employee	6	18.7
Junior employee	19	59.4
Total	**32**	
Professional membership of the respondents		
Probationer	19	59.4
MNIQS	11	34.3
FNIQS	2	6.3
Total	**32**	
Professional registration of the respondents		
Registered with QSRBN	13	40.6
Not registered with QSRBN	19	59.4
Total	**32**	
Year of work experience of the respondents		
0–5 years	20	62.5
6–10 years	4	12.5
11–15 years	3	9.4
16–20 years	2	6.3
21–25 years	1	3.1
Above 25 years	2	6.3

(*continued*)

Table 1. (*continued*)

Profile of the respondents	Frequency	Percentage
Total	**32**	
Numbers of employees in the firms		
0–5 numbers	27	84.4
6–10 numbers	5	15.6
Total	**32**	
Highest academic qualification of the respondents		
OND	4	12.5
HND	10	31.3
PGD	2	6.3
B.Sc./B.Tech	13	40.6
M.Sc./M.Tech	2	6.3
Ph.D.	1	3.1
Total	**32**	

4.3 Barriers to Knowledge Management Capabilities

The responses and information gathered about the barriers to knowledge management capabilities of quantity surveying firms in the study Oyo State, Nigeria are presented in Table 3. The result shows the average mean and rank of respondents.

Table 2. Sources of knowledge

Sources	Overall		MD/principal partner		Senior employee		Junior employee		ANOVA	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	F	Sig
Superior in the profession	4.09	1	3.86	5	4.60	1	4.05	2	0.70	0.56
Personal Knowledge	4.03	2	4.29	2	4.40	2	3.84	10	1.12	0.36
Colleagues experience	4.00	3	4.29	2	4.40	2	3.79	13	1.31	0.29
Books	3.97	4	3.57	12	3.80	9	4.11	1	0.88	0.46
Conference and events	3.97	4	3.71	9	4.20	5	4.00	4	0.38	0.77

(*continued*)

Table 2. (*continued*)

Sources	Overall		MD/principal partner		Senior employee		Junior employee		ANOVA	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	F	Sig
Regular meetings	3.94	6	3.86	5	3.60	11	4.00	4	0.42	0.74
Emails	3.94	6	3.86	5	3.40	14	4.05	2	1.41	0.26
Data bases	3.91	8	3.86	5	4.00	8	3.84	10	0.64	0.59
Seminars	3.91	8	3.71	9	4.20	5	3.84	10	0.39	0.76
Journal and books	3.88	10	3.71	9	4.20	5	3.89	8	0.53	0.66
Peer tutoring	3.88	10	3.57	12	4.40	2	3.79	13	1.23	0.32
Internet	3.75	12	3.29	15	3.60	11	3.89	8	0.87	0.47
Letters	3.72	13	3.14	16	3.40	14	3.95	7	1.46	0.25
Events	3.72	13	3.14	16	3.40	14	4.00	4	1.37	0.27
Interaction with outside party	3.47	15	3.43	14	2.80	18	3.79	15	4.89	**0.01**
External courses	3.47	15	4.29	2	3.80	9	3.16	16	3.78	**0.02**
Internal courses	3.25	17	4.43	1	3.60	11	2.79	19	3.37	**0.03**
Research and development department	3.06	18	2.86	18	3.40	14	3.05	17	0.17	0.92
Company libraries	2.81	19	2.71	19	2.60	19	2.84	18	0.29	0.83

The top five high ranked barriers to knowledge management capabilities of quantity surveying firms in the study area are difficulty in locating knowledge (MS = 4.66) which was rated very high while trying to solve large problems (MS = 4.03), lack of cooperation amidst employees (MS = 3.81) and lack of effective communication amidst employees then unique project (MS = 3.75). The least ranked five factors are multi-disciplinary team (MS = 3.44), government policies (MS = 3.44), large numbers of SMEs (MS = 3.44), cultural activities of the firm have (MS 3.41) and failure to learn from past mistakes (MS = 3.38) ranked moderate.

The respondents' views were tested using ANOVA and the results showed that there is no significant difference on the perceptions of the respondents on barriers to knowledge management capabilities of quantity surveying firms in the study area ($P \geq 0.05$). The results agreed with the opinion of Oke et al. [4], which affirmed that quantity surveying firms do not encourage the culture of sharing knowledge due to lack of knowledge sharing tools.

5 Conclusion and Recommendations

Based on the findings from this paper, it is concluded that quantity surveying firms in Oyo State are sourcing for knowledge through consultations with the superior and colleagues in the profession as well from personal knowledge and consultations with book including attendance in conferences and events. Barriers confronting the knowledge management capabilities of quantity surveying firms in the study area are associated with knowledge location, size of problem requiring solution, cooperation and communication among employees. Based on the above conclusions, the paper recommends the need for:

i. Quantity surveying firms to improve consultations among relevant stakeholders across different job categories to improve and distribute stock of knowledge in the firms.
ii. Quantity surveying firms should put in place a system to easily locate knowledge, simplify tasks when solving problem and improve on interpersonal relationship within firms to enhance knowledge management capacities of firms.

Table 3. Barriers to knowledge management capabilities

Factors	Overall mean		MD/principal partner		Senior employee		Junior employee		ANOVA	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	F	Sig
Difficulty in locating knowledge	*4.66*	1	3.26	16	3.00	15	4.68	1	1.50	0.25
Trying to solve large problems	*4.03*	2	3.86	3	3.80	4	4.11	2	0.61	0.62
Lack of cooperation amidst employees	*3.81*	3	4.43	1	2.80	17	3.79	3	2.55	0.08
Lack of effective communication amidst employees	*3.75*	4	4.14	2	3.40	9	3.68	9	0.85	0.48
Unique Project	*3.75*	4	3.71	6	3.80	4	3.79	3	0.27	0.85
Lack of time	*3.71*	6	3.00	19	4.60	1	3.74	7	1.73	0.18

(*continued*)

Table 3. (*continued*)

Factors	Overall mean		MD/principal partner		Senior employee		Junior employee		ANOVA	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	F	Sig
Funding	*3.69*	7	3.86	3	4.00	3	3.47	14	0.77	0.52
Life span of projects	*3.56*	8	3.00	19	3.60	7	3.74	7	0.91	0.45
Difficulty in generalizing & storing knowledge	*3.53*	9	3.43	12	2.80	17	3.79	3	1.45	0.25
Knowledge capturing	*3.53*	9	3.71	6	3.60	7	3.47	14	0.24	0.87
Inadequate data	*3.53*	9	3.29	16	3.40	9	3.63	11	0.26	0.85
Inadequate technical expertise	*3.50*	12	3.00	19	3.20	12	3.79	3	1.35	0.28
Knowledge sharing tools	*3.50*	12	3.43	12	3.20	12	3.63	11	0.53	0.67
Inadequate IT support	*3.50*	12	3.57	8	3.40	9	3.42	18	0.90	0.46
Multi-Disciplinary Team	*3.44*	15	3.43	12	2.60	19	3.68	10	0.77	0.52
Government policies	*3.44*	15	3.57	8	2.40	23	3.63	11	1.95	0.15
Large numbers of SMEs	*3.41*	17	3.57	8	2.60	19	3.47	14	1.91	0.15
Cultural activities of the firm	*3.41*	17	3.86	3	3.20	12	3.21	21	1.84	0.16
Failure to learn from past mistakes	*3.38*	19	3.43	12	4.20	2	3.11	23	0.86	0.47
Learning system	*3.28*	20	2.71	23	3.80	4	3.37	19	0.80	0.51
Knowledge management model	*3.22*	21	3.29	16	2.00	24	3.47	14	2.70	0.07
Lengthy period of time	*3.19*	22	3.00	19	2.60	19	3.37	19	1.41	0.26
Converting of Knowledge	*3.16*	23	3.57	8	3.00	15	3.16	22	0.49	0.69
Loss of faith	*2.94*	24	2.71	23	2.60	19	3.00	24	1.60	0.29

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Overcoming Communication Complexities on Construction Site

Heinrich Carl Schmidt[1] and Fredrick Simpeh[2(✉)]

[1] Department of Quantity Surveying and Construction Management, University of the Free State, Bloemfontein, South Africa

[2] Department of Construction and Wood Technology Education, Akenten Appiah-Menka University of Skills and Entrepreneurial Development, Kumasi, Ghana

fsimpeh@aamusted.edu.gh

Abstract. There are various ethnicities and cultures within South Africa's construction industry, which frequently lead to ineffective communication or miscommunication. The purpose of this research is to determine the root cause of communication problems on South African construction sites and how such communication challenges can be addressed. A qualitative research method was used in this study. Interview was used as an instrument to collect the data. Purposive sampling was used to select the target population – practicing construction or site managers who actively engage and supervise the work force on the job site. The thematic approach to analyzing qualitative data was used to analyze the collected data. The study found that the main causes of miscommunication is the lack of language and verbal communication proficiency, overload of information or instructions, cultural differences, intrinsic characteristics, and poor cell phone network. It also become evident that approaches including the use of interpreter, training, and the development of construction 'Fanagalo' could be adopted to mitigate these communication challenges. The study proffer strategies that can help to attain effective communication on site. Secondly, it contributes to the body of knowledge in the field of construction communication. This study was limited to selected construction firms in Bloemfontein; however, the strategies proffered could be adopted/adapted in other provinces.

Keywords: Communication · Construction site · South Africa · Workforce

1 Introduction

Globalization contributes to diversity. As the world has become 'small', so has the workforce, which has evolved into a diverse multicultural group of workers. Therefore, it has become critical to recognize the ever-increasing diversity of the workforce in terms of language and culture. This opens up the debate around effective communication. Communication can be viewed as a pipeline for passing knowledge from one person to the next. Good communication is the effective sharing of information, meaning, thoughts, and feelings between people. When communication is effective, the communicator is

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able to explain themselves in a clear manner, and the person with whom they are communicating understands what they mean [1]. Communication challenge is a major concern, particularly where diverse group of people work such as on construction site. The nature of construction project makes communication complex on site. Consequently, the construction sites present unique communication challenges. These difficulties arise as a result of the large number of people who work and come together for often brief periods of time; additionally, the disparity in each person's discipline has a significant impact [2]. Moreover, the diversity of stakeholders and participants involved in a construction project adds to the communication complexities [3]. Reference [4] found that poor communication results in the failing of small and medium construction firms in the Free State province. The Project Management Institute [2] revealed that the lack of communication leads to project failures. This makes effective communication critical in the construction industry [2].

South Africa, which is the context of this study, is an excellent example of a diverse workforce. The South African demographics has a vast rage of different languages and cultures which could contribute to the hindrance of communication on construction sites. It is against this backdrop that this study evaluates the communication problems encountered by managers and the on-site workforce in terms of culture and language, and develop strategies that can help mitigate the challenges.

2 Literature

2.1 Overview of Communication

Communication derives from the term "communicare", a Latin term which means "to share" or "to be in relation with" [5]. The process of establishing, interpreting, and negotiating meaning is known as communication. Communication can take the form of verbal, nonverbal, or textual communication. There are three well known models for communication, these are Linear, Interactional and Transactional [6]. The linear model of communication describes communication as a linear process. This model assumes that communication only goes in one direction, also a person can be a sender or receiver, but not both. The sender, or the one attempting to communicate or send a message, transmits a message to the recipient in this model [6]. In this instance the sender is also the information source. The second model, the interactional model, has two channels. The first is for the intended message or communication to flow, and the second is for feedback to flow or be delivered. The feedback refers to the reaction given by the recipient of a communication or message to the sender of the message. This feedback could be verbal, such as stating "no," or nonverbal, such as shaking your head. The feedback provided by the receiver ultimately aids in informing the sender that the message has been received and comprehended. Communication is viewed as a continuing activity in the interactional model [6]. The transactional model is the final and most dynamic communication model. This approach does not follow the same premise that humans are senders and receivers, but it does emphasize the importance of communicators. This implies that communication is accomplished through people sending and receiving messages. As a result, this model views communication as a collaborative action in which communicators co-create the outcome, process, and effectiveness of the contact [6]. The model believes that parties to communication develop common meaning in a dynamic manner [6]. Therefore, the communicators must share a common ground. In other words, if people are to communicate at all, communicators must share at least some degree of cultural, linguistic, or environmental commonality. This model also acknowledges that communications have an impact on the answers, or subsequent messages, created during the communication engagement [6]. This suggests that messages are not independent, but rather interconnected. The interrelationship concept asserts that communications are linked to and build on one another. Because humans are considered as dynamic communicators rather than simple senders or receivers, there must be some overlap in domains of experience in order to generate shared meaning, and messages are interconnected, the transactional model serves as the foundation for much communication theory [6]. It is also important to note that communication could have various forms – verbal, non-verbal, written, listening and visual communication [7].

2.2 Causes for Miscommunication

Communication could be distorted in many ways. Physical impediments, according to [8], lead to ineffective and even miscommunication. Physical impediments are physical distractions that can interfere with communication, such as noise or a large distance between transmitter and receiver. This barrier emerges frequently, particularly on the construction site, where the environment itself can be a barrier to communication. A simple example of how interference or distortion of the message may take place is when the site manager gives and instruction to a worker, but the worker is unable to clearly understand and process the intended message as the noise of the excavator in the background made him not to hear the instruction clearly. Linguistic limitations also lead to misunderstanding [9]. These linguistic hurdles might range from the usage of jargon to genuine language. Jargons are sentences that are usually used in the work environment and are informal, this is mainly used by people who practice the same profession and may make sense to the sender and certain receivers but are not guaranteed to be understood by all recipients in the communication process [9]. Culture may also impede communication. Tensions may occur between various cultures if they are not used to dealing with or working with a diverse workforce or community. Tensions between people can occur knowingly or involuntarily [10].

Unconscious message distortion can also affect the effectiveness of communications; this is the unintentional act of conveying information in an ambiguous manner. This can be caused by a person's accent when talking, or it can be caused by bad grammar transmitted within a message [10]. As there is unconscious message distortion, there is also conscious message distortion. This is linked to a person's unethical behavior to communicate information incorrectly or in a defective manner [11]. A lack of role clarity can lead to inefficient communication because some individuals operate outside of their area of authority, and when this happens, it is frequently done incorrectly. It is vital that everyone on a construction site understands their responsibilities and authorities in order to work efficiently and communicate when necessary [12]. According to [13], misunderstanding is frequently caused by different levels of knowledge and a lack of training. On-site, there is an obvious disparity in educational level. During the course of a project, a variety of parties at various levels are present on site and constantly engage and communicate [3], such as an engineer to a foreman and supervisors to laborers. Communication with workers might be tough due to the different levels of education. A lack of training prohibits professionals from providing enough and proper information both up and down the chain of command, as well as to on-site staff; also, a lack of training restricts knowledge necessary to carry out a good communication process. Another problem that frequently results in a chaotic environment such as construction site is poor coordination; in a chaotic environment ineffective communication or miscommunication is inevitable [14].

Raymond [12] opined that project complexity also contributes to misunderstanding on the construction site. Because building project entails the engagement of several organizations, sophisticated communication procedures will occur in order for the project to be completed effectively. Stakeholder management, and labor relationships may be highly sophisticated. Under pressure, employees may make mistakes, resulting in inefficient communication. Pressure may also have a psychological and physical impact on people, affecting their productivity [15]. Feedback is an important component of communication. The timing and quality of feedback is important to complete communication transaction successfully especially when the requirement is urgent, thus poor feedback is a big indicator/cause of ineffective communication [8].

2.3 Possible Solutions to Improve Communication

Different forms of communication including signs, drawings, hand signals, and meetings are commonly used to communicate on the construction sites [16]. Every method of communication has advantages and problems. Choosing the appropriate mode of communication can help to speed up and simplify the sharing of information. Sometimes it is best to illustrate what is needed or required, while other times you may just contact a foreman and tell him what is needed [16]. On-site training for basic skills such as interpreting complicated and technical drawings, as well as the development of innovative equipment, software, safety features, and regulations, should be done for the workforce. This will help not only the workforce but also the organization as a whole, because more skilled workers' equal fewer difficulties. This will not only improve communication, but will also offer employees the impression that the firm cares about their growth, providing them a sense of security and loyalty [17]. It is also vital to guarantee that the workforce and those to whom communication is directed understand and communicate in the appropriate language. Because we live in a diversified community, not all of the persons in the workforce may be fluent in English. The site manager's responsibility is to ensure that the personnel on-site knows the lingua franca. As a result, the appropriate multilingual signs, as well as an interpreter to explain instructions and health and safety warnings, should be available on site [17].

3 Methodology

A qualitative research method was used in this study. Qualitative research is exploratory and is employed to gain an insight to enable the development of ideas [17]. There is scarcity of research on communication problems on construction sites in South Africa, therefore, the study employed exploratory research. Interviews is one of the main instrument used in exploratory research. Interviews are a quicker way of gathering data within shorter periods and they are commonly used as a qualitative research method [18]. Unstructured, structured, and semi-structured interviews are the three types of interviews. In this study, structured interview was used. In a structured interview, all of the people being interviewed are asked the same questions in the same order and with the same wording. Throughout the interview, the interviewer will have complete control over the questions. The three main benefits of structured interviews are that the answers can be more accurate, the response rate is relatively high (approximately 60–70%), especially if interviewees are contacted directly, and the answers can be explored by determining 'why' the specific answers are given [19].

The study's intended audience were practicing construction managers who actively engage and supervise the work force on the job site. For this study, purposive sampling technique was use to select the participants. The strength of purposive sampling is embedded in selecting information rich cases or participants to acquire in-depth knowledge [20]. Purposive sampling groups participants according to the pre-selected criteria, which in this case is a site manager's currently involved with a diverse workforce in Bloemfontein, South Africa. Fifteen respondents were selected to partake in the study, however, only nine, (60%) participated in the study.

Thematic analysis was used to analyze the data. Thematic analysis helps to find trends from data. As these patterns arise, certain themes will emerge; themes are just summaries of information relating to a certain subject or data domain; there is no necessity for common meaning organized around a core idea, only a shared topic [21]. These themes are then discussed, and the relevant respondents will be indicated under each theme. There are six steps identified by [22] for thematic analyses namely: data familiarization; generating initial codes; theme identification; review themes; defining and naming themes; and producing the report.

4 Findings

Features of Respondents

Table 1 shows the demographics of the respondents. It is clear that all the respondents were male, demonstrating that the on-site management in South Africa's construction industry is dominated by men. it is evident that all the respondents had at least 5 years of work experience on construction site. Additionally, the respondents had varying levels of education ranging from matric to university degrees. The respondent's diverse qualifications and extensive experience aided in the collection of rich data. The participants were also asked to indicate in which languages they are proficient, all of the respondents indicated that they are proficient in both English and Afrikaans.

Table 1. Respondents profile

Respondents	Gender	Position	Years of experience	Highest qualification	Proficient languages
R1	Male	Jnr project manager	5	Diploma	Afrikaans and English
R2	Male	General foreman	8	Higher diploma	Afrikaans and English
R3	Male	Owner/contracts manager	18	BTech	Afrikaans and English
R4	Male	Director/contracts manager	10	Metric	Afrikaans and English
R5	Male	Construction manager	5	BSc	Afrikaans and English
R6	Male	Site agent	6	BTech	Afrikaans and English
R7	Male	Site agent	15	Metric	Afrikaans and English
R8	Male	Site manager	20	Metric	Afrikaans and English
R9	Male	Construction manager	8	Degree	Afrikaans and English

5 Discussion

5.1 Causes of Communication Problems

Theme 1: Language barrier/proficiency.

Language, according to R1, R3, R6, R7, and R8, creates a communication gap that leads to misunderstandings. All respondents agreed that verbal miscommunication resulting from language barrier is the most common type of miscommunication. R1, R3, R6, and R8 believe that the majority of their workforce is uneducated, so they are not proficient in English and other languages. As a result, they are unable to fully communicate in languages other than their native tongue. This correlate with the study of [13] who revealed that communication with workers might be tough due to the lack of education. The fact that most workers are unable to communicate properly due to the lack of education creates a serious barrier to communication on site.

- *R1 Most of my workers struggle with language and this causes a language barrier, you should remember most of them are unschooled.*
- *R3 remember, most of the workers who comes to site to do manual labor did not go to school or left after grade three.*
- *R6 problem. They are mostly uneducated.*

Theme 2: Misunderstanding and misinterpretation.

According to R4 and R5, miscommunication is caused by misunderstanding and misinterpretation, which are associated with both language and experience (as barriers). For example, a worker who has been working in the industry for the past 10 year has much more knowledge regarding the processes and the requirements of a certain activity. Therefore, when a site manager gives him an instruction he/she comprehends easily where as a person with no experience will not be able to do so. This correlates with the fact that most of their work force have a very low level of education.

- *R4 Sometimes they just don't understand what you tell them but you don't realize it. It is after the instruction was carried out wrongly, then you realize they misinterpreted or misunderstood the instruction.*
- *R5 Sometimes you inform the foreman what to do and what he should tell the workers, and when you get to site there was a total misunderstanding.*

Theme 3: Poor cell phone network.

R2 stated that poor telecommunication signal causes messages to be sent via people, resulting in the message not being delivered on time or in the manner intended. This leads to miscommunication not only on-site but also with other stakeholders. When the site manager is on a tight time schedule and he sees the drawing are outdated, the only thing he can do is to contact the architect or engineer, as it is usually in rural areas. When there is no signal, he is unable to contact the relevant party.

- *R2 Poor cell signal leads to messages being sent via people leading to the message not being given in time or not as was intended. The signal also affects the timeous ordering of materials, the changing of specifications on site, and the communication of changes to personnel which all affect the production rate.*
- *R9 network problems can lead to miscommunication.*

Theme 4: Overload of information or instructions.

Miscommunication is also exacerbated by an overload of tasks or too many instructions, according to R3, R7, and R8. As an example, when they give the scope of the works that should be completed each week or day in written form, the workers are unable to read and understand what and how to complete the works, and when they give it verbally, there is a high likelihood that the workers will forget parts of the instruction, or will not clearly understand the instruction due to the language barrier. Also giving workers a load of work within a tight time frame causes pressure to perform. Reference [14] believes that pressure may have a psychological and physical impact on people, which ultimately affects their productivity.

- *R3 If you give them too much information at once they struggle to complete everything as it seems that they forget.*

- *R7 An overload of instructions confuses them as they sometimes must first clarify with someone who understands the language….*
- *R8 Too much information or "opdragte" (instructions)*

Theme 5: Cultural differences

R2, R3, R6 and R8 all stated that they had encountered cultural differences that contributed to miscommunication. They all gave examples of how different cultures take offense when you raise your voice, whereas another culture believes you should raise your voice when communicating with others outdoors. Another example given is that some cultures find it offensive or disrespectful to be called out or corrected in front of their co-workers and would prefer it to be done in private. The disparity in beliefs hinders cohesion, which has an impact on communication. Below are two examples.

- *R2 Cultural and language differences also contribute to miscommunication in that certain cultural methods of communication may seem offensive to others. For example, if I raise my voice to speak outside to a group it may seem as if I am angry towards the group where this may be related to a military background where this is how one was taught to communicate to a group outdoors.*
- *R6 There are certain culture with who you should communicate in different manners, such as your tone of voice… different cultures perceive things differently therefore you should know the background of the workers. Some want a stricter manner of control while other wants to be heard and want to give an input.*

Theme 6: intrinsic characteristics

R4, R5, and R8 also stated that some members of their workforce have a negative attitude toward their work and/or superiors, making it difficult to ensure good communication and understanding. Intrinsic characteristics relates to inner characteristics of a person such as motivation, work ethic, sympathy and so on. it is characteristics that a person is born with and it is often difficult or impossible to change or learn these characteristics as you are born with them and develop them over the years.

- *R5 Sometimes they are spiteful because they know what they can and cannot do and how they may or may not be reprimanded.*
- *R8 Blatant refusal to insubordination*

5.2 Resolving Ineffective Communication on Site

Theme 1: Interpreter

The most common response from respondents was to appoint an interpreter; R1, R2, R4, R5, R6, R7, and R8 all believe this is the best way to resolve ineffective communication on site. A person who verbally translates from one language to another is known as an interpreter [23]. The respondents pointed out that multilingual general foreman, gang leader, or supervisor should be appointed as an interpreter to translate where and when needed to prevent miscommunication. R6 stated that each team on site, from the earthworks team to the office team, should have a multilingual member. R2 proposed that each team or group appoint a representative who is fluent in the language of communication. The construction sites comprise of a diverse workforce, and not all of the persons in the workforce may be fluent in English or Afrikaans. As a result, the appropriate multilingual signs, as well as an interpreter to explain instructions and health and safety warnings, should be available on site [16].

Theme 2: Education and Training

Workers should be trained in terms of language and reading proficiency, according to R1 and R7. R1 further suggested that formal training helps to improve worker's skills; he acknowledged that this would be a time-consuming process, but he believes it is the correct and most effective way of dealing with the problem. R7 stated that workers who struggle to read or communicate verbally should have a mentor on his team who will teach him to read plans and communicate verbally over time. This will help not only the workforce but also the organization as a whole, because more skilled workers equal fewer difficulties. This will not only improve communication, but it will make employees believe that the firm cares about their growth, providing them a sense of security and loyalty [16].

Theme 3: Fanagalo

Respondents 3 and 9 indicated that the best way to ensure effective communication on site is the establishment of a construction Fanagalo language. Fanagalo is a language used on South African mines to communicate between different cultures and languages. It is a language made up of words from several languages, including English, Afrikaans, Dutch, Xhosa, and seven others [24]. Fanagalo helps to break down language barriers in the workplace by presenting a neutral language that incorporates elements from all of South Africa's spoken languages. R3 stated that the construction industry's governing bodies should assist in the development of a language specifically for the construction sector and the relevant elements of the industry and its processes. Specific elements such as a spade, concrete, or a brick are examples. Everyone in the industry will learn the language, resulting in an industry wide understood language for communication.

6 Conclusion

Communication could influence the success of any organization including construction firms. The aim of the study was to evaluate the communication problems encountered by managers and the on-site workforce, and develop strategies that can help mitigate the challenges. From the interviews conducted, it is evident that the main factor that contributes to communication challenges on site is language barrier resulting from poor education of site workers which further contributes to misunderstanding and misinterpretation. Other challenges include overload of information or instructions, cultural differences, intrinsic characteristics, and poor cell phone network. Strategies such as the use of interpreters, training of site workers, and the use of 'Fanagalo' could help mitigate these communication challenges. This implies that construction firms need to be aware of the specific challenges that applies to their organization so that appropriate and well-tailored strategies that best fit their organization could be adopted. Data was collected from only construction firms situated in the Free State Province of South Africa; therefore, a study that expands on the number of provinces and participating firms is recommended. Moreover, a study that investigates the effect of these challenges of project delivery and success is recommended.

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Integration of Emerging Technologies in Construction Project Delivery: Durban Construction Contractors' Experience

Johannes S'thembiso Mchunu and Iruka Chijindu Anugwo(✉)

Department of Construction Management and Quantity Surveying, Durban University of Technology, Durban, South Africa
IrukaA@dut.ac.za

Abstract. The fourth industrial revolution era has evoked a thrust of disruption and opportunities due to emerging technologies in the construction business and project delivery process. The purpose of this study was to assess the level of understanding and integration of emerging technologies knowledge in project delivery amongst Durban construction contractors. This study adopted quantitative research, whilst data collection was carried out through a questionnaire survey among 40 large contractors in Durban. The study findings revealed that the large construction companies operating in the Durban are aware of and are moderately integrating emerging technologies in their office and construction site activities such as e-procurement; having a website; use of three-dimensional (3D; usage of robotic technology; usage of virtual reality (VR); application of internet of things (IoT); application of element of, Building Information Modelling (BIM); use of radio frequency identification (RFID); and cyber-physical system (CPS) in their construction project delivery. The study concludes that intensifying the integration of emerging technologies in the construction office and site operations would significantly enhance project delivery performance and competitiveness amongst Durban construction contractors as a result of holistic digital transformation.

Keywords: Construction industry · Durban contractors · Emerging technologies

1 Introduction

The 21st-century business environment has created huge opportunities and disruptive forces because of elements of the Fourth Industrial Revolution (4IR). The term Fourth Industrial Revolution was introduced in 2011 by Fraunhofer – Gesellschaft institute and the German Federal government; as a collective term that depicts innovative concepts with regard to information communication technology, exchange of big data, advance automation and manufacturing capabilities [1]. The fundamental of the fourth industrial revolution denotes paradigm shifts in entire supply chain of socio-economic and political value system and exchange of information and values [2]. These paradigm shifts are embedded in the emergence of innovative technologies and digital transformation, which are infusing interconnectedness of physical and biological worlds. They are most

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powerful experience when combined and reinforced in the business environment [2]. Thus, the Fourth Industrial Revolution could be disruptive forces due to its velocity, scope, and systematic impact on business environment especially in the construction industry. However, the 4IR, contrary to the previous industrial revolutions, is progressing exponentially rather than at a linear pace [3] and [4]. It involves the transformation of entire systems across countries, companies, industries, and society with emerging technologies [3].

The 4IR has ushered in massive industrial opportunities and as well as disruptive foreces for the construction industry, both in the developed and developing countries [5] and [6]. However, levels of infrastructural assets deficit in the developing countrues could be significantly bidged as a result of fourth industrial revolution, which can potential foster innovative and effectively infrastructure project delivery in developing countries [5]. The elements of 4IR are most likely to assist South Africa in improving its current declining economy through significant investment in the automation of construction industry is the cardinal catalyse factor toward boosting the economy [7]. In addition, [7] assert that effective implementation of 4IR technologies within the construction industry is mostly challenged by various factors such as lack of adequate, relevant skills, the unavailability of training capacities, expensive technologies, and negative perceptions such as fear of job loss by industry professionals.

2 Literature Review

2.1 Brief Understanding of the Concept of the 4th Industrial Revolution

The core concept of 4IR embodies the seamless integration and interaction of digital automation, human nature, and business activities and operations across sectors of the economy [8]. The fourth industrial revolution has an indisputable impact on the transformation of entire systems across countries, companies, industries, and society, including the construction industry [3]. The 4IR has catalyzed and accelerated technological paradigm shift with rapid industrialization across economies and transformation of industrial market operations and business models and interactions, such as in the manufacturing and construction industries [8]. The concept of 4IR technologies is revolutionizing the Architecture, Engineering, Construction, and Operations and Maintenance (AECO) supply chains and catapulting the built environment sector into a completely new paradigm [9].

In addition, [9], further articulate that the concept of 4IR and its computing dimension have significantly contributed to enhancing project delivery effectiveness. Technologies such as the Internet of Things, Internet of Services, Cloud Computing, Big Data, Smart Factory, 3 D-Printing, Cyber-Physical Systems or Embedded Systems, Augmented Reality, Virtual Reality and Robotics hold immense potential. In other words, Industry 4.0 is the combination of the Internet of Things (IoT), Cyber-Physical System (CPS) and Internet of services cooperating with each other and with a human within a system [1]. Thus, within the construction industry, the concept of 4thIR has elements of emerging technologies such as artificial intelligence, the Internet of Things (IoT), cloud computing, social media, data science, 3D printing, connected wearable devices, quantum computing, robotics, and genetics are the drivers of change and forces of this phenomenon is the core of fourth industrial revolution [3]. These transformative technologies are significantly influencing all disciplines, economies, businesses, societies, and individuals. The awareness of the concept of 4IR in the construction industry would address critical and multiple objectives towards improving project delivery, increased industry productivity and cost savings, site activity monitoring, reporting and project agility methodologies, better workflow processes and reduction of time, cost and material wastage [9].

2.2 Emerging Digital and Technological Transformation in the Construction Industry

The traction among built environment professionals to effectively apply emerging technologies, such as Building Information Modeling (BIM), virtual construction (VC), augmented reality (AR), and digital construction, could be seen as evidence of this paradigm shift in construction [10]. The effort among professionals within construction is geared toward preparing the industry to incorporate the innovative transformation emanating from the 4IR [10]. The emerging technologies such as Virtual Reality (VR), online databases, Geographic Information Systems (GIS), Building Information Modelling (BIM), Unmanned Aerial Vehicle (UAV), 4D Computer-Aided Design (4D CAD), robotics and automation, laser scanning, photogrammetry and sensor-based technologies are effective in tackling construction health and safety-related challenges and improving overall construction project delivery within health and safety measures [11]. Numerous studies have identified the awareness and effective implementation of emerging technologies and digital transformation such as BIM, VR and AR, drones, GIS, automation and robotics, unmanned machinery, sensing and warning technologies; 4DCAD has significantly contributed to site accident prevention and healthy and safe project delivery[11]. In addition, the awareness and knowledge of the automated and autonomous system in construction are empowering concepts of digital construction [10]. The authors [10], further identified elements of digital and emerging technologies in construction. These are radio frequency identification sensor network to examine performance; track near-miss incidents; safety alert system, system for multiple 3D structures based on the reinforcement learning method; customized shop floor control methodology for off-site production; aerial robot construction system for planning the construction of the 3D structure(s); an IoT based autonomous system designed to ensure safety in the field; and a system for concrete crack detection [10].

3 Research Method

This study adopted a quantitative research method utilising a questionnaire survey (online and hand delivery) as a primary data source. The quantitative research approach analyses data with features that can be measured in a more or less accurate manner [12]. The quantitative approach usually arrives at measurements that imply a form of magnitude, usually expressed in numbers and range from extremely simple mathematical procedures such as percentages to complex or sophisticated statistical tests or mathematical models. The data were analysed using percentages, mean score, standard deviation, and ranking of each question with the support of using the SPSS statistical package. The target population for this research study was large construction contractors in civil engineering and general building. The sample calculation was based on cidb grading of contractors between grades 7 to 9 on the Construction Industry Development Board (cidb) Register of Contractors (RoC) within civil and general buildings, which are regarded as large construction contractors in the Durban construction market. This study assesses the level of awareness and integration of emerging technologies presently linked to the Fourth Industrial Revolution (4IR) among large contractors in the Durban construction industry (Table 1).

Table 1. The Durban CIDB register of contractors

Contractors grading designation	Maximum tender value (R)	Total contractor (active-currently in Durban)	Size
1	R200,000.00	7141	Small
2	R500,000 to R1000,000	404	Small
3	R1000,000 to R3000,000	198	Small
4	R3000,000 to R6000,000	102	Medium
5	R6000,000 to R10,000,000	53	Medium
6	R10,000,000 to R20,000,000	39	Medium
7	R20,000,000 to R60,000,000	33	Large
8	R60,000,000 to R200,000,000	20	Large
9	R200,000,000 to No limit	3	Large
Grand total		8118	
	Overall Population size for this study		
Contractors in 7 to 9	Large	56	Large

Source cidb (2020)

Note Grade 1–3 = small contractors; Grade 4–6 = medium contractors & 7–9 = Large contractors. According to cidb register of contractors' site, there are 56 contractors listed under cidb grades 7 to 9 for GB and CE classes. Based on the estimated population provided by the Construction Industry Development Board (cidb), which is 56 (large contractors), the researcher used Slovin's formula with a margin of error of $\pm$ 5%, the confidence level being 95%. The calculated sample size is as follows: Say = 49 contractors (Sample size of large contractors). The research questionnaire was distributed randomly among selected research respondents (grade 7–9 contractors), based on the sample size through two main strategies, namely: online (survey monkey), emailing and when necessary hand delivery was done whilst covid-19 regulation was observed accordingly.

4 Research Result and Discussions

The online questionnaire was sent out mostly through email and a few hand delivery to construction contractors in Durban within the cidb grades 7 and 9 contractors. Thus, only contractors operating as general building contractors and civil engineering contractors were selected for this study, which consist of Civil engineering (CE) grade 7 (9.8%), general building (GB) grade 7 (6.3%), civil engineering (CE) grade 8 (2.1%), general building (GB) grade 8 (7.7%), general building (GB) grade 9 (1.4%), and civil engineering (CE) grade 9 (0.7%) respectively (Table 2).

Table 2. Questionnaire survey response rate among grade 7–9 cidb register of contractors

Contractors grading designation	Sample size (No.)	Questionnaire received (No.)	Response rate (%)
7	28	23	82.14
8	18	14	77.78
9	3	3	100.00
Total	49	40	81.63

Source Researchers' construct (2022)

4.1 Respondents' Years of Experience in the South African Construction Industry

Figure 1, depicts the experiences of respondents (cidb grade 7 to 9 contractors) in the Durban construction industry. Thus, 72.5% of contractors within the cidb grade 7–9 contractors had between 5 to 15 years of experience in the industry, 15.0% of contractors have been in the construction business between 16 to 25 years, whilst 7.5% of them had between 26 to 35 years of experience, and 5.0% of the large contractors had between 36 to 45 years of experience in the Durban construction industry. Figure 1 indicates that the respondents have a piece of extensive knowledge and experience to make strategic business decisions in their respective organisations with regard to the integration of emerging technologies. This provided reliability and accuracy in their responses.

4.2 Respondent's Highest Educational Qualification

Figure 2 depicts the level of educational qualification among the respondents. The highest educational qualification of the respondents revealed that 2.5% of contractors within the cidb grades 7 and 9 had FET certificates, 45.0% of contractors had diploma certificates, 35.0% of contractors had bachelor's degrees, 2.5% of con-tractors had honour's degree, and 15.0% of contractors had master's degree and 0% of contractors had doctor's degree. The results show that the majority of respondents were well educated and were likely to provide the correct information.

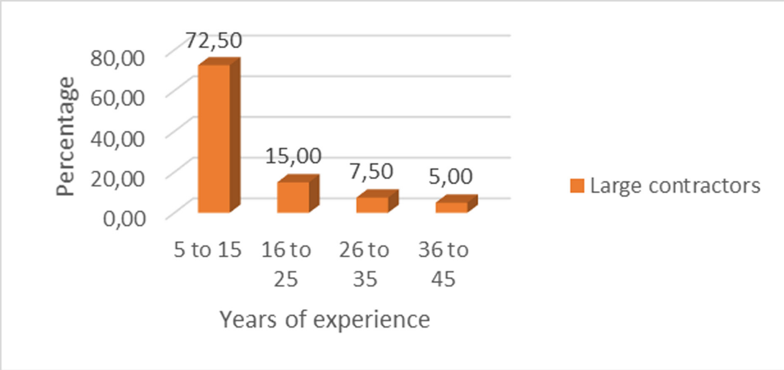

Fig. 1. Respondent's years of experience in the construction industry

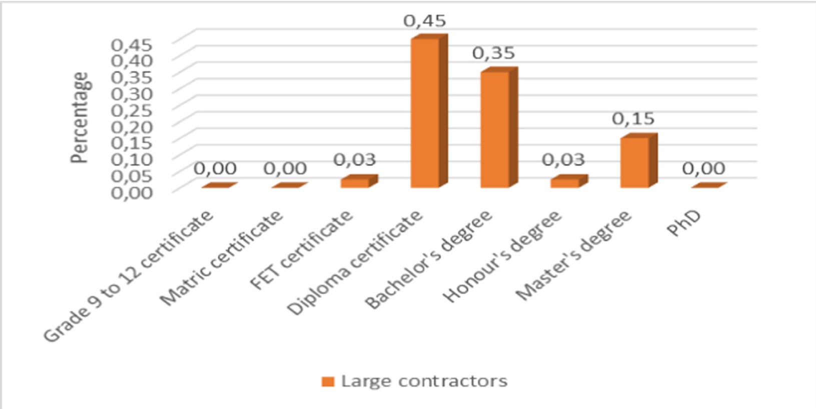

Fig. 2. Respondent's highest educational qualification

4.3 Response Analysis from Large Contractors on Benefit of Integration of Emerging Technologies Within Construction Site and Office: Large Contractors' Perspectives

Questionnaires were used in the collection of data. These featured a 5-point rating scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. These were used to assess the integration/ implementation of emerging technologies within the construction sites and offices amongst large construction firms in Durban.

Table 3 is based on the ranking (R), using the computer calculated standard deviation (SD) and mean score ($\bar{x}$) to assess the level of integration/ implementation of emerging technologies in the construction site and office operation amongst large construction companies in Durban. Thus, emerging technologies assessed were Electronic procurement (e-procurement), use of robotic technology, use of Building Information Modelling (BIM), usage of Three-Dimensional (3D) technology, use of Virtual Reality (VR) technology, usage of the Internet of Things (IoT), Cyber-Physical System (CPS), and Radio

Table 3. Ranking on integration/implementation of emerging technologies within the construction site and office operation: large contractors' perspectives

Questions	Mean score	Std. dev	Asymp. sig (2-sided)	Rank
Q1: Electronic procurement (e-procurement) utilising the electronic communication technologies (ICT), is used in transaction processes to buy services, goods, and works so as to improve delivery, reduce paperwork and lower administrative costs	4.41	0.91	0.000	1
Q2: Implementing of robotic technology has the capability to generate higher output at a lower unit cost, with better quality product	4.13	0.74	0.000	2
Q3: The use of Building Information Modelling (BIM) in planning and procuring a construction project is benefiting all phases of the facility's life cycle	4.09	0.92	0.000	3
Q4: Implementing Three-Dimensional (3D) technology brings significant benefits to the organization, in terms of increased customization, reduced construction time, reduced manpower and construction cost	3.97	0.89	0.000	4
Q5: Application of Virtual Reality (VR) allows costly mistakes to be identified and rectified before they occur and fosters easy communication among site staff and office staff	3.93	0.84	0.000	5
Q6: Safety systems in construction sites have integrated the usage of the Internet of Things (IoT)	3.9	0.77	0.000	6

(*continued*)

Table 3. (*continued*)

Questions	Mean score	Std. dev	Asymp. sig (2-sided)	Rank
Q7: Cyber Physical System (CPS) system operations are used for monitoring (plant and equipment), coordinating, progress tracking, construction process control, and as-built documentation	3.87	0.55	0.000	7
Q8: Radio Frequency Identification (RFID) technology is used to address the challenges associated with tracking resources on construction sites	3.9	0.86	0.000	8

Frequency Identification (RFID) technology. These findings collaborate with the assertions of [10], and [11]. According to the study findings as presented in Table 3, electronic procurement (e-procurement), is used in transaction processes to buy business services, goods, and works to improve delivery, reduce paperwork and lower administrative costs. Thus, electronic procurement is the most integrated technology among large contractors ($\bar{x} = 4.51$; SD = 0.644; R = 1). Findings from the data analysis utilising the chi-square goodness-of-fit-test, it has shown that there is a strong and significant agreement that electronic procurement is the most integrated emerging technology among large contractors in the Durban construction industry, $p < 0.001$. Whilst, the integration and implementation of robotic technology within large contractors: ($\bar{x} = 4.13$; SD = 0.741; R = 2). Findings from the data analysis utilising the chi-square goodness-of-fit-test, it has shown that there is a strong and significant agreement that the implementation of robotic technology has the capability to generate higher output at a lower unit cost, with better quality products among large contractors, $p < 0.001$. These findings collaborate with the assertions of [3] and [9].

In addition, the integration of Building Information Modelling (BIM) in planning and procuring a construction project is considered to be highly beneficially to all phases of the facility's life cycle among large contractors ($\bar{x} = 4.09$; SD = 0.919; R = 3). Findings from the data analysis utilising the chi-square goodness-of-fit-test, it has shown that there is a strong and significant agreement that the use of Building Information Modelling (BIM) in planning and procuring a construction project is beneficial to all phases of the facility's life cycle among large contractors, $p < 0.001$. In addition, integration and usage of Three-Dimensional (3D) technology show statistics figures as $\bar{x} = 3.97$; SD = 0.890; R = 4. Findings from the data analysis utilising the chi-square goodness-of-fit-test, it has shown that there is a strong and significant agreement that the integration of Three-Dimensional (3D) technology could bring significant benefits to their organisation, reduced construction time, and reduced manpower and construction costs among large contractors, $p < .001$. Analysis of the integration of Virtual Reality (VR) application show statistical figure of $\bar{x} = 3.93$; SD = 0.842; R = 5. Findings from the data analysis utilising the chi-square goodness-of-fit-test, it has shown that there is a strong and significant agreement that the application of Virtual Reality (VR) would allow costly mistakes to be identified and rectified before they occur and allows easy communication among site staff and office staff in large contractors, $p < 0.001$. These findings collaborate the assertion of [10], and [11].

Further analysis, assessing the integration and usage of the safety systems based on the Internet of Things (IoT) has shown statistical figures such as $\bar{x} = 3.90$; SD = 0.772; R = 6. Findings from the data analysis utilising the chi-square goodness-of-fit-test, it has shown that there is a strong and significant agreement that safety systems in construction sites have utilised the Internet of Things (IoT) among large contractors, $p < 0.001$. More so, the utilisation of Cyber-Physical System (CPS) system operations to monitor (plants and equipment) shows statistic figures such as $\bar{x} = 3.87$; SD = 0.548; R = 7. Findings from the data analysis utilising the chi-square goodness-of-fit-test, it has shown that there is a strong and significant agreement that the utilisation of Cyber-Physical System (CPS) system operations to monitor (plant and equipment), coordinating, progress tracking, construction process control, and as-built document within large con-tractors, $p < 0.00$. These findings were in agreement with [12], who claimed that the use of CPS has potential benefits to different fields of the construction industry, including the project delivery process. However, analysis to assess the integration and usage of Radio Frequency Identification (RFID) technology to address the challenges associated with tracking of resources in the construction sites indicated statistical figures such as $\bar{x} = 3.90$; SD = 0.860; R = 6. Thus, based on the findings from the data analysis utilising the chi-square goodness-of-fit-test, it has shown that there is a strong and significant agreement that integration and usage of Radio Frequency Identification (RFID) technology are useful in the addressing challenges associated with tracking of resources on construction sites with $p < 0.001$. These findings were in agreement with [13], who claimed that RFID technology makes it an attractive technology that has the potential to address the challenges associated with tracking resources on construction sites.

4.4 The Implication of the Findings of This Study

The implication of the findings of this study depicts the need among construction contractors to intensify the adoption and integration of emerging technologies embedded in the elements of 4IR to heighten their level of productivity and competitiveness. Thus, inadequate integration of emerging technologies within construction business operations would potentially lead to overall poor performance among construction contractors.

5 Conclusion and Recommendation

The study has provided empirical evidence and insights with regard to Durban construction contractors' integration of emerging technologies in their construction site and office operations.. Thus, based on the analysis of collected data in this study, it was revealed that there is a moderately significant level of knowledge and integration of emerging technologies among Durban construction contractors within the cidb grades 7 and 9 contractors. Thus, among large contractors, the study concluded that there is an agreement among contractors that the integration of emerging technologies such as e-procurement; usage of three-dimensional (3D); robotic, virtual reality (VR), internet of things (IoT), radio frequency identification (RFID), and cyber-physical system (CPS) are beneficial within their construction sites and office operations. Thus, the study recommends that construction contractors in Durban and at large South Africa should strive earnestly towards integrating emerging technologies in their construction site and office operations in order to enhance project delivery performance and competitiveness in the construction industry. This study only considered large construction contractors in Durban; and it could potentially be a limitation of this study in terms of the generalization of research findings.

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Delphi Approach to Operation Environment Indicators for Public-Private Partnership Risk Management in Construction Industry in Ghana

Timothy Adu Gyamfi[1,2](✉), Clinton Aigbavboa[1], and Wellington Didibhuku Thwala[3]

[1] Faculty of Engineering and Built Environment, University of Johannesburg, Johannesburg, South Africa
agttimo78@gmail.com, caigbavboa@uj.ac.za
[2] Faculty of Built and Natural Environment, Koforidua Technical University, Koforidua, Ghana
[3] University of South Africa College of Engineering, Science and Technology, Johannesburg, South Africa
Thwaladw@unisa.ac.za

Abstract. The peaceful economic environment necessitates the implementation of national policies, institutional structures, and a stable political environment that resolve corruption-related issues, attracting investors and increasing their confidence to invest in such an economy. Public-private partnership (PPP) is an innovative mechanism that requires private partners to inject their financial resources into developing infrastructure in a given economy. Hence the research enquires to ascertain the impact of PPP operation environment indicators to manage PPP risk in the construction industry in Ghana through the Delphi approach. The study employs 12 Delphi panelists who are experienced in PPP projects and risk management. Out of 15 indicators, the panelist attains consensus on 13 of the variables in three iterations and the variables were ranked accordingly. The findings of the study imply that government institutions, private institutions, investors are necessitated to engage in PPP where there is a tranquil environment in other to attain value for money on their investment. The discovery of the research can be adopted on the ground to manage PPP risk in construction in Ghana as well as other developing countries. The study discoveries contribute to body of knowledge as regard managing PPP project risk in construction industry.

Keywords: Public-private partnership project · Risk · Ghanaian construction industry · Risk management · Operation environment

1 Introduction

According to World Bank [1]. Countries that are undergoing rapid development necessitate considerable investment in infrastructure. This attainment is challenging since the traditional approaches to government procurement are ineffective and limited due to the availability of government funds to provide infrastructure projects. In order to

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confront these challenges and empower countries to meet developmental demands, an array of public-private partnership (PPP) provisions have been recognized. These PPP engagements have quickly become the favored choice to offer public services in several countries, including Australia, Jin and Doloi [2]. The PPP structure encompasses several variables depending on the necessity and complication of the project. Notwithstanding the complication, the structure of any PPP arrangement is meaningfully swayed or formed by its model or contract type Carbonara et al. [3]. Hemming [4] posited that, PPP originates in a wide diversity of models hence no clear determinant of PPP compositions. The model describes the duties of the contracting parties by design (D), construction (C), financing (F), operating (O) and maintenance (M) of the project. Moreover, it aids in stipulating who is accountable for risk and in what way the private party regains its used fund. However, most literature on PPP risk management centered on management of PPP risk identification, risk classification, risk assessment, risk estimation, PPP risk factors, PPP risk allocation, Xul et al. [5], Xiao-Hua [6], Xu et al. [7], Chan et al. [8], Cheung and Chan [9], Chan et al. [10]. Nevertheless, Sanda and Anigbogu [11] developed PPP risk management framework for housing construction in Nigeria and one of the constructs in the framework was PPP operation environment. Kaletnik and Lutkovska [12] study on implementation of public-private partnership models in the field of ecological modernization of the environmental safety system, found that implementing PPP in Ukraine demanded meeting operating environment characteristics such as meeting institutional requirements, defining entry operation requirements, prove of financial security and government control mechanisms, etc. Çimen [13] studied construction and built environment in circular economy: a comprehensive literature review, and founded that the least studied area in construction and built environment is operation and design.

According to Ministry of the Interior and Safety [14] PPP cloud environment management comprises security control and operation. Youngkon and Ukhyun [15] opined that operation is provided via a PPP cloud service providers or private company. The current study seeks to employ a Delphi survey to explore the influence of PPP operation environment in managing PPP construction risk in Ghana. The utilization of PPP operation environment to determine the impact of PPP risk management (PPPRM) in Ghanaian construction industry has received limited or no scientific enquiry in that context, hence the study. The objective of the study is to employ Delphi survey to acknowledge attribute that could measure PPP operation environment, and its impact on the success of PPP risk management practice in Ghanaian construction industry.

2 Managing Risks in PPP Construction Projects

Risk is uncertainty characterized by negative and positive outcomes. This is vital to PPP, since not all PPP projects are advantageous due to inherent risk arising unexpected which turn to endanger the success of the project objectives. The occurrence of risk affects projects negatively Chiken and Posner [16], Zou et al. [17]. It is not always the case that risk denote negativity, it can also convey positive impact or some lucrative outcomes on the project objectives. Akerele and Gidado [18] studies identify 10 risks factors in operation of PPP as political risk, inflation risk, currency risk, completion risk, regulation risk, availability risk, operation risk, technology risk, market risk (demand)

and resources risk. These risks related to PPP projects must be appropriately recognized and resourcefully managed to warrant project accomplishment.

Construction projects including PPP can be successful if risk management is an effective practice. Risk management has been deliberate by numerous researchers and different risk management models or framework can be found in the literature Flanagan and Norman [19], Cano and Cruz [20], Bolai and Price [21], and Project Management Institute (PMI), [22]. Irrespective of the disparity in these models, there are key essentials that are common to the risk management process and they comprise risk identification, risk estimation, risk response and risk monitoring and control. When risks are properly identified and estimated to determined their potentials, appropriate responses can be provided whiles monitory and control are offered from time to time.

2.1 The PPP Operating Environment in Building Construction Project

The introduction of Public-Private Partnership (PPP) in construction project necessitates a conducive environment to operate and also require the engagement of PPP essentials such as operating environment and PPP outcome. These essentials are acknowledged through comprehensive analysis of PPPs. The opinion of Yang et al. [23] was that the PPP structure, the background and prevailing factors at times denoted as operating environment and PPP outcome. Well-organized PPP contract requires favorable environment to guarantee that production expenses and public restraints are minimized to an acceptable degree. The operating environment is mostly consisting of two important features: the existence of laws and anticorruption mechanism Yang et al. [23] which may perhaps result to legal and institutional frameworks for controlling the operation of the PPP engagements. When the laws are in place and enforceable it serves as guarantee to private partners for protecting their interests and lessening risk and in the same way aid in limiting unscrupulous behaviours in PPP. Rigorous legal system moreover promotes effective operation of partnerships in harmony with wider policy objectives and without this the result is insolvable disputes Grimsey, Lewis [24]. The existence of anticorruption mechanisms protects institutions by inculcating transparency in PPP engagements. Corruption is application of public authority for either private gain or state capture. The regular occurrence of corruption in PPPs in some cases is the result of government regulating institutions or its affiliate involving (investor or party of interest) in the project. Corruption levies extensive transaction expenses on private party. The appropriate instrument used to curb corruption is enhancement of openness, fairness, and transparency in the bidding process; the provision of strict supervision of operation; the reinforcement of performance, appraisal, and auditing Neshkova and Kostadinova [25], Yang et al. [23]. The credibility of the public partner or the government is key element in PPP arrangement. Credibility is very significant in enticing private investment. Government or public partner credibility is improved by indicators such as availability of political checks and balances, an autonomous juridical system, and independent by-laws. In developing economies, credibility deficiency is common among participating governments in PPP implementation Yang et al. [23]. In developing economics some government propose more than their capacity can perform to attract foreign investment Ho [26]. The success of PPP necessitates a robust policy implementation through effective administration. The emphases of good governance as a criterion for successful PPPs cannot underestimated. Badshah [27] and Li et al. [28], posited that, good governance involves, transparent and accountable and includes some features which have fair insinuations in the performance of PPP engagements. The political environment is also contributing factor leading to successful PPP. Private partners would continuously require political freedom to operate. This is because public-private partnership contract operates in the presence of numerous political changes. The private partner in PPP arrangement may suffer from political risks including contract expropriation or unilateral termination of the contract in the case of change in government. According to Zaharioaie [29], the public-private partnership agreement not under the regulation of commercial law, can be altered by the power of the public institutions contrary to agreed information privy to the private partner. The private investors will be more interested to invest in unchanging political environment. The point is that private investors have little control about the political, financial and usage risk that are sustained by the government. Furthermore, availability of market for PPP products is key factor to successful PPP agreement. The market can be categorized base on the demand of the segment and level of supply competition Carbonara et al. [30]. Demand-side scrutinize faces of the market base on sources of funding and pricing approaches and the technology employed in service or asset delivery while the supply-side scrutinize the market through willingness-to-pay. In the case of PPP building construction project such as market stores, lorry terminals, recreational centres, etc. the private party requires readily available market for their investment. In instances wherever low demand is anticipated, the private party demands form of protection such as bank guarantee or funding to safeguard their investment in the situation where the product receives low patronage at end of the contract duration. The usage of both demand- and supply-side analysis, approaches can be established to treat ineffectiveness and create chances for various private sector participation USAID [31].

3 Methodology

The study employs Delphi method to solicit responses from professional panels who have known how in PPP and risk management. In the views of Rowe and Wright [32] Delphi technique is based on the premise that forecasts from a group of well-organized personalities are generally accurate in comparison with forecasts from unprepared groups. Also, Aigbavboa [33] posited that choices made by a group of personages are primarily true as compare with individual decision. According to Shariff [34] the Delphi technique is substantiated on the principle that, shared intelligence augments selection by individuals and accomplishes the combined opinion of panels of experts. Again, Tilakasiri [35], opined that the Delphi method is advocated to advance the principles, concept, framework or models. The Delphi technique was employed to determine the operation environment indicators that influence public- private partnership risk management (PPPRM) execution in Ghana. Nevertheless, the panelist for the Delphi study for this current survey were acknowledge from origin. The panel members consisted researchers and academicians, procurement officers at national level, development officers at the Universities in Ghana, and board members superintend PPP infrastructure delivery at Metropolitan, Municipal, and District Assemblies (MMDAs). The member's demographics were checked to verify their qualifications to be part of the study. The professionals were e-mail the 1st round of the Delphi questionnaire. In all aggregation fifteen (15) Delphi questionnaires were sent out and out of 15 questions 12 questions were returned. All the twelve respondents completed round 2 and 3. For example, as opined by Delbecq et al. [36], 10 to 15 groups could be acceptable if the background of the groups is homogenous, which was accomplished in the present research. Once again, Rowe and Wright [37] suggested that the Delphi group size could change from three to 8 in peer-reviewed studies. Whereas, Hallowell and Gambatese [38] maintained that since most studies contain between eight and 16 groups, a minimum of eight is recommended. Henceforth, information from prevailing research showed that the panel of 12 professionals for the present Delphi survey was considered sufficient. Whiles Table 1 displays demographic characteristics of Delphi experts.

4 Results and Discussion

With regard to PPP Operation Environment criteria fifteen variables were identified. Ten (10) and five (5) indicators were viewed by the experts to be most important and important based on a median score of 9.00 and 8.00 respectively and the result revealed that all the indicators had very high impact in determining the success of PPPRM implementation. The Interquartile Deviation (IQD) score for two (2) indicators were 2.00, exhibiting a low level of consensus. Nevertheless, thirteen (13) out of the fifteen (15) variables were ≤ 1, exhibiting of strong consensus. Moreover, mean score ranking was utilized to rate the mean value of the variables and out of fifteen indicators measuring PPP operation environment, credibility of the private partner was raked first (1st) follow by the availability of legal institutional framework second (2) whiles setting of commercial law were ranked fifteenth (15). Table 2 presents the outcome of these results.

Among the PPP operation environment variables with a very high impact on PPPRM implementation is the credibility of the private partner which was ranked 1st with a mean score of 9.08, this confirms the findings of Yang et al. [23] that private party credibility is significant to motivate the public partner in engaging in PPP. Again, the availability of legal institutional framework was ranked 2nd with a mean score of 8.92 and this were viewed by experts to have very high influence in addressing PPPRM in construction industry. This supports the assertion by Grimsey, Lewis [24] that rigorous legal system promotes effective operation of partnerships in harmony with wider policy objectives and this in turn contribute in solving disputes. Furthermore, adequate supervision of operations and commitment to partners responsibilities were ranked 3rd and score as having a very high impact on PPPRM execution with mean value of 8.69 whereas auditing service was rank 5th. The findings are in line with Neshkova and Kostadinova [25], Yang et al. [23] who posited that provision of strict supervision, auditing service are employed to curb corruption and enhance openness, fairness, and transparency in the bidding process. Whiles each partner is assigned various role to perform to enhance the effective execution of PPPRM. Again, enforcement of legal framework was rank 6th with mean value of 8.54 this revelation is in collaboration with Grimsey, Lewis [24] who opined that when existing laws are enforced it aids to ensure the protection to private partner's interest and decrease risk and at the same time assist in curbing unscrupulous behaviours

Table 1. Demographic data of Delphi professionals

Regional location of Delphi experts	Number of Delphi experts from each region
Greater Accra	2
Western	1
Bono	2
Eastern	1
Ashanti	2
Central	2
Upper East	1
Upper West	1
Total	**12**
Qualification of experts	Number of experts
Doctor of philosophy	2
Master's degree	10
Total	12
Job title for experts	Number of experts
PPP infrastructure developer	2
Quantity surveyor	2
Lecturer	2
Building engineer	1
Procurement manager	3
Contract administrator	1
Consultant	1
Total	12
Work experience in PPP project	Number of experts
6–10	3
11–20	8
21–30	1
Total	12

in PPP. In addition, the study discovered autonomous judicial system with a mean score of 8.46 and public partner credibility with mean score of 8.38 these discoveries agree with findings from Yang et al. [23] who expressed that autonomous judicial system aid in improving the credibility of public partner since credibility defect is generally associated with government participating in PPP implementation in developing economies. Even some governments in developing economics, try to attract more investors by promising beyong their capacity Ho, [26]. Moreover, the findings from the study reveal conducting

Table 2. PPP operation environment indicators

PPP operation environment	M	$\overline{x}$	σx	IQD ≤ 1	Mean score ranking (R)
Availability of legal institutional framework	9	8.92	1.04	1.00	2
Availability of anticorruption mechanism	8	7.92	1.50	1.00	13
Enforceability of legal frameworks	9	8.54	1.20	1.00	6
Adequate supervision of operations	9	8.69	0.95	1.00	3
Reinforcement of project performance	9	8.08	2.06	1.00	10
Availability of appraisal services	9	8.23	1.74	1.00	9
Availability of auditing services	9	8.62	0.96	1.00	5
Credibility of the public partner	9	8.38	1.33	1.00	8
Credibility of the private partner	9	9.08	0.86	1.00	1
Provision of autonomous juridical system	9	8.46	1.85	1.00	7
Provision of independent by-laws	8	8.00	1.78	1.00	11
Setting of commercial law	8	7.69	1.44	2.00	15
Availability of market for PPP products	8	8.00	1.15	1.00	11
Commitment to partners responsibilities	9	8.69	0.63	1.00	3
Setting targets for each partner	8	7.85	1.14	2.00	14

("M = Median; $\overline{x}$ = Mean; σx = Standard Deviation; IQD = Interquartile Deviation")

of appraisal services and reinforcement of project performance with a mean score of 8.23 and 8.08 respectively and these findings assert with Neshkova and Kostadinova, [25] and Yang et al. [23] that appraisal services and reinforcement of project performance are form of anticorruption mechanisms that safeguards institutions by instilling transparency in PPP engagements. The study finally discovered that there is a need for market availability for PPP products and this finding is in agreement with Carbonara et al. [30] who posited that the market for PPP products is a significant influence on successful PPP arrangement. The market can be grouped on the premise of a degree of competition in the supply. In situations where low demand for PPP products envisages, the private party demands form of protection such as a bank guarantee or funding to safeguard their investment in an instance where low patronage of the product is encountered at the end of the contract duration.

5 Conclusion

This research has clearly shown that PPP operation environment has a significant impact on PPPRM in the Ghanaian construction industry. The private party requires a conducive environment to engage in their investment that could bring higher returns. The Delphi study discovered that out of the fifteen (15) variables proposed to measure PPP risk management in the construction industry thirteen (13) attained consensus among the Delphi professionals. The revelation of the finding suggests that when private partners are credible it enhances public partner effectiveness to participate in PPP arrangement. The available legal system such as institutional framework, autonomous judicial system and its enforcement heavily motivated the private investor to commit huge resources to PPP projects, whiles investors assured of adequate supervision, appraisal system, auditing service and enforcement of project performance as mechanism to deal with corruption related issues that may arise during the project execution. Again, the source of motivation for investors to invest in PPP project is available market to aid in recouping the amount invested at end of the contract period. The study adds to literature in Ghana regarding PPP risk management in construction industry and developing countries that are challenge in managing PPP risk in construction sector. The study recommend institution that engage in PPP project to adopt the findings as guide in managing PPP risk. However, the study is limited to Ghanaian construction industry and only qualitative Delphi technique were employed.

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Critical Success Factors for Construction Projects Delivery: Emerging Contractor's Perspectives

Christopher Amoah[1](✉), Peter Viwe Venter[1], and Emma Ayesu-Koranteng[2]

[1] Department of Quantity Surveying and Construction Management, University of the Free State, Bloemfontein, South Africa
amoahc@ufs.ac.za, 2015106152@ufs4life.ac.za

[2] Department of Building and Human Settlement Development, Nelson Mandela University, Gqeberha, South Africa
Ayesu-Koranteng@mandela.ac.za

Abstract.
Purpose The unsatisfactory performance of emerging contractor projects in South Africa has been a concern over the years. The study aims to identify and analyse factors critical in ensuring the successful delivery of construction projects from emerging contractors' perspectives. A qualitative approach was used to gather empirical data using interviews. Data was collected by interviewing 26 emerging contractors in the Free State province. Data were analysed via thematic contents analysis. The findings indicate many emerging contractors have been involved in projects that did not meet the planned schedule and budget. Again, it was revealed that emerging contractors perceive proper planning and good communication amongst project team members, using management software, good management of stakeholders, and pro-activeness in resolving problems and continuous supervision as critical factors for project success. Data was collected from emerging contractors operating from Free State only; thus, the findings may not be generalisable. Emerging contractors are aware of the factors that will enhance the success of their project, yet they usually fail to apply these factors. Therefore, emerging contractors must be sensitised about implementing effective strategies to improve their project performance. The study gives an insight into the critical factors for construction project success that will guide other contractors on what they must do to ensure the success of their projects.

Keywords: Critical success factors · Construction · Critical path · Communication · Projects

1 Introduction

Construction projects have a pivotal influence on the economic development of every country. According to Mosenogi et al. [23], the construction industry contributes to employment, household income, and economic growth. It further develops its infrastructure capital, resulting in increased economic activities. However, documents indicate

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that projects are not finished on time and within the initial budget, thus losing economic validity and reliability [11]. Based on KPMG's Global Construction Survey, over 60% of the organisations that spent 10 million U.S. Dollars or more had at least one that failed, and most were attributed to personnel issues [6]. An analysis of the South African construction industry statistics in 2019 undertaken by Wood [33] showed that the industry is experiencing labour disruptions and poor productivity, cost overruns, shrinking profit margins, a lack of skilled workers labourers, and increasing costs of input.

Amaidas [5] explains that following the steep incline that the industry underwent before the FIFA World Cup in 2010, the construction sector in South Africa has experienced a considerable decline. This decline can be attributed to cautious investors, government inaction, restrictive legislation, and poor performance from project stakeholders. In addition, factors such as state capture and corruption have also led to investors' reluctance to invest in South Africa [33]. Thus, identifying and implementing Critical Success Factors (CSF) for construction projects is essential. It allows the project team to emphasise their efforts to structure their capabilities and direct their resources towards fulfilling the CSF [28]. CSF is defined as measures implemented and exercised to ensure the successful delivery of the project within time, cost and specifications as the three barometers by which a project is usually measured [3]. Singh and Sharma [28] believe that construction project success depends on the company's effectiveness, and better performances by project managers will lead to the success of the projects.

Langley [17] shows that organisations lose 109 million for every billion invested in construction projects and programs. A project is deemed successful when it is finished timely and within the allocated budget. Using this definition of success, Kakulu et al. [15] discovered that most companies have a project failure rate of 70%; poor project management is the main reason for this failure. In addition, Schoppman [27] states that contractors pay more attention at the start of the project and their efforts and attention decline as the project proceeds. Projects and programs aligned with the organisation's strategy are completed more successfully than those misaligned [17]. Successful construction projects can be accomplished through various techniques, but the overriding theme requires effective preplanning, oversight, cooperation and anticipating problems, and managing them before they become delays, failures, and catastrophes [26]. This research aims to identify critical success factors of construction projects from the perspective of emerging contractors who are crucial players in the South African economy and future construction industry leaders.

2 Literature Review

2.1 Emerging Contractors in South Africa

Based on Malongane's [18] findings, an emerging contractor is defined as a sole proprietor, joint venture or legal entity which complies with the statutory practices registered with NHBRC, with a Construction Industry Development Board (CIDB) grading between 1 and 3, and under guidance and incubator programmes. Worku [34] defines emerging contractors as those construction companies which have not yet succeeded in developing into major companies but are showing all signs of maturity. McCutcheon and Muzondo [20] define an emerging contractor in South Africa as an entity owned, managed, and controlled by a previously disadvantaged person(s) and overcoming business impediments arising from the legacy of apartheid. This refers to companies graded 1–3 by the CIDB.

According to Worku [34], emerging contractors cannot maintain service level agreements with clients due to their lack of capacity and expertise. They generally lack technical skills and complete projects within the allocated time. The South African Construction Industry Development Board, governed by the CIDB Act 38 of 2000, is a public entity formed to lead construction industry stakeholders, particularly contractors. All contractors in South Africa intending to partake in public sector projects and tenders must be in the CIDB register as stipulated by the act.

Table 1. Designation/grade maximum value of the contract that a contractor is capable of performing

Designation/grade	The maximum value of the contract that a contractor is capable of performing
1	R 200,000
2	R 650,000
3	R 2,000,000
4	R 4,000,000
5	R 6,500,000
6	R 13.000,000
7	R 40,000,000
8	R 130,000,000
9	No limit

Source CIDB [7]

The CIDB promotes uniformity in construction procurement, efficient and effective infrastructure delivery, construction industry performance improvement, and development of the emerging sector, including industry transformation and skills development [29]. In addition, any contractor or enterprise that is owned 50% or more by previously disadvantaged individuals can apply to be classified as a potentially emerging contractor. Moreover, the CIDB is also responsible for categorising and grading contractors based on their work and financial capabilities [8]. Works' capability is determined by the most significant contract a contractor has undertaken and completed in their class of construction works. In contrast, the financial capability depends on the turnover of the company and the available capital, as indicated in Table 1 [8]. Table 1 shows the work capability of contractors as per CIDB grading. According to CIDB [8], an emerging contractor registered with the CIDB may be awarded a contract at one level higher than the contractor's grading designation if the client is satisfied that the contractor has the potential to qualify and perform in that higher grade and provided that financial management and other support mechanisms are present.

2.2 Critical Project Success Factors in the Construction Industry

Gudienne et al. [13] explained that several studies had been done in literature to discover CSF. However, the reality is that project teams find themselves in different situations with varying circumstances, meaning that their definition of project success will differ from that of the next project team. Project success is a topic that is always in discussion but rarely agreed upon. Alashwal et al. [2], in their study, advocate the fact project success might mean different things to different stakeholders. According to Worku [34], the project manager may view success as the defining completion parameters within time, cost, and quality. Contrastingly, users may view success in terms of the functionality of the end product or building, while contractors will be looking at turnover from the project, timely completion, safety, number of claims, and commercial performance.

Gudienne et al. [13], stated that success is always the end goal of all businesses, and the construction industry is no different. Project success has evaded the construction industry, whereby satisfying existing clients has proven to be a severe challenge, let alone attracting new clients, as big and complex projects are becoming more challenging to finish successfully. Alzahrani and Emsely [4] defined Project success as when everything turns out as planned, predicting all project needs, and having adequate resources to meet needs timeously. In Yong and Mustaffa's [35], CSF was defined as those relatively small numbers of significant matters on which a particular industry should focus to achieve success. These matters represent critical factors to the industry for ensuring success is achieved. In Alashwal et al. [2], project success was defined as situations, facts, or influences that play a role in the project's outcome. Typically, the success of construction projects includes client and top management support, thorough planning, team and project manager competency, decisive leadership, commitment and enough funding, sufficient resources and effective project monitoring and control. From the contractors' viewpoint, project success comprises and consists of competency and performance of the construction manager and the team, adequate project funding, availability of resources and commitment to the project from various professionals [35].

In addition, Alashwal et al. [2] identified other project success factors, including effective communication among project key players, project manager's authority and empowerment, procurement method, risk management, and government support. Alazhrani and Elmsey (2012) point out the appointment of the right contractor as a critical success factor because the ideal contractor will ensure quality and save costs. Gudienne et al. [13] discovered that construction projects have been difficult for clients and contractors due to limited budgets and scheduling requirements in the past twenty years. Sustainable development is an issue and challenge that must be incorporated and considered as organisations nowadays use projects to exercise strategic goals. Therefore, seeking sustainable development from a project management viewpoint is essential. Withal, construction managers can enhance their probability of completing projects successfully and meeting clients' requirements by implementing management tools during the planning, designing and execution stages [14]. Alzahrani and Emsely [4], in their study, identified a total of fourteen CSF related to implementation success across a wide range of companies and projects. Project mission, top management support, project schedules, client consultation, personal recruitment, technical tasks, client acceptance, monitoring and feedback, communication and troubleshooting, project team leader characteristics, power and politics, environmental effects and urgency.

Furthermore, when using analytical hierarchy processes, they identified sixty-seven project success factors relating to four project aspects: project characteristics, contractual agreement, project participants and interactive approach [14]. Contractors' success factors were addressed as contractor's key personnel's capability, contractor's proposed team's competency, contractor team turnover rate, contractor track record, and contractor level of service [4]. Yusof et al. suggested that there would be no point in determining success factors until one has identified the success criteria in the first place. They further identified that most authors in the literature, regardless of time-space, have postulated time, cost, and quality to assess project success. Alzahrani and Emsely [4] dispersed the success criteria into micro viewpoint completion criteria (time, cost, quality, performance and safety) and macro viewpoint completion (time, satisfaction, utility and operation). They further dispersed project success criteria into objective measures (time, cost, safety and environment) and subjective measures (quality, functionality, and satisfaction of different project participants). Furthermore, Yusof et al. suggested a model which consisted of project success (adherence to quality target, scheduling, budget and captured knowledge) and market success (profitability, market share, revenue, reputation, competitive advantage, customer satisfaction). These two were combined to form project success criteria to evaluate building projects and implemented in countries like Malaysia.

Mohamed [22] summarises the CSF for construction projects under various categories: contractor-related, project management-related, procurement-related and project manager-related. He mentioned CSF under contractor-related as contractor's experience, cashflow, and site management and supervision. Project management-related CSFs are effective decision making, project experience and project team monitoring. CFS under procurement and project manager-related are project delivery system and project manager's experience, respectively. If these factors are adhered to and implemented well shall improve the performances, yield better results for emerging contractors, and ensure successful delivery of construction projects.

3 Methodology

3.1 Research Approach

The study adopted a qualitative approach. The reason for adopting this approach is that it provides depth and detail. It provides a platform to analyse thoughts, feelings, behaviours and explore why certain events occurred [19]. Vaughan [32] states that a qualitative approach provides a more flexible approach. Researchers can quickly adapt questions, change the setting, or any other variable to improve responses if valuable insights are not being captured. Daniel [10] explains that relying on collecting non-numerical primary data by the researcher who serves as an instrument makes qualitative research well suited for providing factual and descriptive information. Since the study identifies what emerging contractors consider critical success factors for their construction projects, it is ideal for this study to use a qualitative approach.

3.2 Target Population and Sampling Method

Taherdoost [30] define a target population as the group of individuals from which the intervention intends to conduct research and draw conclusions. In this study, the target population were emerging contractors within CIDB grades 1–3 located in Bloemfontein and within the Mangaung region in the Free State province. Sample size refers to the number of participants or observations included in a study. According to Taherdoost [30], sampling can make inferences about a population or generalisation concerning existing theory, but this depends on the chosen sampling technique. In this research, the researcher opted for purposive sampling. Dudovskiy [12] explains that convenience sampling is known as judgement sampling and refers to when the researcher relies on judgement when choosing population members to participate in the study. Also, convenience sampling helped collect data and permitted participation from emerging contractors. Furthermore, it will help determine the views of emerging contractors to improve and enhance project performance.

3.3 Data Collection Techniques

According to Pucket [25], there are various techniques for collecting primary data; notable among them is the interview. Interviews allow the researcher to uncover deep insight from the respondent's responses and collect non-verbal data. Telephonic interviews provide a degree of anonymity which might motivate the interviewee to be more open with their answers [1]. The interview was used to collect data, face-to-face and telephonically. Interviews allowed the researcher to observe the non-verbal behaviour of the respondent and ask further questions for clarification where necessary. In addition, interviews allowed a reasonable response rate as the respondents could respond to the questions instantly.

3.4 Data Analysis Techniques

Creswell [9] defines data analysis as collecting, modelling, and analysing data to extract insights that support decision-making. There are various methods and techniques to perform analysis depending on the industry and purpose of the analysis. Creswell [9] identifies narrative analysis that analyses participants' insights and perspectives through their stories as valuable for analysing qualitative data. In this study, a narrative analysis was used to analyse the experiences and opinions of the respondents. Based on Kawulich's [16] findings, the narrative analysis focuses on discovering repeated similarities in people's stories. Creswell [9] states that the first step of data analysis is organising and preparing data, which involves transcribing interviews, optically scanning material, typing up field notes, and sorting and arranging data into different types depending on the source of information. After getting a general sense of the information and an opportunity to reflect on its overall meaning, the next step is coding the data [21]. Coding is organising data by bracketing chunks and writing a word representing a category in the margins [9]. Miles et al. [21] and Creswell [9] agree that sorting and sifting through these coded materials to identify similar phrases, relationships between variables, patterns, themes, categories, distinct differences between subgroups, and common sequences in the following stage of data analysis. In addition, isolating these patterns, processes, commonalities, and differences formed the basis of the analysis, allowing certain judgements to be made [21] The participant's features are indicated in Table 2.

Table 2. Respondents' profile

	Respondents	Frequency	Percentage (%)
Gender	Male	9	35
	Female	17	65
	Total	**26**	**100**
Profession	Quantity surveyors	5	19
	Architects	3	12
	Engineers	3	12
	Business owner	15	58
	Total	**26**	**100**
Qualifications	None	1	4
	Grade 12	3	12
	National Diploma	6	23
	Bachelor degree	9	35
	Postgraduate	7	27
	Total	**26**	**100**
Experience	0–10 years	14	54
	10–20 years	8	31
	Over 20 years	4	15
	Total	**26**	**100**

The information on the participant's profile indicates that the majority (65%) are female, suggesting that most emerging contractors are female-owned. Again 58% of them are the owners of the business. This also indicates that the information given could be reliable as they manage the business and thus know how to deliver projects successfully. Also, most (54%) participants have been in the construction business for less than 10 years. This also may show that more people are entering the construction business recently.

4 Findings

4.1 Participant View on Project Delivery Issues

The interviewees were asked to identify the frequency of their involvement in projects that have exceeded schedule, cost and contract being terminated. Table 3 shows how the participant's responses.

Table 3. Participant view on project delivery issues

Variables	Never happened	Hardly happens	Most of the time	All the time	Mean
How often have you been part of projects that have been delivered over the allocated budget	0 (0.00%)	4 (15.38%)	16 (61.54%)	6 (23.08%)	3.08
How often have you been part of projects that have been delivered over the allocated schedule	1 (3.85%)	5 (19.23%)	12 (46.15%)	8 (30.77%)	3.04
How often have you been part of projects whereby the contractor terminated their services	20 (76.92%)	6 (23.08%)	0 (0.00%)	0 (0.00%)	1.23

The findings indicate participants had been involved in projects that had exceeded their budget (mean score = 3.08) and schedule (mean score = 3.04). However, hardly have these resulted in the termination of the project contracts (mean score = 1.23) between the clients or the main contractor and the emerging contractors.

4.2 Participants' Views on Critical Success Factors

Participants were again asked to mention essential success factors for construction projects. This question aimed to get interviewees' perspectives regarding what they consider crucial and what areas prioritise construction projects. Table 4 shows the main themes from the interviewees' responses to this question.

As reported in Table 4, 38% of the respondents identified proper planning and effective communication, 35% indicated they use construction software programs, 15% identified the excellent management of stakeholders, and only 12% pointed out pro-activeness and continuous supervision the critical success factors for projects.

5 Discussion

5.1 Critical Success Factors for Project Execution

Based on the findings obtained from the interviews, it is evident that there are factors that all of the respondents agree to be critical for the successful delivery of construction

Table 4. Critical success factors

Question	Main themes	Frequency	Percentage (%)	Ranking
What are the critical success factors for construction projects?	Proper planning and effective communication	10	38	1
	Make use of construction software programs	9	35	2
	Good management stakeholders	4	15	3
	Being Proactive and continuous supervision	3	12	4
Total		**26**	**100**	

projects. The most frequently mentioned factors are proper planning and good communication amongst project team members, the ability to use management software, good management of stakeholders, and pro-activeness in resolving problems and continuous supervision.

Theme 1: Proper planning and effective communication.

Proper planning and effective communication among the project stakeholders are critical success factors for project execution. Planning for a project help identify a potential adverse event that may negatively affect the project's success. Effective communication among the project team and stakeholders will let each person know their responsibilities and project expectations. This allows the project team to properly execute their tasks and discuss project challenges to attain the objectives. For instance, participant 13 indicates that proper planning and communication will enable the project team to adjust to the client's requirements. Participants 11 and 26 state that lack of planning at the initial stage is ineffective in ensuring project success.

Participant 13*: "Clear communication amongst the team to prevent any confusion and misunderstandings".*
Participant 11: *"In most cases, there is lack of planning and projection of the upcoming project. Though a plan can be done, it needs to be initiated or supervised".*
Participant 26: *"Contractors should plan a job better. Get the whole team involved from the beginning and make allowance for additional costs that may prevail as the project commences".*

The factors above identified by the participants support the findings of Alashwal et al. [2] that communication, planning and pro-activeness were critical factors of success for construction projects. McCutcheon and Muzondo [20] stated that 32% of emerging contractors in South Africa fail within the first seven years of operation due to poor project planning and execution strategies adopted. Thwala and Phaladi's [31] findings indicated that construction professionals' poor management skills and planning during the early stages have proven to be a significant cause of construction project failures in South Africa. These findings imply that emerging contractors know the factors for effective project execution. Yet, they usually fail to carry out these strategies effectively to ensure the success of their projects.

Theme 2 Make use of construction software programs.

Construction software was also mentioned as an effective way of monitoring cost and time. This is because it will assist in identifying any deviations that will necessitate corrective actions to achieve the set project objective. Participants 7 and 20 opine that project managers should know construction software for accounting delays or material shortages.

Participant 7: *"It goes without saying that the delivery of materials and number of personnel should be well thought out to account for any delays or shortages. They need to improve planning, find good construction management software like CCS Candy and start using Building Information Modeling".*

Participant 20*: "If contractors would improve their management of the critical path using software programs, they are guaranteed an improvement in their project performance".*

It has been suggested by Alashwal et al. [2] that effective project monitoring and control could ensure project success. However, their findings did not mention using construction software for that purpose. Again, Saari [26] indicated that the failures of emerging contractors could be attributed to a lack of construction technology equipment; the use of construction software is seldom found in the literature. With the introduction of effective construction monitoring software, emerging contractors believe this software could be used for proper project monitoring.

Theme 3 Good management of stakeholders

Project stakeholder management was identified as an effective way of ensuring project success. Project stakeholders have different expectations and influences on the project. Thus, managing them to ensure their satisfaction is critical. For instance, Participant 18 indicates that adjusting to stakeholder expectations is crucial for project success.

Respondent 18 *indicated that "the ability to adjust to client's expectations and good stakeholder management is the most critical success factor of a project".*

Some stakeholders have been categorised as not favouring the project [24] and may always resist the project implementation. The way these stakeholders are managed will determine whether the project will be a success or not. Singh identifies subjective project success measures to include the satisfaction of different project participants.

Theme 4 Being Proactive in problem-solving and continuous supervision.

Being proactive in managing project challenges and adequate supervision is critical to project success. Not identifying problems in projects proactively may generate serious issues that will be challenging to resolve, thus affecting project progress. Again poor project supervision may lead to poor quality and ultimately derail the project's success. As indicated by participants 1, 12 and 11;

Respondent 1: *"Consistent supervision, being proactive and detailed planning especially before construction begins, those are essential and important factors for construction projects".*
Respondent 12*: "Planning and time management. To be proactive and can solve problems. Clear communication amongst the team to prevent any confusion and misunderstandings".*
Respondent 11*: "Proper planning and Supervision. In most cases, there is a lack of planning and projection of the upcoming project. Though a plan can be done, but it needs to be initiated or supervised".*

Mohammed revealed that the contractor's experience, project managers' decision decision-making effectiveness, site management and management of the cash flow are critical factors of success. Alashwal et al.'s [2] findings identify project success factors to include competency of the team and decisive leadership.

6 Conclusion and Recommendation

Poor management skills during the early stages have proven to be a major cause of business failure for small and medium-sized contractors. It further became apparent that contractors' lack of construction equipment also contributed greatly to project failures. In addition, the inability to access funds due to poor credit records and inexperience were also classified as factors that detrimentally affected contractors' performances and consequently led to their failures. The findings indicate that many emerging contractors have been involved in projects that did not meet the set schedule and budget; however, this did not lead to contract cancellation. Again, the findings revealed the critical success factors for construction projects proper planning and good communication amongst project team members, the ability to use management software, good management of stakeholders, and pro-activeness in resolving problems and continuous supervision. The findings implication is that emerging contractors in the study area are primarily aware of their strategies to ensure project success. Yet, according to the literature, most of their projects failed to meet the set requirements. To improve project success rate among the emerging contractors, there is the need to invest sufficient time in the planning stage and ensure they plan as thoroughly and accurately as possible to ensure that their schedules are realistic and practical. Again, emerging contractors should empower and equip themselves with construction software programs and stay abreast with new technological advances. Contractors must, together with other project team members, create and maintain good communication and channels of communication from the inception to the completion of projects. The study is limited to the Free State province in South Africa; however, the findings may apply to emerging contractors operating in other provinces. Future research could investigate emerging contractors' challenges in complying with project success indicators.

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Tiny Housing Development: A Vaccine for Unaffordable Housing Delivery in Africa

Temidayo O. Osunsanmi(✉), Mark Deakin, Suha Jaradat, and Timothy O. Olawumi

School of Computing Engineering and the Built Environment, Edinburgh Napier University, Edinburgh, Scotland

{T.Osunsanmi,M.Deakin,S.Jaradat,T.Olawumi}@napier.ac.uk

Abstract. The menace of unaffordable housing delivery has spread like a virus across the countries within the African continent. The virus has infested numerous activities and is responsible for the slum development and other social vices on the continent. Towards combating the virus this study makes a case for developing tiny houses as a vaccine for unaffordable housing delivery. The prospect and challenges of developing tiny houses were examined in this study. A random sampling technique was used in collecting data from construction and housing stakeholders within the study area. The data were collected with the aid of a questionnaire and analysed using statistical tools such as mean score, Kruskal Wallis test, and factor analysis. The study discovered that there is a high prospect for tiny houses in overcoming the menace of housing unaffordability. Findings from the factor analysis revealed that the development of tiny houses is hindered by occupant's acceptance, government permit/approval, and security. The study's findings revealed that stakeholders in the construction sector are willing to develop tiny houses. The study recommended that the government should create and support policies that encourage the development of tiny houses. The study provides the roadmap for creating an innovative method of ensuring housing affordability in Africa.

Keywords: Affordable Housing · Sustainability · Tiny houses · Zoning laws

1 Introduction

The Government of most nations has strengthened its program and effort on housing delivery to meet its commitment to ensuring affordable and quality housing for the ever-growing population [1, 2]. Unfortunately, Daniel and Owotemu [3] affirmed that the Government's commitment to affordable housing delivery over the years has proven difficult both in developed and developing nations owing to the rapid population growth. Ajayi, Ajayi, Akinsiku and Osunsanmi [4] believed that the difficulty is more enormous in developing countries owing to the uncontrolled population growth. Aside from the rapid population growth. Mills [5] indicated that the problem of housing delivery in developing nations, especially in Africa, is compounded by an increase in housing prices that is resistant to numerous housing policies and strategies. Pillay and Naudé [6] and Osunsanmi, Aigbavboa, Oke and Ohiomah [7] asserted that the population of developing

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countries is increasing at a pace beyond the capacity of the existing housing delivery strategies.

To enhance housing delivery in Africa, numerous housing delivery strategies have been created by countries within the African continent [4, 8]. For instance, the South African Government created a housing delivery strategy focused on creating subsidies for low-income households. The housing delivery scheme was called the reconstruction and development program (RDP), and it operates by building a basic house with the installation of sanitary and water services [9]. Booyens and Rogerson [10] affirmed that the RDP plans were laudable but failed to solve the housing backlog problems in South Africa. A similar housing delivery strategy was adopted in Nigeria to ensure affordable housing in Africa. According to Ajayi, Ajayi, Akinsiku and Osunsanmi [4] the Nigerian Government launched the new national housing and urban development policy (NHUDP) in 2002 targeted at ensuring that all Nigerians own decent housing. Ibem [1] postulated that ever since, different housing policies and strategies have been enacted by the Nigerian Government. Unfortunately, all the housing strategies and policies have failed to meet the housing demands within the country [8]. Aigbavboa and Thwala [11] opined that aside from Nigeria and South Africa the Government of other African countries has also failed to adequately cater to the housing needs of its citizens.

African countries' failure to provide housing for their citizens has led to the partnership with private companies in ensuring housing provision [2, 12]. Dunga and Grobler [13] describe this arrangement as unaffordable because private developers are only interested in making profits, making housing unattainable for low-income earners. Thus, low-income earners in Africa are left to provide housing for themselves. Landman and Napier [14] opined that low-income earners meet their housing needs by developing houses excluded from a sustainable neighbourhood thereby preventing its contribution to urban economic and social life. Ademiluyi [8] attributed the activities performed by low-income earners and the failure of the Government in providing suitable policies to the creation of slums in most African countries. The menace of unaffordable housing delivery has spread like a virus across the countries within the African continent.

Unaffordable housing originated from the high cost of land, including the bureaucratic and corrupt practices of Government in providing affordable housing [4, 15]. The virus has infested numerous activities of the country and is responsible for the slum development and other social vices in the continent. Towards combating the virus this study makes a case for developing tiny houses as a vaccine for unaffordable housing delivery. This study describes a tiny house as a building that is less than and equal to 37 square metres in floor area excluding lofts and follows the health and safety regulations for ceiling height, stairways and emergency escape and rescue. The prospect and challenges for developing tiny houses were examined in this study.

2 Housing Affordability Strategies in Africa

The concept of housing affordability became popular in the early 1980s intending to provide accommodation for low-income earners [4]. Ever since the term has achieved international stature despite the absence of a precise and consistent definition. Likewise Landman and Napier [14] and Daniel and Owotemu [3] discovered that housing affordability has different meanings and opinions from the literature. However, most of the definitions describe housing affordability as encompassing social housing, low-income housing, and financially assisted housing for middle-income households. Aigbavboa [9] believed that affordability is not a characteristic of housing rather it is a relationship between housing and people. This is because for some people all housing is affordable regardless of the price whereas for others no housing is affordable.

Ajayi, Ajayi, Akinsiku and Osunsanmi [4] asserted that affordable housing in most African nations functions as a tool in catering to the welfare of their citizens. It works as a tool by enacting policies that support the delivery of housing below the market price. In comparison to other African countries, South Africa has a strong and effective policy and strategies in ensuring affordable housing for its citizens. Booyens and Rogerson [10] revealed that in the delivery of affordable housing South African Government combines numerous policies and strategies. Miraftab [16] opined that the policies were established to provide accommodation for the less privileged post-apartheid period. The policies were targeted to ensure affordable, sustainable housing for low-income families at a reduced cost [17]. One of the notable policies is the reconstruction and development program (RDP) housing policies [18]. The RDP was developed to curb housing inequality during the apartheid regime. Osunsanmi, Aigbavboa, Oke and Ohiomah [7] and Dugard [19] submitted that the RDP policy was effective but was confronted with Government bureaucracy, corruption, and other shenanigans. Thus, it can be deduced that the Government policy failed in ensuring affordable housing.

Self-aided housing delivery strategy was another strategy adopted by the African Government in ensuring affordable housing [11]. The concept of self-aided housing is based on the notion that Government may assist individuals in developing their houses [20]. Osunsanmi, Aigbavboa, Oke and Ohiomah [7] affirmed that the self-aided housing delivery scheme was practiced in South Africa prior to the apartheid period. After the apartheid regime, it was changed to the people housing process (PHP). Under this scheme, the Government is charged with the responsibility of supporting low-income earners through land provision, urban services, and options for the piecemeal development of houses [14]. Bradlow, Bolnick and Shearing [15] opined that the strategy and concept of PHP were laudable as they assisted in the effective delivery of affordable housing. Although, critics such as Fish [12], Osunsanmi, Aigbavboa, Oke and Ohiomah [7], and Booyens and Rogerson [10] perceived that self-aided housing scheme as the potential of creating slums if not properly managed. Booyens and Rogerson [10] attributed the slum development in major cities in South Africa to the PHP housing delivery strategies.

The shortcoming of PHP housing delivery strategy leads to establishing another housing delivery strategy called the enabling markets. Aigbavboa [9] describes enabling the market as an indirect approach to ensuring affordable housing. The strategy works through the subsidy provided by the Government and directed at the construction industry. The subsidy functions through reducing the tax on building materials, training construction tradesmen and provision of building loans [18]. Aigbavboa [9] submitted that the strategy assisted in effective housing delivery. Unfortunately, the strategy failed to target the low-income earners that need affordable housing. Ajayi, Ajayi, Akinsiku and Osunsanmi [4] discovered that enabling the market is not a sustainable strategy for affordable housing delivery. This is because the low-income earners usually do not meet the criteria for accepting building loans. The absence of an effective affordable housing delivery strategy in Africa leads to the proposition of tiny houses.

2.1 Tiny House Development

The idea behind tiny house was brought to live after recognising the short coming in the obesity trend in residential architecture [21, 22]. Shearer and Burton [23] and Evans [24] affirmed that the concept of tiny housing became popular from the scholarly work of two architects and designers in the United States around 1990. In the early 1990s most tiny houses were on wheels to achieve home ownership without the cost of land and freedom to change location [25]. Ever since, the movement has continued growing has tiny houses were developed as a response to natural disasters [26]. For example, during the Hurricane Katrina a tiny cottage with 28.6 Square metre was developed for the survivors of the hurricane. Shearer and Burton [23] opined that in Australia, the interest in the development and construction of tiny houses has increased significantly to achieve housing affordability. Anson [27] opined that the tiny house concept drew on previous small/micro house typologies. The past typologies of smaller housing are prefabricated post war housing, cottage-style houses.

Unfortunately, no formal or legal definition exist for tiny house in Africa including some developed countries like Australia and the United Kingdom. Although Shearer and Burton [23] affirmed that the international residential code in the United States defines a tiny house as a building with 37 square metres in floor area excluding lofts, ceiling, emergency escape, and rescue. This study adopted a similar definition and describes tiny houses as a building with less than or equal to 37 square metres and functions as a tool for affordable housing. Tiny houses are often confused as meaning the same as Caravans [26, 28, 29]. However, the major differentiating factor originates from the tiny house's functionality and regulatory features. Ford and Gomez-Lanier [29] indicated that tiny houses are sometimes detachable and have the functionality of a permanent house as opposed to a caravan. Tiny houses have economic sustainability and design parameters that reflect the architectural pioneers of the movement [24]. Shearer, Bares, Pieters, Winkle and Meathrel [30] discovered that they are three major types of tiny houses. They are tiny houses on wheels, potentially moveable tiny houses like containers or relocatable/prefab houses and tiny permanent houses.

Regardless of the tiny house types Petersen and Parsell [31] opined that they are enormous benefits emanating from the ownership of tiny houses. Owing to the absence of land purchase. Ford and Gomez-Lanier [29] believed that tiny houses are affordable in comparison to regular buildings. The unique characteristics of tiny house makes it a suitable tool for ensuring housing affordability in African countries where there is a high cost of land. Another crucial benefit of tiny houses is energy management. Most of them are off grid and therefore use significantly less electrical power and water for day-to-day activities [24].

Furthermore, Byram [32] submitted that tiny house assists in saving energy due to the numerous alternative and renewable systems incorporated in most tiny houses. Shearer [26] examines the benefits of the tiny house from other perspectives. The scholar revealed that tiny houses provide social benefits as it provides accommodation for those in lower socio-economic class or status. Anson [27] discovered that in Australia, interest in tiny houses is higher for older women and singles, that are also the fastest-growing demographic for homeless individuals in Australia. Thus, it can be deduced that tiny house has the potential in ensuring housing affordability. Table 1 also presents some other potential benefits, drivers and challenges to tiny housing development.

3 Research Methodology

Housing unaffordability is a major challenge to the South African Government [10]. The recent and frequent violent and the establishment of slums in major cities in South Africa has been attributed to the housing unaffordability in the country [33]. This study proposes the utilisation or the development of tiny house as a vaccine for unaffordable housing delivery in Africa. The study aimed to discover the factors that hinder the adoption of tiny houses and the prospects for developing tiny houses in South Africa. The study utilised quantitative method in sourcing and gathering information from respondents (stakeholders in the South African housing sector). The quantitative research method was adopted because of its ability to adequately study the relationship between facts and relate them in accordance with findings or theories from existing or past studies [34].

A random sampling technique was used to obtain data from the South African housing sector stakeholders. The random sampling was used because of its ability to give equal opportunity to the selection of stakeholders within the study area. Gauteng province in South Africa was selected as the study area for this study for numerous reasons. One of them is attributed to high housing prices within the country. Pillay and Naudé [6] and Fomum [35] discovered that Gauteng is the epic center of unaffordable housing. The instrument for gathering the data is a close-ended questionnaire that was structured into three sections. The first section examines the characteristics of the respondents such as; academic qualifications, working experience and respondent's affiliation. The second section appraises the prospect for the development of tiny houses in South Africa. The last section examines the challenges confronting the development of tiny houses in South Africa. The variables supporting the development of the questionnaire were sourced from reviewing relevant literature, as shown in Table 1.

A total of 170 questionnaires were used for analysis out of the 200 distributed to the respondents. The questionnaire was analysed using the statistical package for social science (SPSS) version 24 and adopting statistical tools like frequency distribution, mean item score and factor analysis. The questionnaire was validated using a Cronbach Alpha and yielded a value of 0.857. [36] indicated that a Cronbach alpha above 0.6 is deemed valid. The frequency distribution and mean item score was used to analyse the first portion of the questionnaire that focused on the personal characteristics of the respondents. The findings from the respondents' personal information revealed that all the respondents are educated and will therefore provide a valuable response to this study. More than half (56%) of the respondents possess a Bsc or Btech students, while the remaining proportion are qualified with either masters and PhD degree as their highest level of publication. The survey on working experience revealed that all the respondents have an ample working experience regarding the provision of affordable or unaffordable housing in South Africa. Regarding the affiliation, the findings from the survey revealed that all the respondents are affiliated with the appropriate bodies responsible for housing delivery. The relevant bodies are the national association of social housing organisations (NASHO), the Engineering Council of South Africa (ECSA) and other reputable professional bodies.

Table 1. Drivers and challenges to tiny house development

Authors	Drivers and benefits of tiny house movements	Challenges to tiny house development
Shearer, Bares, Pieters, Winkle and Meathrel [30]	A tiny house is an emerging housing design and strategy that originated in the United States of America. Tiny house has the potential to be a catalyst for infill development. The tiny house allows both homeowners and tenants to situate well designed buildings on sub urban plots	High cost of construction, complex legislation and building permit cost
Shearer and Burton [23]	The motivating factors for tiny house movement are secure tenure and sustainable community. Tiny houses represent a small specialised housing niche with the potential of functioning as a panacea for housing unaffordability	Legislation, maintenance and absence in obtaining mortgage
Penfold, Waitt and McGuirk [28]	The major supporters of tiny house movement tap into the narratives that less is more, debt free living, off the grid living and affordability	No pets, lack of information on tiny houses and building materials
Byram [32]	The tiny house movement has moved from a fringe phenomenon to an object of building occupants' desires and fantasies. The significant drivers are affordability and sustainability	Absence of co-operation from building occupants, legislation and security
Carlin [22]	Tiny house provide a fantastic alternative for homeowners seeking for alternative in reducing carbon footprint. It contributes to reducing carbon footprint by reducing indoor heating and cooling throughout the year	Bland design, absence of mortgage funding, large family, legacy and ostentatious life style

(*continued*)

Table 1. (*continued*)

Authors	Drivers and benefits of tiny house movements	Challenges to tiny house development
Evans [24]	The interest in tiny houses grew owing to the issues of addressing housing unaffordability and as a means of pursing counterculture lifestyles	Land use barrier and integration into the urban land space

Source: authors review of literature

4 Discussion of Findings

The discussion of findings emanating from this study was presented in this section. The discussion was centered around the two major objectives that made up this study. The objectives were assessing the prospect of developing tiny house and the challenges emanating from its development.

4.1 Prospect of Developing Tiny House

Tiny houses are presently in the grey zones and are not recognised or accepted by most local or state planning legislation bodies [29]. The prospect was defined defined as the possibilities for developing tiny houses. Based on this, this study accessed the possibilities or prospects for developing tiny houses in South Africa. The prospect was sought by using a five-point Likert scale from strongly agree to disagree strongly. The respondents presented the Likert scale with the findings presented in Table 2. The table revealed that more than half (52.9%) of the stakeholders agreed that there is a prospect of developing tiny house as a vaccine for housing unaffordability. The findings of this study coincide with the work done by Shearer [26] and Shearer, Bares, Pieters, Winkle and Meathrel [30] who discovered that there is a high prospect for developing a tiny house in Australia. Likewise, Evans [24] found that there is a huge prospect for the development of tiny houses in the urban landscape.

Table 2. Prospect in developing tiny houses

	Frequency	Percentage	MIS	X^2	Sig
Moderate	36	21.2	4.10	4.24	0.003*
Agree	90	52.9			
Strongly agree	44	25.9			
Total	170	100			

4.2 Factors Hindering the Development of Tiny House

This study adopted principal component analysis, also called factor analysis, to determine the factors that hinder the development of tiny houses in South Africa. Prior to conducting the factor analysis, the KMNO and Bartlett's test of sphericity were analysed to examine the validity of the data for a principal component analysis. The findings from the analysis were presented in Table 3, and it shows that the KMNO gave a value of 0.625 which is above the recommended threshold of 0.4. According to [37] a KMNO value greater than 0.4 is deemed adequate. Further investigation revealed that the chi-square was significant, with a value of 325.439 at a 120 degree of freedom. Thus, it can be deduced that the data collected for determining the factors hindering the development of tiny houses supports principal component analysis.

Table 3. KMNO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.625
Bartlett's Test of Sphericity:	
Approx. Chi-square	325.439
Degree of freedom	120

The study adopted varimax rotation method, which shows the sixteen (16) factors loaded differently on 3 components which hinder the development of tiny houses in South Africa. The findings from the analysis are presented in Table 4.

Table 4 presents the rotated component matrix and it revealed that the factors hindering the development of tiny houses in South Africa are divided into three components. The components are usually named based on the factors with the highest loadings. Thus, the first component were called "occupants acceptance" owing to the two top variables in this components. The findings from this study coincides with similar studies in Australia [26, 30]. According to Shearer and Burton [23], one of the major impediments to the adoption of tiny houses as a tool for affordability is the acceptance and willingness of individuals to change their lifestyles. The findings from the component analysis revealed that "occupant acceptance "accounts for 37.1% of the factors hindering the development of tiny house as a tool for affordable.

The second component was called "government permit/approval" due to the variables under the components. The topmost variables in this component are building permit approval, government approval and legislative policies. Petersen and Parsell [31] discovered that government policies or permits can serve as a tool to either hinder or drive the development of tiny houses as a tool for affordable housing. Shearer, Bares, Pieters, Winkle and Meathrel [30] discovered that government policy and obtaining building approvals are the major impediments to planning tiny houses. The third component from Table 4 comprises of six variables with the topmost being security of tenure, occupant's security, difficulty in accessing mortgage, and integration into urban land space. Due to the variables within this component, it was called the occupant's security. Dunga and Grobler [13] discovered that occupants' security had been a significant challenge in

Table 4. Rotated component matrix

	Component			
	1	2	3	Variance explained
Accepting tiny house designs	.940			
Acceptance of living in a tiny house	.870			
Sense of community	.810			**37.1**
Large family	.758			
Bland design	.648			
Building permit approval		.894		
Government approval		.760		
Legislative policies		.710		**12.2**
Maintenance		.650		
Lack of information on tiny house		.550		
Security of tenure			.850	
Occupants security			.800	
Difficulty in accessing mortgage			.756	6.**5**
Integration into urban land space			.690	
High cost of construction			.628	
Building materials			.547	

curbing unaffordable houses. Mills [5] opined that affordable housing occupant's security occurs in the form of physical security and financial security. This study discovered that both physical and financial security hinders the development of tiny houses as a tool for unaffordable housing.

5 Conclusion and Recommendation

The menace of unaffordable housing has plagued most African nations' development and advancement, especially in South Africa. The unaffordable housing within the country is responsible for in-security, slum development and other shenanigans within the country. Towards curbing the menace of unaffordable housing in South Africa the Government has implement numerous strategies and policies. One of the notable policies is the reconstruction and development program (RDP) housing policy. The policy was laudable but failed to curb the problems associated with housing unaffordability. Other housing delivery policies and strategies adopted by the Government were unsuccessful.

This created the need for establishing a strategic approach for developing quality and affordable houses. This study proposes the development of tiny house as a vaccine for unaffordable housing delivery in Africa. The literature review revealed that tiny house development is an emerging field of study with little scholarly research and few legislative guidelines. Tiny houses assist in densifying the missing middle with low rise, medium density housing and ease affordability issues, especially for older women, singles and students. If adequately implemented, tiny houses could serve as a tool or vaccine for curbing housing unaffordability. However, the development of tiny houses is hindered by three significant factors: occupant's acceptance, Government permit/approval, and security.

The security occurs in two dimensions which is the physical and financial security. The financial security is attributed to the failure of obtaining mortgage from financial institutions. Whereas, the physical is a function of theft and damage to tiny houses. Despite the factors hindering the development of tiny houses this study discovered that stakeholders in the construction sector are willing to develop tiny houses. The study recommended that the Government should create and support policies that encourage the development of tiny houses. Also, awareness should be created of the proposed benefit attributed to constructing a tiny building as a vaccine for housing unaffordability. The study provides the roadmap for creating an innovative method of ensuring housing affordability in Africa.

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Investigating Effective Infrastructure Delivery in South Africa: An Assessment of Infrastructure Delivery Reforms

Refiloe Malete[1,2](✉) and Nthatisi Khatleli[1]

[1] Faculty of Engineering and Built Environment, University of Witwatersrand, Johannesburg, South Africa
0305268n@students.wits.ac.za, nthatisi.khatleli@wits.ac.za

[2] Regulatory Framework and Government Initiatives, University of Witwatersrand, Johannesburg, South Africa

Abstract. South Africa, like many other developing nations, faces significant challenges in delivering effective and fair public services. Africa in particular suffers from a catastrophic shortage of public infrastructure, and a variety of factors contribute to the infrastructure deficit. Public entities around the world are battling with effective service delivery and have adopted different models to enhance and improve infrastructure delivery. However, the models currently deployed have shortcomings, thus frustrating the efforts to deliver infrastructure effectively to the general populace. South Africa has similarly had its fair share of false starts. The 2010 introduction of Infrastructure Delivery Management System (IDMS) was specifically to facilitate effective, timely and sustained infrastructure development, and tackle the challenges in public sector infrastructure delivery. The study employs a multi-case study, qualitative approach through content analysed data to look at four nations that implements infrastructure projects in Europe and Sub-Saharan Africa and analyze the advancement of infrastructure delivery. A systematic review of infrastructure delivery models/reforms in the context of public sector was carried out through literature and descriptive analysis was applied. The findings reveal a knowledge vacuum about the diverse techniques taken by various countries in the execution of public sector infrastructure projects, and provide little precise evidence on the performance of delivery systems and lessons learned. It is here recommended that interventions such as IDMS should be contextualized cognizant of the country's developmental imperatives.

Keywords: Reforms · Infrastructure · Delivery · Construction industry · Public sector

1 Introduction

Infrastructure is a crucial engine of long-term economic growth and social well-being, yet public infrastructure development in many countries has proven to be sluggish and poor [50]. The nature of infrastructure delivery is evolving, and reforms that bring infrastructure solutions to the public sector have emerged around the world. Infrastructure delivery

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is challenging because of financial, technological, and institutional constraints [8]. Reference [49] elucidate that overcoming infrastructure difficulties is critical for delivering value through the planning, delivery, and operations stages, as well as for developing and implementing national infrastructure strategies and policies. Effective public administration is necessary for modern states to function, whether they are developing or not [37].

The level of confidence the public sector has in its infrastructure should influence the delivery strategy. The construction industry provides society with conveyance or delivery techniques for a variety of political, economic, social, and environmental needs, making its products fundamental to people's societal and physical lifestyle changes [16]. A brief scan of literature indicates that numerous researchers, including [16, 18, 27, 28] indicate on research in other countries that nonperformance is quite common in the construction discipline. Furthermore, there appears to be a dearth of research looking at the infrastructure delivery systems needed to ensure successful implementation of infrastructure projects.

Given the importance of infrastructure to socioeconomic development, an integrated delivery approach that results in greater expertise and effective infrastructure solutions is required. According to [39], a sound policy framework is required to efficiently construct, maintain, and manage a country's infrastructure stock. While this study aims to contribute to this evaluation, it focuses on setting the groundwork for an investigation into infrastructure delivery systems by identifying the changes that have been implemented in other nations to ensure long-term delivery. The remainder of this paper is organized as follows: a review of current literature on infrastructure delivery system, a thorough examination of the infrastructure delivery models, justification of the research methods used, presentation and discussion of findings, and a conclusion.

2 Literature Review

As more infrastructure is developed and maintained, the requirement to properly manage projects and adapt to new possibilities needs organizations to effectively draw on lessons gained in order to prevent repeating mistakes and, ultimately, to provide infrastructure more efficiently and sustainably [29].

2.1 The Elucidation of 'EFFective and Efficiency' Concepts

There are substantial variances in how 'effectiveness' and 'efficiency' are regarded and portrayed depending on the author's professional environment and study disciplines. According to [47], "effectiveness" refers to an activity's capacity to deliver the targeted outcomes, it has to do with how well the outputs achieve the desired results. Meanwhile, [34], state there is no efficiency without effectiveness, hence effectiveness is a prerequisite for reaching efficiency. Efficiency is defined as performing things in the most economical way possible [9]. The goal of efficiency is to maximize output for a given input or to minimize input for a given output while maintaining quality [47]. The distinction between efficiency and effectiveness is that efficiency relates to how successfully you do a task, whereas effectiveness refers to its usefulness. Being efficient and effective, according to [27], implies that team members and stakeholders achieve project goals to the maximum satisfaction and acceptance of all parties involved. The concepts of efficiency and effectiveness are used to evaluate the infrastructure delivery management system.

2.2 Infrastructure Delivery

The acquisition and delivery of infrastructure is a complicated process [4]. There are a variety of ways that can be used to plan and construct a successful project, and the delivery method chosen has an impact on the infrastructure output. A project delivery method, according to [35], is a system for organizing and financing design, building, operation, and maintenance operations, as well as facilitating the delivery of a good or service. A competent and established organization is the cornerstone of an infrastructure environment conducive to effective project execution [10]. In a project-specific environment rife with unpredictability, infrastructure is designed and supplied through a disconnected supply chain linked together by contracts. Reference [30] alludes that in a planned economy, the planning and construction of projects are solely carried out by government institutions and agencies, while private entities, on the other hand, can execute the function for public works projects through competitive bidding processes.

2.3 Progression of Infrastructure Delivery in Other Countries

The public sector's infrastructure delivery units are feeling the pinch as demand for infrastructure grows. The severity of infrastructure problems varies significantly by nation type; unstable governments are swamped, while resource-rich countries, despite their wealth, lag behind [25]. Governments all over the world have embraced a variety of innovations and ways to build and improve infrastructure delivery.

i. **United Kingdom**

The UK has been a pioneer in developing innovative public infrastructure project delivery systems. The biggest hurdles to infrastructure investment in the UK, according to [39], a 2011 study of British firms, are a lack of a clear overarching government policy, delays and expenditures in the planning system, and regulatory constraints. The Gateway Review Process was designed as a critical tool for enhancing infrastructure as a result of the options presented, and it has been embraced across government [43]. Reference [41] elucidate that the method was first implemented in the United Kingdom in 2001, then adopted by the Victorian government in 2003, the New Zealand government in 2006, the Australian government in 2007, and Texas in 2013.The Gateway review process is a project management/development system that seek to minimize budget/time overruns and scope changes in departmental projects, increase alignment with government policy goals and departmental corporate strategies, and improve portfolio evaluation across government [43]. The program's focus is to enhance the procurement process, make tracking easier, enhance monitoring and authorisation evaluation simpler, and increase the governance framework for project development phases [41]. Policy formulation and execution, organizational reform, acquisition programs, and construction development are all part of the system. Reference [43] defines gateway as a systematic process that encompasses policy development, activity implementation, and analysis.

ii. **Ethiopia**

Ethiopia has achieved significant infrastructure improvements, and its infrastructure indicators compare favorably to those of low-income nations [21]. Ethiopia's construction sector, has risen enormously in the preceding eleven years, as has the expansion of other infrastructure projects [11]. As part of its attempts to overhaul the present public service structure and achieve rapid economic growth, the Ethiopian government has initiated a number of public sector reform programs. According to [45], in the early 1990s, the Ethiopian government implemented reforms to improve government institutions in the delivery of the country's public services. To promote and maintain human rights, the government has created a multiparty legislative framework, devolved authority to regional state and local administrations, and developed norms, policies, and institutional structures [3]. Business Process Reengineering (BPR), Balanced Scorecard (BSC), Change Army, Citizens Charter, and Deliverology, according to [22], have been implemented in the country's public sector institutions. Observations of [1], the reform efforts have shown that they have not achieved their objectives at the level anticipated. Reference [45] state that there is inadequacy during the implementation of Ethiopia's rehabilitation programmes. This is correlated with the competitiveness of the construction sector, sustainability, efficiency and community service capability [44].

iii. **Rwanda**

In recent years, Rwanda has reprioritized infrastructure and achieved great progress. After defining critical sector policies to repair infrastructure and improve service delivery, the government has initiated infrastructure reforms. Rwanda's Vision 2020, Poverty Reduction Strategy, Economic Development and Poverty Reduction Strategy, 2008–2012, and Economic Development and Poverty Reduction Strategy II, 2013–2018, are among the measures that have been implemented to achieve rapid economic growth [46]. To solve service delivery challenges, Rwanda's infrastructure planning is guided by strategy and vision documents in the National Vision 2020 framework. Infrastructure development, institutional frameworks, good governance, and a competent state are all interwoven into the framework [46, 51]. The government has made headway in reconstructing the country, as seen by infrastructure project development, planning, and procurement. The growth of Rwanda's infrastructure, however, is constrained due to inadequate institutional capacity among government and parastatal institutions, project selection, prioritizing, and planning [51]. The issue in relation to infrastructure is whether the policies of the government and the effectiveness with which they are enforced are adequate to attain the goals of the country.

iv. **South Africa**

Poor infrastructure has long been a thorn in the side of the South African economy and inadequate maintenance in certain regions has resulted in service loss or degradation [33, 36]. Despite limited resources, South Africa has worked hard to achieve a balanced socioeconomic growth by extensively investing in infrastructure [2]. The government has gone through several reforms [31].Various governmental efforts have been established over the years, the government has implemented a number of initiatives to address structural imbalances, including: Growth, Jobs, and Redistribution (GEAR), 1996; National Development Plan (NDP), 2012; Reconstruction and Development Program (RDP), 1994; Accelerated and Shared Growth Initiative (AsgiSA) structure, 2006 (GEAR extension); and Accelerated and Shared Growth Initiative (AsgiSA) structure, 2006 (GEAR extension) [17]. The various reforms had similar goals, but they were different in terms of how they were formulated and which regulatory frameworks they employed [32]. The observed shortcomings were evaluated during the execution of each plan to shape the building blocks for formulating new development plans aimed at satisfying the citizens' infrastructure needs, which is a continuous process. The fundamental issue, however, was that poor service delivery remained even after the various changes were implemented. The government was obliged to reconsider, which resulted in the creation of IDMS [12]. The intervention is to enhance effective infrastructure delivery and address the problems confronting infrastructure institutions.

2.4 Infrastructure Delivery Management System (IDMS)

IDMS is a collection of processes and a body of knowledge for public sector infrastructure delivery management introduced in 2010 [36] and offers a documented body of information and procedures that outlines common and established best practices in managing infrastructure project delivery, with a goal to improve project capabilities in organizational structure, procurement, governance, risk management, systems integration, and asset management [40]. It is created under the National Treasury's aegis, in partnership with national and provincial departments, the Construction Industry Development Board (CIDB), and the Development Bank of Southern Africa (DBSA) with the objective of offering critical guideline needs and procedures for delivering, utilising, maintaining, and managing infrastructure [36].

The system provides for government, technical support, planning, procurement and management processes which it categorizes into delivery phases [36]. This helps the project implementation management team to drive a uniform motion for project management and compliance with the applicable statutory criteria [13]. IDMS ensures linkages between people, tasks, information, and resources in order for stakeholders to have a shared understanding of the project's objectives [15; 26]. The infrastructure delivery management system promotes progress in delivery of projects, construction, rehabilitation and maintenance, or change in scope of infrastructure which cannot be executed in separation from acquisition and program management systems [36]. IDMS has evolved over a number of years and developed over time, with various modifications and the intention to tackle the challenges of inadequate capacity and organisational non-performance [13].

3 Research Methodology

Research is a process followed to investigate certain subject areas whilst broadening knowledge [40]. Any methodology must describe the research process in sufficient detail for the research findings to be credible to the research report's readers, and the analysis methods used must be able to substantiate its validity [24]. The research methodology adopted is a qualitative multi-case study. A case study is an extensive probe into certain circumstances in their natural state [52]. The case study strategy does enable retainment of the holistic and significant factors of literal events. This design was chosen because it could be used to conduct an in-depth investigation into phenomena in its natural setting. Within the case study research orbit, there are various data sources namely documentation, history logbooks, interviews, and observations [52]. The research was carried out using content analysis. With the goal of obtaining a greater understanding of the research field, the study was done through a comprehensive assessment of literature on infrastructure delivery. The paper, is part of an on-going study focusing on the effectiveness of infrastructure delivery management systems in the public sector. The study's focal point is to explore and analyse the effectiveness of infrastructure delivery management system in the public sector.

4 Findings and Discussion

Infrastructure development uses a substantial amount of natural and capital resources and has a long-term impact on society's socio-culture; therefore, infrastructure delivery and service must be sustainable [38]. According to the literature, efforts have been made to address inefficiencies and ineffectiveness in a variety of ways using various methodologies. The intensity of the obstacles and issues vary depending on the type of program, the methodology, and the circumstances of the participating countries. The desktop comparison demonstrates that South Africa is not alone in this situation; other developing and expanding countries face similar serious infrastructure delivery issues. The fundamental concern of the public sector is to improve the provision of social infrastructure, which has an impact on the economy and the lives of citizens.

- The Gateway model provided by the European governments was introduced with the aim of improving infrastructure delivery. Reference [20] state that there is no sufficient evidence to confirm that the Gateway initiative is a success.
- Reference [45] provides interesting insights into the transformation of Ethiopian infrastructure and confirms that there is inadequacy during the enforcement of the rehabilitation programs in Ethiopia. Reference [51] acknowledges that the issue in relation to infrastructure is whether the government's policies and the effectiveness with which they are implemented are sufficient to achieve the country 's goals.
- A study conducted to identify the challenges in the delivery of social and economic infrastructures through public-private partnership procurement arrangements in the Sub-Saharan African region, using South Africa as a case study, found that there is a lack of capacity, policy direction, and clarity among political leaders and implementing agencies in the delivery of social and economic infrastructures through public-private

partnership procurement arrangements [37]. Reference [48] opine that many of these delivery management duties are currently being failed by government institutions in South Africa, which is one of the key contributors of poor infrastructure outcomes.
- A lack of governance, as well as inadequate procurement and delivery management methods, are frequently the core causes of project failure or bad project outcomes, all of which are under the control of the government [48].

The reform models have been adopted in a range of countries, still face inherent challenges in reform program adoption and implementation. In terms of attempting to solve the problem of public infrastructure requirements, certain third-world nations have made progress. The solutions that attempted to solve delivery issues did not take a holistic approach to achieve a specified goal, and the results were inconsistent. Reforms have frequently failed not because they were not properly implemented, but because they failed to generate the desired results, only superficially matching donor-endorsed best practices [12]. Management controls that have shown to be effective in one country can prove ineffective or even inefficient in another country [5]. According to [23], there is a rising realisation that policies do not succeed or fail on their own; rather, their success is determined by the implementation process.

The dominant leadership and delivery model for infrastructure projects has not evolved to reflect profound changes [14]. Evidence-based decision-making, lead to greater effectiveness and efficiencies in achieving strategic results across the government [3]. Therefore, to enhance the efficiency of infrastructure projects, there is a desperate need to deal with the ambiguities in an integrated manner in order to accomplish the best practice in effective infrastructure delivery. Establishing an institutional architecture that allows for a specific degree of public service necessitates precise process, policy, skills, leadership, and capacity, all of which are required for successful infrastructure delivery.

Though experiences differ greatly by country, there is evidence of limited success in terms of effective infrastructure delivery systems in the public sector in both developed and developing countries. In this aspect, empirical evidence gathered from throughout the world isn't particularly helpful. Considering the evolving nature of the infrastructure sector, systems implemented to deliver infrastructure should be reviewed to allow for any improvements that might become essential. This suggests that there is a lot of room for improvement in infrastructure delivery processes in the public sector around the world. It's important that the systems in place allow for sufficient adaptability and flexibility in responding to infrastructure demands and implementing changes. [3] contributes that an efficient government is one that can protect residents from any aggression while simultaneously providing and maintaining infrastructure that allows for the interchange of goods and the delivery of services.

5 Conclusion

Public infrastructure reforms have a direct role to play in improving infrastructure delivery, but as discussed, they have not been able to make the necessary progress to date, a fundamental shift in the way these policies are designed, implemented, and evaluated is required. The literature shows most countries have made progress in infrastructure provision through various systems, the solutions in different countries have been found to be constrained in effective delivery of infrastructure. Most strategies administered by countries on various continents to rehabilitate their public bodies were in vain, primarily due to inadequate strategy enforcement [7]. Although the relations between infrastructure reforms and performances are complex, the conclusion can be drawn that enhancing processes can have significantly improved performance. While the IDMS promotes a standardized approach to infrastructure delivery, there is a knowledge vacuum regarding how infrastructure delivery systems affect the performance of public-sector service delivery. It will take systematic collection of cross-country infrastructure data to empirically untangle the ties between distinct infrastructure delivery systems and ultimate industry results. A deeper understanding of how to develop effective delivery systems is urgently required.

Governments should evaluate their institutional capabilities considering the infrastructure delivery systems and intended outcomes. This evaluation will assist governments in determining how to enhance current processes by integrating new ideas, developing targeted skills, and having an integrated delivery model. Since the implementation of IDMS, it has been important to monitor current performance and trends to enhance processes, examine potential alternatives, and prescribe appropriate remedial action. Infrastructure gains are fully realized only when initiatives result in demonstrable public benefits. Drilling down and more operationally into the system to fill the gap in relevant literature in enhancing infrastructure delivery and establishing an integrated delivery model for public infrastructure is of interest.

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Complexities in Metrorail Project- A Case Study of Hyderabad Metro Rail

Sruthilaya Dara(✉) and Aneetha Vilventhan

National Institute of Technology, Warangal, India
sruthilayadara@student.nitw.ac.in

Abstract. In India, the importance of urban transportation is quickly increasing, and it has become a prerequisite for economic and social progress. The development of MRTS (Mass Rapid Transit System) is essential for growing urban transportation. There are various studies on the technical and economic analysis of metro rail projects, but there are only a few studies on the study of complexities. In this paper, the complexities of metro rail projects are identified through an ethnographic case study on the Hyderabad Metro Rail project. A detailed case study analysis revealed that there are political, technical, interface, stakeholder, and other complexities in the project. Based on the findings of the case study, factors for reducing the occurrence of complexities and improvements have been suggested, which will assist metro organizations and stakeholders in the smooth implementation of metro project constructions.

Keywords: Metro rail · Project complexities · Case study

1 Introduction

The expansion of transportation projects all over the world has increased the development of MRTS (Mass Rapid Transit System) like metro rails in urban cities. These kinds of transportation projects in the construction industry are causing complexities with technological advancements [1]. Complexities in projects occur as a result of several interrelated elements involved and are managed in terms of interdependence and differentiation conditions [2]. Uncertainty, interdependence, etc. are the characteristics of large infrastructure projects. Such characteristics occur as a result of higher investments, planning, design methodologies, deadlines, political influences, etc. [3]. Along with these characteristics, the project's complexities must be identified because they cause significant problems [4]. Effective recognition of complexities and their factors in the project must be identified and managed for successful project planning and management. Therefore, this paper aims to study the type of complexities that have occurred in the Hyderabad metro rail (HMRL) project. A detailed case analysis is done on Hyderabad metro rail to identify the complexities that occurred in metro rail projects. This analysis and findings will be beneficial to stakeholders of the project in metro organizations in terms of improving mechanisms to reduce complexities.

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2 Literature Review

Megaproject constructions, such as metro rail projects, are regarded as difficult and uncertain projects. Several mega projects are being developed all over the world as technology and human life are improving. Metrorail projects are regarded as innovative construction projects that use advanced technologies. The majority of construction projects are using new methods and technologies for planning, execution, and management of large-scale projects. Each type of construction project has unique characteristics that contribute to its complexity and can be attributed to stakeholder demands and other technological advancements [1]. According to [2] construction projects are classified as complex projects because of their interdependence and differentiation characteristics. Rapid growth, technological developments demand of stakeholder, environmental, accountability, transparency, and sustainability concerns are regarded as few complex factors [5]. These complexities and uncertainties associated with construction projects are regarded as the primary cause of numerous difficulties [5]. Each type of megaproject has its characteristics and complexities, necessitating personalized management solutions and strategies. Researchers have been tracking the performance and characteristics of mega projects all over the world, and analysis has revealed that megaprojects have cost and time overruns [6].

Metro rail projects are regarded as megaprojects, and they are rapidly expanding to become the most common mode of transportation in most urban areas. Underground and elevated metro constructions in urban areas are widely used as convenient transportation due to the rapid development of cities. However, these structures necessitate large investments and take a long time to design and build to achieve all of the anticipated regional, social, and national benefits [7]. Metro rail projects are known as inter-organizational structures hence, it is necessary to investigate the interdependence of the project's elements, activities, and uncertainties that cause complexities in the projects [6]. The complexities should be identified as it poses a substantial risk to public and government trust. As they are considered the important stakeholders of the projects and each phase of the project has the perspective to influence the progress of the project [8]. Furthermore, metro systems are typically designed for use in congested areas of cities. The construction procedure certainly disrupts civilian daily lives. These examples demonstrate the significance of proper management and planning throughout the metro project's whole process for it to be completed on time, on budget, and with high quality and efficiency. As a result, the purpose of this article is to look into the special complexities of building an underground metro rail system. There is a lack of literature on identifying complexities and uncertainties for successful megaproject implementation, and there is a need for knowledge in the area of complex project implementation and management, particularly about the complexity of metro rail projects. Reference [8] proposed a six-category complexity framework in his literature, which included technological, organizational, goal, environmental, cultural, and information complexities. Stakeholders, organizational and hierarchical structure, various number of departments, experience, etc. are a few factors causing organizational complexity. Use of new technology and innovation in the megaprojects based upon the size, and building type. Contractual type. Design type, overlapping of construction and design, diversity in technology, interdependence process, risk of using difficult technology, mixed design problems, manufacturing of materials causes technological complexity. Natural conditions, political influence, market conditions, and organizational environmental conditions casues environmental complexity. Type of contract, changes in clauses in the contract, arbitration and termination problems, changes in design, Cultural diversity, delays in permissions, land acquisition, delay in relocation utilities, delay in transportation of materials causes location and contractual complexities. The factors causing quality complexiy are Causes of accidents, improper safety precautions, improper mix design, lack of experience, lack of knowledge. This framework maps the complexity categories that have been occurred in the megaprojects. Hence, this complexity framework was used as a reference in this research to identify the complexities in Hyderabad metro rail project.

3 Research Methodology

In this study, the case study approach is considered to be an appropriate strategy for capturing detailed information in complex construction projects like the metro rail to retain the holistic and meaningful characteristics of real-life events [9]. The objective of this research is to identify the complexities occurring in metro rail projects. The unit of analysis complexities in the Hyderabad metro rail project in Telangana, India.

4 Background of the Case Study

Around the world, there are approximately 200 urban mass rapid transit (MRT) systems, with the majority of projects being built through a Public-Private Partnership (PPP) system. The Hyderabad Metro project is one among them. The Telangana government initiated the Hyderabad Metro Rail project to reduce traffic congestion and pollution in the city. This metro project, with a total length of 72 km, covers three high-density traffic corridors in the city and is being built using the design, build, finance, operate, and transfer (DBFOT) model with a Public-Private Partnership (PPP). The total cost of the project is Rs. 14,132 crores (USD 2.36 billion), with the government of India allocating Rs. 14,132 crores (USD 0.24 billion) as a one-time grant awarded through competitive bidding. Concessionaire M/s L&T Metro Rail Hyderabad Ltd, a subsidiary of India's infrastructure and manufacturing conglomerate invested Rs. 16,674 crore (USD 2.12 billion). This project is being carried out following international quality and safety standards, with an emphasis on design novelty, aesthetics, energy conservation, and natural ventilation. The stations, pillars, and viaduct of this elevated metro rail are all designed to enhance the beauty of the city. This is a large-scale project that will transform the city with a low carbon footprint. The types of complexities observed in the Hyderabad metro rail are organizational, technological, environmental, contractual, location and quality.

Technological complexity

The elements and conditions of the design specifications for the project are interconnected. According to [10], the Coordination of design specifications containing the overall details of projects may result in unknown mistakes causing technological complexities. The Hyderabad metro rail project is governed by the Railway Act, which includes Main Technical Specifications (MMS), key performance indicators, and RDSO (Research Development Service Organization) guidelines that prioritize time, cost, safety, and quality. New design methodologies are used during the construction stage, such as the installation of a parapet wall behind the viaduct to accommodate overhead electrification (OHE). Because OHE is a continuous span of 30–40 m, small cantilevers and supports have been used in between. The modeling techniques are known as "build dimensions" are used at every stage of the laying of foundations, piers, and other structures. Every station is designed with the "spine and wing" concept in mind, and rolling stock consumes the most power (i.e., 30% of operating cost in power), with friction energy converted back to electrical energy via power regeneration. The factors of technological complexity are represented in Fig. 1 and few innovations in technology challenges faced in HMRL are listed below.

- CLSM – Controlled Low Strength Mortar used to reduce foundation depth
- Curing compound used to reduce curing time, no natural sand is used, stone crusher and fly ash is used and admixtures are used for durability
- Pier Cap is integrated with Pier stem with a single pour
- Using Three-span continuous segments and a precast portal beam is used
- Bridge Builder used for installing ROBs and Winch and Underslung launching girders are used
- In ROBs, segment to segment intermediate pre-stressing is done to reduce overall stresses.

Technical complexities faced in the metro projects are as below:

- Construction in Urban Environment and Traffic Management
- Technology Selection – Modern and Proven technology
- System Integration – Interface between highly complex systems
- Vendor management – Global constraints forcing disruptions (AFC – Samsung) and Technology Obsolescence – Constantly evolving technology rendering existing systems obsolete.

Contractual complexity

In this project, cost-plus, lump sum, supply contract, and BOQ contracts were used, and a few changes to the contract terms were made due to the extension of time (EOT). Several complex factors are observed during the construction of the project and are listed below:

- There were a few disputes during the pre-construction stage, such as Right of Way (ROW), during construction Extension of Time (EOT), and disputes in the post-construction. Negotiation is used as a technique for resolving conflicts that arose during the project. During the project's life cycle, the contract was terminated due to the closure of the company. There have been no specific issues reported that result in misinterpretation of project clauses, and there have been no liquidity losses as a result of delays.

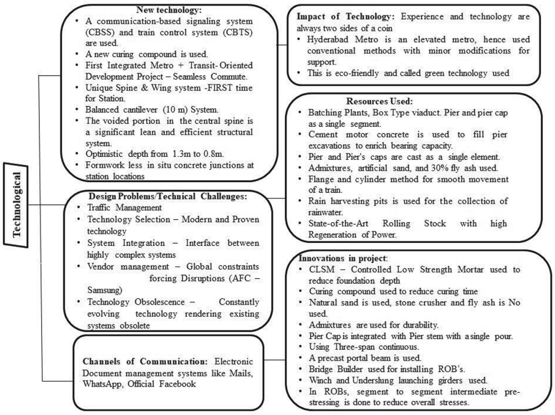

Fig. 1. Factors of technological complexity

- The project experienced changes in scope (addition and deletion), EOT, and price variation.
- Contracts presented a few challenges, which are listed below.
- Technical expertise –vendor monopoly.
- Contract enforcement, particularly with contractors from all over the world.
- AMC support from a vendor during operations.

The details of location complexity are represented in Fig. 2.

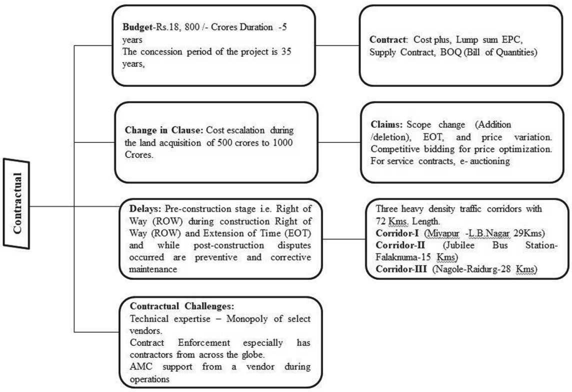

Fig. 2. Factors of contractual complexity

Location Complexity

Land acquisition, utility relocation; permissions for geological conditions, clearances for traffic diversions, and interference with existing structures have all contributed to the location's complexity. In this metro, land acquisition is a major source of complexity, and it has an impact on other factors. Due to high land inflation rates in this city, this has proven to be a difficult task; only 10% of the land was acquired before the project began, and 60% afterward, resulting in a one-year delay in the project. Due to cost inflation, 30% of the land was never purchased, and the design had to be adjusted accordingly. Road widening for construction has also been a problem due to this complexity. The road width has been increased to 120 ft and is usually limited to 100 ft. However, due to land acquisition near Sultan Bazar, the width of the road has been reduced to 60 ft, resulting in a significant design change. One of the factors that contribute to this complexity is design changes. Aside from land acquisition, interference with existing structures such as government buildings, rail over bridges (ROB), and religious structures prompted the design change. Other factors, such as utility relocation, land acquisition, and interference with existing structures, have all contributed to the process's delay. Utility records and drawings are unavailable in Hyderabad because it is one of the world's oldest cities. Construction of foundations, excavation, and utility relocation has all become more difficult as a result. The relocation of a 100-year-old masonry stormwater drain that collects water from the Nampally area and leads to the Musi has been a major consideration. These geological conditions have made construction difficult. The details of location complexity are represented in Fig. 3.

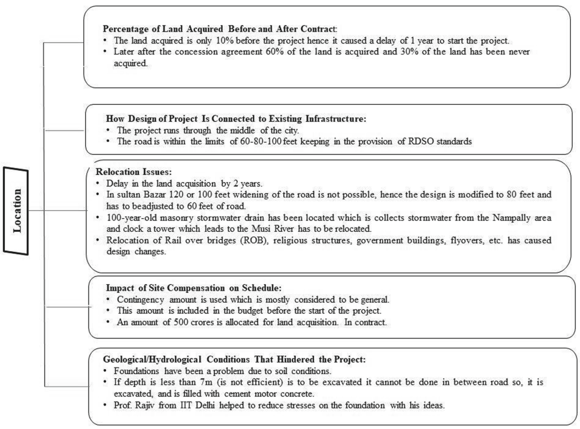

Fig. 3. Factors of Location Complexity

Environmental Complexity

External factors such as the number of stakeholders, regulatory requirements, policy changes, and interface issues are the most important causes of environmental complexities [11]. Many external characteristics, such as shareholders, contractors, governments, and suppliers, are involved in megaprojects, resulting in social conflicts as a source of complexity [12]. Disagreements between the government and stakeholders led to changes in the design of this metro rail, which is regarded as an environmental complexity factor. The change in alignment had an impact on the work that delayed the project.

Such differences in opinions and perspectives among stakeholders can be reduced by increasing the transparency of the work done. In an organization, interface problems have an impact and may have been advised; however, beneficial aspects and politics had little impact on this project and are managed through SAP inventory. Another factor to consider is cultural differences among workers, which are observed at the beginning of the project. Suppliers and material transportation have been identified as a source of complexity. Because materials are obtained from various countries, there is a delay in the supply of materials, which had caused a delay in the project and the environmental complexity details are represented in Fig. 4. To overcome the complexity factors, the Kaizen method of continuous self-improvement is used, and problems in construction methods are modified accordingly to eliminate the error. If the error persists, the construction method is either modified or eliminated.

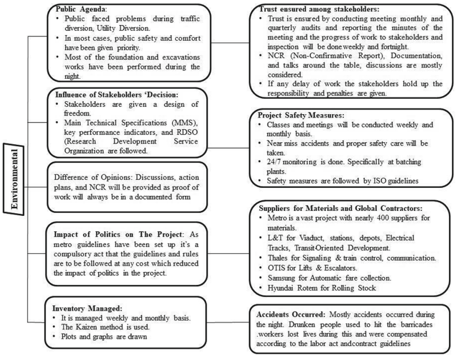

Fig. 4. Factors of environmental complexity

Organizational complexity

The degree of differentiation that exists among the elements of the organization is referred to as organizational complexity [13]. It is concerned with the differences that arise within the various elements that comprise an organization, which may also include a wide range of different specializations. Specialization, authority, control focus, product attributes, personnel, technologies, and structural differentiation are all examples of elements found in an organization [13]. L&T is a major organization that built the Hyderabad metro rail with total revenue of 16,000 crores and an annual employee turnover of 0.3 crores. It is a multidisciplinary organization that is linked to numerous interfaces to reduce cost and time escalation delays. One of the most common causes of organizational complexity is interface issues. Language and cultural barriers are thought to influence the occurrence of organizational complexity. The common languages used in this project are Hindi, English, and Telugu, but English is the language of communication, according to the contract. At first, workers had difficulty adjusting to the local conditions because they came from different places and had different cultures. However, Hyderabad is regarded as a cultural crossroads where cultural differences have little impact on project productivity in later stages. Because the information is coming from the same source, the people and employees are well aware of the project's scope and goals. As a result, departmental and team interdependence had less impact. This organizational structure followed hierarchy from the start of the process, and decision-making was placed in the hands of the hierarchal structure. Employees are aware of the goals and scope of the project due to constant updates through seminars and graphical progress representations, even if a hierarchical structure is used. The organization's outcome goals are timely execution, meeting milestones, proper information flow, and world-class quality output. Hence the chances of making mistakes in a multidisciplinary project like this are less as the source of information is the same. The organizational complexity factors and details of the project are represented in Fig. 5.

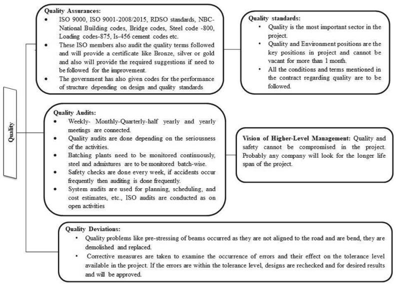

Fig. 5. Factors of organizational complexity

Quality Complexity

The primary goal of an organization is to provide the highest quality service possible by understanding the complex factors that affect safety and quality. ISO 9001-2008/2015 quality standards are used in metro rail construction. To ensure quality, audits are performed on a weekly and monthly basis. The L&T Company does not provide quality assurance for this metro rail. As a result, few quality deviations occurred, and it is regarded as a complex factor. Several design flaws were discovered during construction, like beams that were not aligned with the road and were bent, as well as quality issues in pre-stressing. Before being replaced, these structures were discovered and demolished. Corrective actions are implemented to investigate the occurrence of errors and their impact on the project's success. The in-depth details of quality factors are represented in Fig. 6.

5 Discussions

The results of the case study analysis are discussed below. The technological and environmental challenges are the significant complexities in the Hyderabad metro rail project, according to the case study analysis. The factors that cause technological and environmental complexities include land acquisition, utility relocations, geological conditions,

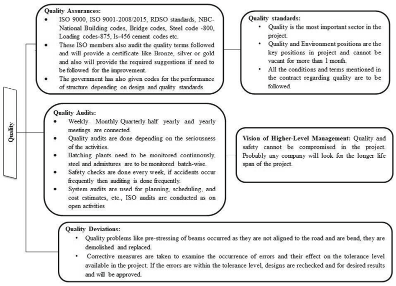

Fig. 6. Factors of quality complexity

delays in obtaining clearances, the use of new technologies and materials, and interface issues. Because Hyderabad is a metropolitan city with fast urbanization, land acquisition has become a complex issue, delaying the project by three years. Utility relocation has been considered one of the key complexity factors and has a significant impact on the progress of the work due to the older utility infrastructure. Excavation work has been difficult during construction due to older structures and varied geological conditions. The interface among the stakeholders in the organization is regarded as one of the complex factors that impact the project's development due to the inter-organizational system.

6 Conclusions

Metrorail has become the ultimate urban transportation megaproject, serving as a lifeline in cities around the world. Megaprojects like these have become most important in cities like Hyderabad, India. Complexity is considered a significant characteristic of transportation megaprojects, according to the case study analysis of the Hyderabad metro rail. From the empirical case study research, it is identified that complexity factors like new technologies, utility relocation, interface issues, interference with existing structures, political issues, delays in obtaining permissions, the number of participants, and stakeholder interests are the major contributors to the occurrence of Technological, organizational, location, environmental, contractual and quality complexities. The case study analysis showed that the technological and environmental factors impacted the Hyderabad metro rail project. The identification of complexities in metro rail projects reduces the impact of uncertainties, delays, and time and cost overruns throughout the project's life cycle. As a result, throughout the project's life cycle, the study of complexities must be prioritized. Governance mechanisms must be improved to reduce the occurrence of complexities and their impact on metro rail projects. To decrease the land acquisition problem caused by location complexity, mixed land use must be developed. To avoid environmental and organizational complexities, environmental, cultural, and social impacts must be considered as part of the EIA process. Smooth operation necessitates participatory decision-making and information transparency for the metro organization to function smoothly and avoid the occurrence of organizational complexity. A comprehensive vision and mission must also be established before the start of the project to reduce the overall significance of complexity in the project's life cycle. The limitations of this paper are that the occurrence of each complexity is not analyzed in detail. The impact of complexities and its factors need to be quantified further. In the future, the research could focus on complexity models for identifying and measuring the impact of complexities on metro rail projects. The study can be expanded for identifying the complexities and factors in underground metro projects.

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A Study of Challenges in Utilising Decentralised Electrical Systems in South African Residential Properties

Alireza Moghayedi(✉), Mark Massyn, Karen Le Jeune, and Kathy Michell

Sustainability + Oriented Cyber Unit for Built Environment, Department of Construction Economics and Management, University of Cape Town, Cape Town 7700, South Africa
alireza.moghayedi@uct.ac.za

Abstract. Currently, South Africa's power utility produces 96% of the residential properties' electricity and only 4% of the power generated by sustainable Decentralised Electrical Systems (DES). Therefore, this study aimed to understand the reasons for this low adoption rate of decentralised electrical systems in South African residential properties by investigating the challenges and barriers to utilising this system in residential properties. Three groups of experts, namely local Suppliers, Engineers and Residential developers, were interviewed and collected data scrutinised using thematical analysis to create a holistic view of the trends and answer the research question. The study identified that the cost and regulation challenges experienced in the installation and operation of DES in South African residential properties are the main obstacles and negatively affect the adoption rate of these systems. The main overarching factor to the lack of adoption was found to be mainly cost-related, high cost of installation and the long period of return on investment. The research also identified the key areas that need to be focused on, such as more stakeholders' involvement in promoting and increasing the uptake and adoption of DES in South African residential properties. Finally, the study deduced that South African local and national governments, as critical stakeholders, can make the earliest and most significant impact on the adoption of DES in residential properties by providing appropriate financial incentives and reducing excessive regulations.

Keywords: Capital cost · Challenges · Decentralised electrical systems · Level of adoption · Residential properties

1 Introduction

South Africa's power utility, Eskom (Electricity Supply Commission), produces 96% of the country's electricity [1]. Eskom's main form of power generation is coal. This supplies 92% of the electricity to the grid, with 5% of supply resulting from nuclear and the remaining 3% classified as other [2].

With the economy and South Africa's population growing much quicker than in past decades, the electricity demand steadily grew. This increase in demand took advantage of the extra capacity that the already built infrastructure offered. With the current

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infrastructure growing old, there was more downtime for maintenance, planned and unplanned [3]. Simply supplying to more users without increasing generation capacity creates a bottleneck down the line, and this was first experienced in 2008 with the first implementation of load shedding. Eskom then initiated a first initial price increase of 14.2% between 2006 and the end of the first quarter of 2008 [2]. This was implemented to finance the massive infrastructure upgrade, with a review that a further price increase of 35% per annum from the second quarter of 2008. These price increases were to be felt by all sectors evenly and weren't proportioned across sector usage. The industrial sector uses significantly more electricity than the residential sector, but both sectors are treated equally.

Initially, sustainable solutions to renewable energy were expensive, hence the heavy reliance on Eskom and its coal as a fuel [4]. However, the South African government has committed to reducing greenhouse gasses by 42% by 2025 [1]. Furthermore, the implementation of the Renewable Energy Independent Power Producers Procurement Programme shows a significant intent toward more sustainable and renewable sources of power generation, mainly solar and wind. Comparatively, with other countries worldwide, South Africa has some of the best solar conditions and yet is not using this abundant resource to its full potential [5]. Initial costs of installing large scale solar farms involved high capital costs as a few developed countries are the leading manufacturer of these systems, and there is little competition in the market [1]. With Eskom's electricity prices constantly increasing and the growing concern around climate change and the future of our environment, more South Africans are trying to move towards more sustainable and renewable forms of DES. The most common form of DES in the residential context is the use of Photovoltaics (PV) panels and batteries. This system is becoming more appealing to people as the system is more available in local markets, and the installation price is decreasing. However, the high initial capital outlay was a deterrent and a reason people did not opt for this system sooner. Still, as DES is improving, governments subsidising projects and increased demand have promoted mass production of these systems, which decreases the overall cost [5].

DES can provide many solutions to the unstable power supply that South African residents are experiencing [6]. The most significant of these systems is being self-sufficient and not relying on an electricity provider [7]. In addition, having sustainable DES reduces the reliance on fossil fuel power generation. This old form cannot be relied on in the longer term as a finite resource, and the negative environmental impact is significant. A renewable, decentralised system has none of these challenges; there are no environmental impacts, and it relies on infinite resources for power generation like solar [8]. DES also reduces the loss of electricity through transmission [9]. Compared to centralised systems, there is a wastage of electricity through the cables with the vast distance travelled from production to consumption. Long term advantages of decentralised independent systems are the ability to sell excess production back into the grid, either reducing the amount owed to the service provider if a hybrid system is used or credit from the service provider [9]. According to predictions, South Africa's renewable energy production will account for 70–80% of the country's total energy production by 2050 [10]. This shows that the predicted trend will move towards decentralised renewable energy sources. Although DES have many advantages, they have some drawbacks, such as the efficiency of the generation of electricity fluctuates with the weather conditions, ambient temperature, and levels of irradiation [7].

As mentioned above, DES has many benefits, but these systems are new technologies that are beginning to emerge into the South African energy market. As this technology is relatively new in South African residential property and still emerging, there is no significant information available about the challenges in adoption. Therefore, the current study aims to provide insight into a growing decentralised electrical systems market and help understand the current problems people face when implementing these systems into their houses. This information can then be used to define a clear strategy for the future to better suit the requirements of the people who are implementing these systems.

2 Methodology

Since the adoption of decentralised electrical systems in South African residential properties is still a less explored area, it requires utilising a qualitative research approach for collecting data from the experts to investigate this little-understood phenomenon. Therefore, deploying semi-structured interviews in the present study aimed to provide a practical basis for conceptualising the key influential factors in adopting decentralised electrical systems in residential properties in South Africa.

The number of interviewees was considered between 3 and 16 as a reasonable preliminary estimation for defining the sample size [11]. Thus, an initial list of 15 experts from three groups of local suppliers, engineers and residential developers was identified. As a result, interviews reached saturation point after conducting interviews with three interviewees in each group, whose profiles are detailed in Table 1.

Table 1. Interviewees' profiles

	Local suppliers			Engineers			Developers		
Code	Sup1	Sup 2	Sup 3	Eng 1	Eng 2	Eng 3	Dev 1	Dev 2	Dev 3
Experience (year)	5	7	12	14	21	18	24	35	17

For this research, an inductive approach has been adopted. First, the structure of the study was developed through the data that was collected. Following this, a thematical analysis of the data collected was employed as this is a commonly used inductive approach to analysing data. Finally, common themes were identified in the interview transcripts using NVivo, and these themes are discussed in the following section.

3 Results

The collected data was analysed and presented according to the three expert groups: local suppliers of decentralised systems, engineers who install the systems, and developers who incorporate these systems in their projects.

3.1 Suppliers

Available Systems

When looking at a residential aspect, the predominant choice of DES and renewable energy generation systems is solar power. The selection of solar power comes down to its ease of installation and is the most versatile. All three suppliers distinguish between the two types of DES used, namely: hybrid and non-hybrid systems. There are many differences between these two systems, as listed in Table 2.

Table 2. Comparison of hybrid and non-hybrid DES

	Hybrid	Non-hybrid
System	All systems are linked internally and form one built-in system. The system does not have a transformer	The system is formed of individual parts linked externally to form the system. Transformer included
Pricing	Cheaper: due to the system not having a transformer	Expensive: system having individual systems installed and having a transformer
Repair	Suppose one of the systems within the built-in unit fails. The whole system needs to be replaced	Simple to repair. The damaged system is taken out and repaired. Users will still have power in their houses

Demand for DES

The customers for DES live in various housing types: stand-alone houses, complexes, and estates:

> Where a homeowner has their own roof space and control over it, the proper system can install.

There hasn't been a demand for DES in apartment buildings where the homeowner doesn't control the roof space. However, suppliers did note that where a customer lives in a complex or an estate with a body corporate, they would need to acquire additional approval to install the system:

> In an urban area where there is a capability to have both the supply from the solar system and a supply from the municipal grid, a hybrid system is more common.

Regulation

There are different requirements for the two distinct categories. A hybrid system provides greater complexity in that it has to incorporate the municipal supply grid. With the incorporation of the municipal supply grid, more approvals need to be given to the system owner:

> A municipality needs to be aware of all independent power producers so that the local grid can be stabilised and controlled accordingly.

Life Cycle Cost of DES

The type of system chosen at the beginning of the installation will dictate how long the system will last:

> it's safer to go for a reputable brand that costs more but will increase the system's life span due to the management software and systems that form part of the system.

The average life span of the systems is fifteen to twenty years and is dependent on how the batteries are managed and the software that has been installed. The required maintenance on residential solar systems is very little to none:

> The PV panels are deficient maintenance and will only need to be cleaned for the energy production to be as efficient as possible.

Installation of DES

The main challenges that the suppliers mentioned were the system's capacity that can be introduced, with the limitations of a house being the amount of available roof space for the PV panel installation. Suppliers also identified that the local products available on the market are not comparable with those of higher quality imported products:

> to be a price decrease in the systems, the local market needs to create a higher quality product comparable with international products, thus reducing the end cost that the client has to pay.

Furthermore, the DES needs to be coded to operate efficiently. All the management systems need to speak to each other, and the incoming supply needs to be monitored. As a result, the difficulties of incorporation varies between systems.

3.2 Engineers

Capital Cost and Investment

The cost of DES is highly variable due to the scalability of the infrastructure:

> When a system includes a battery system, the system's price increases significantly.

The system's location is a critical contributor to cost. A location does not have the optimum exposure to the sun, like a highly shaded area, so that the installation will require more panels than a location with high exposure to sunlight. This will inevitably increase the cost of the installation. Engineers elaborated that the smaller the system, the more expensive the end product is per kilowatt produced. A comparison can be seen in Table 3.

Table 3. The energy output of system vs price per kilowatt produced

Production	Less than 100 Kwp	100–500 Kwp	More than 500 Kwp
Price per kilowatt peak	R14/Kwp	R10–R14/Kwp	< R10/kwp

The return on investment is equally dependent on the initial capital outlay. In addition, as identified above, the initial capital depends on the type of system installed and what infrastructure and equipment were used.

> On average, a DES without a battery will take 3 to 5 years to realise the initial capital investment, while a battery installation system will take between 5 to 6 years.

Moreover, engineers argued that these are average durations, and a return on investment is highly dependent on the type of system installed, the system's efficiency, and the electricity tariff that the user would need to pay the municipality if the system weren't in use.

Installation of DES in houses

Residential developers are installing systems but do not intend to be completely off-grid. Engineers highlighted that those systems installed now in South African houses are not intended to be completely off-grid and act as a backup rather than a primary source. Most of their work involved creating a supply for intermittent supply issues like load shedding and reducing the consumer's reliance on the municipal electrical grid.

There are three main factors that homeowners should be considered before installation:

> The amount of money that the homeowner is willing to spend, the amount of available space for the system, the requirements of the installation and what output it will need to provide.

The optimisation of an installed system is critical to the user achieving the highest value for money:

> The more efficient installed system costs more but allows the user to generate more energy with the same amount of space.

Technologies should be improved for the installation size required to reduce an equal amount of electrical output:

> space effectively is very critical because, in some developments, space is a limiting factor.

Furthermore, in domestic housing, the peak demand times are not in line with peak electrical production from the solar system, which creates the need for battery storage for the energy to be used later.

Advantages vs disadvantages of DES
Engineers mentioned many advantages of utilising DES like PV residential properties:

> reduces power outages, electricity costs, and being renewable and green.

Moreover, engineers pointed out that significant increases in electricity have moved people into using DES, decreased the user's reliance on the grid, and allowed them to be independent when required:

> The main benefit is the guarantee of supply at constant cost.

On the other hand, the most significant disadvantage of the DES is the high upfront cost that the user has to pay:

> with a solar system when the peak production is not in line with peak demand, there is a need for a storage system that is very expensive.

Engineers stated that installing solar systems in residential houses is not yet as financially feasible and attractive as commercial buildings. Therefore, some public incentives are required to motivate the homeowners to utilise DES. Furthermore, engineers highlighted the need for government/municipalities' approval to install a system, which makes the installation process longer:

> all systems need to complete the small-scale embedded generation application to be compliant.

3.3 Developers

Government involvement
Developers identified the lack of government involvement in the solar industry as the main contributor to the high cost of technology and the main reason for the low level of adoption in residential properties in South Africa:

> there is a lack of incentive and subsidies from the government toward the customer to adopt solar systems.

Recently, there have been a few modifications in regulation regarding DES in South Africa. With legislature changes allowing the independent production of power and the requirement for each installation to go through an approval process. The government are aware of these installations and is keeping track of them but is not as enthusiastic about helping make the infrastructure affordable for more customers.

Capital Cost and Return on investment
The high initial cost is why the systems are not being as widely adopted and, from

a developers' point of view, not feasible with the profitability of a development. The incurred capital cost will depend on the type of system installed, the system's required output, and what technology is used in the system. Return on the initial capital investment is proportional to the amount spent:

> a longer return period for the higher the initial payment was

However, the technology used plays a vital role because the expensive equipment will last longer and maintain the system better, thus not needing to be replaced as soon as less expensive equipment.

DES installations in residential developments
The incorporation of DES in houses is beneficial to the end-user. It decreases the cost of electricity to the household and gives the user independence in electricity production:

> installation of DES in new developers increases the development's marketability.

Developers discussed how it increases the property value of the development as solar energy has seen an increase in demand and interest in South Africa. However, the most significant benefit to the developer of installing a renewable energy production system is purely the development's marketability:

> The majority of the systems that they've seen being installed is intended to be used for an unerupted power supply for load shedding.

The biggest reason developers do not install DES is that developers do not benefit from the installed system. The selling price of the development with a DES will be higher than a development without a DES. Still, the difference in selling prices does not create enough profit to justify the system's installation:

> The profit generated from a development without a solar installation is more than what the margin would be with an installation.

Developers are also aware that the number of knowledgeable buyers is very low, so potential buyers do not understand the system's value and will buy a similar house without DES, which is cheaper. Developers also discussed how large-scale developments do not have enough available space and where roof areas are shared. In addition, the electricity generated from the system will need to be shared amongst the homeowners, and the difficulty comes in where the liability of repair and costs are generated from the system. Moreover, developers believe the high capital cost of the system and the long payback period is the main challenges in installing DES in South African residential properties. Developers also mentioned other more feasible options in creating a sustainable development apart from using solar power, such as solar geysers:

> Solar geysers don't take as much space on a roof as a solar power installation and significantly reduce the electricity cost to the end-user.

4 Discussion

When analysing the opinions of the three target groups of suppliers, engineers and developers, it is evident that there are many similarities in opinions about utilising the DES in South African residential properties. This research has found that the most apparent barrier and challenge when installing a DES is the upfront capital cost. All of the groups identified the cost of the systems to be the main challenging barrier when installing a system. Even though the prices have decreased over the last few years, the overall cost of the system remains high. Aghamolaei and Shamsi [12] also identified the high capital cost of the systems and infrastructure as the primary barrier to the adoption of DES systems in residential properties. The high prices were mainly due to the system requiring a battery installation, which significantly contributed to the overall cost. The second common barrier that the three groups individually identified was the amount of space that a DES requires. Available space is a limiting factor where all groups recognise the challenge of generating enough power to provide for the client's needs. This finding is aligned with Beausoleil-Morrison, Kemery [13]. Finally, the relationship between cost and quality was occurring as the system's longevity was identified as a challenge, not to installation but the maintenance and use of the system. Every user wants to achieve the best value for money by having a short return on investment and optimising their system to achieve the longest life span possible so the system can reward the consumer before replacement occurs. The research identified the long return on investment as another challenge to adoption. It is not financially feasible for homeowners as they will not recoup their money fast enough. Firouzjah [14] proved that DES in a residential context is not attractive due to the long payback periods that support the research findings. The findings from the suppliers showed that more money spent initially on higher-rated products enables the system to last longer because the management systems are more sophisticated and prolong the system's lifespan compared to a cheaper product. This all derives back to the system's upfront cost and how much capital the user is willing to spend.

Statutory regulation is another barrier that needs to be overcome for installation. If a user wants to be connected to the domestic supply grid, the user requires the approval of the relevant municipalities. The solar system will also be required to be configured and coded to be synchronised with the municipal supply grid. This formality causes a delay in the installation process and creates the need to change to a prior approved product from the municipalities. The findings also identified the lack of government involvement in the industry as a barrier to adoption. There is a lack of incentives provided by the state to make the adoption more appealing. Moghayedi et al. [15] stated that the lack of government incentives contributes to the low levels of adoption. The research uncovered those homeowners should change all the heavy electricity appliances to gas and solar heat pumps before adopting DES, thus decreasing the reliance on the grid. This was agreed upon by Palm and Eidenskog [16]. It was identified that homeowners are aware of energy use and are converting their appliances to more efficient versions, decreasing the amount of electricity used.

Experts agreed that using DES in residential properties provides many benefits, especially in South Africa, where the electricity supplier is running at full capacity. The three groups of experts were also independently identified by installing a DES. The benefits provided are not only to the user because having a renewable system reduces the reliance and demand on the municipal supply grid. Enteria and Yoshino [17] agreed that the increased use of DES decreases the consumed grid electricity and provides electricity back into the grid. The reduced demand either minimises the length of load shedding or decreases the tariff of electricity to the users. Enteria and Yoshino [17] discussed the ability to be net-zero, thus reducing the cost of electricity to the user. The summary of research findings is clustered and summarised in Table 4.

Table 4. Summary of findings

Challenge	Nature of challenge
Cost	High initial capital investment is required to purchase all the needed infrastructure
Space	PV panels are less efficient, requiring a large area to generate the required load
Return on investment	A long period before the initial capital investment is recuperated
Regulation	Lack of incentives and subsidies from the government
Benefits	*Nature of benefits*
Reduced reliance on domestic grid supply	Generating electricity independently reduces the need for municipal supplied electricity
Reduced electricity tariffs	Less municipal energy is consumed; thus, less money is owed to the municipality

5 Conclusion

Regardless of the high tariff rate of electricity and current energy crises in South Africa, the level of adoption of DES in South African residential properties is still significantly low. The interviews with industry professionals have allowed the study to identify the challenges and barriers to utilising DES as the main cause of this low adoption in South African residential properties.

The research concludes that the challenges and barriers faced when installing DES heavily impacts the adoption. The findings of this research prove that for there to be a higher adoption level of sustainable DES and mainly renewable solar energy in residential properties, the capital cost of these systems needs to decrease. This study further deduces that the most effective way to combat the high capital cost of DES as the main barrier to adoption is through government intervention. The national government aiding in subsidies and tax incentives will allow the user to purchase the infrastructure for less as they are being subsidised or receiving an incentive elsewhere that saves them money. This also makes the installation more appealing to others, increasing the demand for the technology and allowing the suppliers to grow their businesses. With the growth in demand, the suppliers will be able to invest more in research and development, which evolves the technology. The product will become more efficient and potentially cheaper. With a sustainable electrical system, efficiency is crucial. It generates more energy from the same sized area, thus benefiting the user as their generating capacity increases and the return on investment is shorter. These factors all link back to the reduction in the cost of the systems and thus are imperative to the increased adoption of such systems. If the adoption rate of DES increased in South African residential properties, it would decrease the reliance on the national electrical supply grid, decreasing the overall cost of electricity as there will not be as high demand. In addition, the movement toward sustainable DES also reduces the reliance on fossil fuel energy, which is the dominant form of energy generation in South Africa and moves toward a more sustainable future.

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Investigating the Effects of Innovative Technologies on the Delivery of South African Affordable Housing

Jeffrey Jr. Mahachi(✉), Alireza Moghayedi, and Kathy Michell

Sustainability + Oriented Cyber Unit for Built Environment, Department of Construction Economics and Management, University of Cape Town, Cape Town 7700, South Africa
MHCJEF001@myuct.ac.za

Abstract. This paper examines the cause of untimely delivery of affordable housing which is of great importance due to the rising urbanisation rates and increased affordable housing demands. The rationale for this examination stems from the various issues causing inefficient delivery of affordable housing such as ineffective collaboration, coordination, and miscommunication which results in prolonged delivery time. Various scholars indicate a possible solution to such issues is the implementation of innovative technologies. A critical review of existing literature within the realms of innovative technology adoption in a project's design and construction phases was undertaken to guide the research. Although there are various innovative technologies, not all will positively affect the delivery of affordable housing, thus a review of relevant technologies like Cloud-Based Building Information Modelling, Construction 3D-Printing and Modular Construction. Based on the findings, the adoption of innovative technology can improve the rate at which affordable housing can be delivered. Unfortunately, it comes at the cost of training and enforcing industry professionals to forfeit previous design and construction methods. However, it can be proposed that further research can be undertaken to examine the impact of deeper scales of social, business, and financial impacts.

Keywords: Affordable housing · Innovative technologies · Housing delivery · Housing affordability · Supply chain

1 Introduction

Developing nations like South Africa often struggle with rapid urbanization. South Africa had substantial growth in urbanization from 62.22% in 2010 to 67.35% in 2020 [1]. Such urbanization has caused the migration of families from townships to suburban areas [2], thus higher demands for affordable housing. With such rising affordable housing demands, the affordable housing sector will take a toll due to the prolonged period to deliver such housing types, according to the National Home Builders Registration Council [3], an affordable house will take between 3–5 years to reach construction completion and then be delivered. In addition, there remains a substantial backlog in the delivery of affordable housing which requires R800 billion (approximately US $53.3

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Billion) to completely eradicate by 2020 [4]. These prolonged delivery periods are often caused by various issues that may occur during the different stages in the housing delivery process. Studies indicate that most delays in affordable housing delivery tend to be affected by: insufficient funds to finance the project to completion, changes in designs and drawings, ineffective communication amongst the parties involved, slow decision making (due to zoning, building permits, etc.) and contractors insolvency [5]. The usage of traditional methods of design and construction plays a negative addition to the delays in affordable housing delivery. Traditional methods of designing and construction can often lead the design and construction team towards sloppy workflow, miscommunications and ineffective collaboration between the design and construction team can [6].

Ultimately, this paper will examine innovative technologies as a possible remedy for these inefficiencies in affordable housing delivery and evaluate their effects on the delivery process. The paper will focus on identifying the relevant issues facing affordable housing within South Africa, examine the various innovative technologies that can be used during the design and construction of affordable housing, identify the advantages and disadvantages of said technologies, and evaluate the usefulness of each technology within the South African context.

2 Literature Review

Developing nations with a wealthy economic climate tend not to grow only in GDP, but also in population. Hence South Africa's population growth rate of 1.28% per year, with growth from 40.6 million people in 1994 to 60 million people in 2021 [7]. Such population growth contributes to a natural increase in urbanization. In addition, Africa is now in the process of experiencing a triple process of rapid population growth, high urbanization, and digital transformation, and with these processes in mind, this continent is moving from a rural majority to an urban majority [8]. With such rising urbanization, naturally, the demand for affordable housing should rise and the housing supply should increase to satisfy the demand. However, even post-apartheid, South Africa's affordable housing distribution and delivery struggle to keep up with the growing demand [9].

2.1 Affordable Housing

According to Moghayedi et al. [10], the affordability of housing comes down to three main factors: household income, the price of the house, and the housing financing methods. However, with low urban household income, high mortgage interest rates, and little to no finance methods, this results in extremely low housing affordability, and unfortunately, Africa is subject to these issues.

To understand the appropriateness of affordable housing, one must understand its definition. The term "affordable" is subjective depending on an individual's location, upbringing, and financial situation. Each country has a different definition of 'affordability', so trying to determine a universal definition with an absolute value won't be accurate. Although there is no distinct method for measuring housing affordability, it can be determined in most cases through a household's income to the expense ratio [10]. Moghayedi et al. [10] proposes a suitable definition for an affordable house stating that *affordable housing can be categorized as affordable housing when the cost of such housing does not exceed more than 30% of the occupants' income*. This definition also compliments the definition articulated by the Australian Housing, Local Government and Planning ministers (2006), which states that "*affordable housing is housing that is appropriate for the needs of the low and moderate-income households and priced well enough for these specific households so that they can meet other essential living costs*".

2.2 Affordable Housing Delivery in South Africa

The affordable housing sector in South Africa remains constant with various issues, like a lack of adequate and accessible affordable housing, high costs of affordable housing (not affordable) [11] and low adaptation of technologies within this sector [6]. In addition, due to the rising urbanization rates South Africa is facing, the nation is currently in dire need of providing these individuals with housing. According to Simbanegavi (2021), there was an approximate shortage of housing that amounted to 3.7 million and is expected to grow by 178,000 annually. Considering this, there remains an urgent demand for affordable housing delivery. The South African housing sector must act appropriately to raise the affordable housing supply. Inefficiencies in housing delivery are what delay the increase in housing supply, issues like prolonged periods to complete construction [3], miscommunication and mismanagement between the design and construction team, and rework in construction due to an underperforming supply chain [6]. A suitable solution to help ensure effective delivery of affordable housing is by using innovative technologies.

2.3 Innovative Technology in Construction

Ultimately, the delivery of affordable housing remains inefficient [6]. However, possible strategies and technologies that can solve these issues are ever-growing. The development of innovative technology has always been with the intent of increasing productivity, efficiency, and maximization of the quality of outputs in human activities, for example, across various industries, the usage of Innovative Technologies has seen a 30% growth in productivity over 5 years [12].

2.4 Innovative Technologies Used for Affordable Housing Delivery

Cloud-Based BIM

Although Building Information Modeling (BIM) technology has been widely used within the construction industry as a substandard for construction designs, cloud-BIM has made it easy for real-time collaboration between industry professionals from initial design to comprehensive construction drawing during the design process [13].

Cooperation, Collaboration and Communication

Cloud-BIM creates a higher level of cooperation and collaboration with a clear and effective real-time communication platform among the construction project's team members

[14]. Cloud-BIM incorporates the fundamental aspects of BIM with cloud computing capabilities. According to the National Institute of Standards and Technologies [15], "*cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storages, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction*".

Sustainable Construction

Redmond et al. [16] researched to understand the potential application of Cloud-BIM was undergone; 11 industry professionals were interviewed and found that the usage of cloud-based BIM would allow various stakeholders in a construction project to share and exchange the necessary data for making important decisions at an early design stage. Wong et al. [14] reported that the fusion between cloud computing and BIM can create an effective and efficient system among relevant stakeholders, aiding in sustainable construction throughout a project's lifecycle.

3D Printing

In their research, Buchanan and Gardner [17] pointed out that 3D printing, although experimental and innovative, can revolutionize the construction industry. The technology has made its rounds already in various industries, aerospace and biomedical, and is now being explored as a form of additive manufacturing within the construction industry. The application of such technology has several benefits including [17]: *higher structural efficiency*, a *decrease in material consumption and wastage*, *streamlining of the design-build process*, *vast customization*, *a larger scope of architectural freedom*, *and improved accuracy* and *greater safety on site.*

Construction Time

Research by Leal et al. [18] and Buchanan and Gardner [17] have shown that the usage of 3D-Printing can shorten the period between the start of a project and the completed outcome *there is less time taken to set up the manufacturing components using this technique*, *and the time taken to build key components is decreased substantially.* During the early days of 3D-Printing, Buswell et al. [19] observed that it took 100 h to build a structural concrete wall while it took 65 h to print a smaller wall. Because of the less human intervention, the quality assurance of construction 3D-Printing is expected to be significantly more accurate and capable of printing complex structural elements within a short frame of time, reducing the manufacture time of said elements from weeks to hours [20].

Lower Production Costs

The usage of 3D printing can serve as a possible tool to decrease construction costs due to its cost-saving nature [21]. Mahachi [21] states that what often causes the delay in delivering affordable housing is the high costs of construction. Not only that, because the houses are printed onsite, the costs of logistics and travelling construction materials are reduced, which indirectly decreases waste materials and energy consumption. In addition, within construction projects, the longer the duration between the start of a project and the completed finished structure, the greater the financial costs of the project [17]. However, because it has been established that construction time can be decreased using 3D-Printing, the cost of construction will thus be decreased, resulting in affordable approaches to construction methods.

Modular Construction

Over the years, the construction industry has had stagnant productivity, with limited growth and minimized production efficiencies. Thus, various research has taken place to find alternatives to improve productivity, one innovative building technology being Modular Construction which can improve construction delivery by 20–50% [22]. Using modular construction as a building tool has a few advantages like [22]: *reduced building costs throughout the duration of the project, improved build schedules that reach completion faster, improved certainty on the overall build times and costs, and a better quality of building with better energy consumption or seismic performance.* There are a few specifications that are associated with Modular construction. This paper will focus on 3D volumetric and 2D Panelised.

3D Volumetric

3D volumetric solutions are fully fitted-out units that can consist of a room or part of a room that can easily be assembled on site like Lego blocks, usually developed using timber, steel or concrete. Most of the work with this solution is done offsite at the manufacturing stations [22]. 3D volumetric solutions are best suited for buildings that are highly repeatable like hotels, hostels, or affordable housing. Unfortunately, such construction methods come with a few disadvantages, like increased transportation costs and size limitations.

2D Panelised

This solution is a "*flat-pack assembly approach used in home furniture*", this is where panels contain the necessary conduits for services like electrical wires, heating, ventilation, air conditioning (HVAC), and plumbing [22]. This method is a lot more complex to assemble but is drastically cheaper to transport compared to 3D Volumetric. Such manufacturing methods give room for more flexibility, which results in it being more appropriate in high-end residential projects, single-family housing, or apartments [22].

Hybrid 3D Volumetric and 2D Panelised

This consists of both methods to get the best of both manufacturing solutions. This can be used to construct sections of a house that would be best assembled using each solution, for example, bathroom pods can use 3D modules while the remainder of the house uses 2D panels [22].

2.5 Summary of Literature Review

With the growing concerns of rapid population growth and urbanisation, there remains an urgent call for the affordable housing sector to increase the supply of highly demanded affordable housing. However, the usage of innovative technologies like Cloud-Based BIM, 3D-Printing and Modular Construction can serve as a potential solution to improve cooperation, collaboration, and communication amongst industry professionals, and decrease negative environmental impacts and construction delays resulting in faster handovers.

3 Methodology

A critical literature review method was used to find and identify published articles that have investigated the relevant innovative technologies that can be used to improve affordable housing delivery and sustainability of such housing. These articles have either been sourced from publications with refereed journals, or conference proceedings and various scholarly publications. Each paper studied is closely related to the focused keywords which include affordable housing, sustainability, cloud-BIM, 3D-Printing, Modular Construction, etc. Using search engines and references used within journal articles closely related to this paper aided in a clearer and more focused search procedure. Ultimately, there were in total, 36 research papers that were used in the literature review to give a more in-depth understanding of the topic, each paper was addressing the keywords for this paper. These papers were then examined to understand the application of innovative technologies in a developing nation like South Africa. Not all the papers were based in developing nations but gave good context into the state of each technology. Once these papers were examined, a technology evaluation method was put together to understand their advantages and disadvantages, this gave context to the usefulness of the technologies. This then was followed by a detailed discussion to understand the overall usefulness of these technologies in the context of the South African construction industry.

4 Results

Table 1 presents a summary of the advantages and disadvantages of the different innovative technologies found to be appropriate to the South African housing construction industry.

With a focus on each technology within the South African construction context, these technologies have their prescribed advantages and disadvantages to the affordable housing sector. The technologies have the potential enhancing design and construction of affordable housing. However, they do have their limitations. The applicability of these technologies is highlighted in the following sub-sections.

Cloud-Based BIM

When it comes to implementing BIM standards and specifications, South Africa tends to lag behind other industries, due to various barriers, like the lack of support from the South African government, and that most clients in South Africa do not contractually enforce the usage of BIM [29]. From the research articulated in the literature review, the usage of Cloud-Based BIM, or any BIM solutions will have a noticeable impact on the overall cooperation, collaboration, and effective real-time communication amongst the relevant stakeholders. However, barriers like, legal and contractual barriers, technical

Table 1. Innovative technologies used in affordable housing delivery

Technology	Pros	Cons
Cloud-based BIM	• Creates a space for higher levels of cooperation, collaboration, and effective real-time communication amongst the relevant stakeholders • Can ensure an effective and sustainable construction process, minimizing project delay • Architects, engineers, or contractors can access their designs and data from any location, giving them space to work remotely and in sync [23] • Any issues or clashes with designs can be uncovered in real-time, this gives space to designers to find and resolve issues instantaneously [23]	• The cost of set-up, maintenance and training has been a challenge in implementing cloud-based BIM in most [24] • Although useful at times, the system is dependent on a good internet connection, so in various developing countries or areas with a limited internet connection, this technology won't be useful [13] • A few other challenges include access authorization to users, information sharing boundaries and legal and contract limitations which have made it difficult for industry professionals to trust cloud-based BIM [13]
3D-printing	• There is an array of customization that comes with the usage of 3D-printing, this is a revolutionary asset to have within the construction sector [17] • Using 3D-printing as a construction tool can substantially decrease the construction time, which also indirectly decreases the financial costs of construction projects, the reason being, the longer the time to completion, the higher the financial cost of the project [17] • Construction industries often cause severe damage to the environment; thus the utilization of 3D-printing can minimize the environmental impact by 70% lower than traditional techniques [17] • Often, the labour cost of a construction project accounts for 15–50% of a project [25]. With the usage of automated 3D-printing, such labour costs can drastically decrease, as well as the potential for human errors or safety risks during the construction process [26]	• Currently, the manufacturing process of 3D-printing lacks a clear standard and set of guidelines and practices. Because there are various materials and processes when it comes to 3D printing, these materials and processes need to be tested and calibrated [27] to ensure these parts meet the required strength and reliability requirements [17] • Because of its early phase, the adoption of the technology can raise costs as the construction industry is highly volatile to changes in costs, in addition, the raw materials costs are often higher than conventional processes [17] • Although automation can help improve efficiencies, there are various societal issues with its adoption; the wider public is increasingly seeing the rising usage of robotics and automation as a threat to their job security [25]. Such speculation and fear were proposed to hold back the greater adoption of the 3D-printing [17]

(*continued*)

Table 1. (*continued*)

Technology	Pros	Cons
Modular construction	• Using modular construction techniques, the foundation and substructure are a lot cheaper due to the lightweight materials and products [22] • Onsite construction work is made simpler due to offsite manufacturing, this just allows construction workers to merely assemble the constructed modules, resulting in a faster and cheaper construction process [22] • Minimized rework is done, as there is better quality control in a factory environment, minimal rework improves construction schedules [22]	• Modular construction requires efficient planning and coordination among the design team. When in an environment that does not consist of such, there will be severe quality assurance problems [28] • Transportation costs can rise depending on the various loads carried from offsite manufacturing • The weight of the constructed output is limited by the lifting equipment's capabilities, this means the construction parts needed to be over-engineered to avoid any damages during transit, thus increasing design and construction costs [28]

and technological barriers, and organisational and human barriers cause minimal adoption of this technology in South Africa [29]. Based on the current issues faced within the South African construction industry, there are still major backlogs and delays in affordable housing delivery, these issues come down to ineffective collaboration, poor communication, and mismanagement [6]. Successful adoption of said technology will be of benefit to the South African affordable housing sector. Research indicates that local governments' firm legislative BIM standards and specifications will play a vital role in the application of such advantageous technologies [29].

3D Printing

A repeating theme within South Africa is the challenges faced with the uptake of innovative technologies within the construction industry, the ever-increasing affordable housing backlog needs innovative solutions to overcome this issue [21]. The literature review and results have shown that the implementation of 3D Printing can serve as a viable solution to decrease construction time and costs and positively impact the environment. Such benefits are crucial within the South African housing sector. Although 3D Printing has been around for several years, the technology has only gained a noticeable amount of traction in the past few years. However, the South African construction industry has a reluctance to embrace innovative technologies like 3D printing, even with its possible benefits. This then limits production outputs, productivity and a lack of dynamism and creativity [21].

There are a few contributing factors to the reluctancy behind technological adoption, this would include: insufficient collaboration between technology suppliers and contractors, inadequate knowledge and skills transfer, anxiety from professionals in the built environment to adopt and explore innovative ideas and solutions, and misconceptions on the costs and acceptability of technologies [21].

Modular Construction

When it comes to the adoption of modular construction in developing nations like South Africa, there has been a fair share of challenges and barriers. The reason for this is that modular construction needs good project planning and coordination [28]. However, based on the literature review, the construction industry remains ineffective when it comes to conducting efficient planning and coordination [6], hence the severe backlog in affordable housing delivery. The design work for modular construction is intricate and comprehensive, thus the importance of planning to successfully adopt modular construction. There needs to be proper communication and effective coordination during the construction process [30]. However, another barrier to adoption within developing nations is often modular construction is negatively associated with "mobile homes" often seen in the U.S. [28]. These negative social perceptions have caused great speculation and worry when it comes to the adoption of the technology. Although this technology has positive impacts on the environment, construction time and costs, if there is a scenario where a client is thrilled to use such technology, unfortunately, there is little to no regulation to ensure the standardisation of Modular Construction within developing countries [31]. This has resulted in minimal adoption of modular construction by clients and professionals in developing countries [32].

5 Conclusion and Recommendations

The construction industry is faced with various issues that either cause problems to consumers waiting on their affordable housing to be delivered, or the industry has caused a severe impact on the social and environment. The literature review has identified the current challenges facing this industry, (i) *rising urbanization rates have caused a growing demand for affordable housing, and* (ii) *the lack of technological adoption is often causing inefficiencies within this industry.* In theory, using innovative technologies like 3D-Printing, Cloud-Based BIM and Modular Construction will have a positive impact on the construction time, construction costs, and delivery of affordable housing, and can be a proper mechanism to improve the affordability of housing in South Africa. However, when these technologies are introduced to the South African context, some reoccurring challenges and barriers inhibit the full adoption of these technologies in this country. The challenges include *fear and speculation from construction industry professionals, lack of knowledge transfer, little to no regulations or standardizations of these innovative technologies, and often clients don't contractually mandate these technologies during the project's design and construction processes.* Although there is a slight and slow change to the acceptability of these technologies in South Africa, until some of these innovative technologies are regularly enforced, the South African construction industry will still struggle with the ever-increasing affordable housing backlog and unsustainable delivery of these housing types. Future research should explore the impact these technologies would have on a social and economic level within the affordable housing sector, although they can be of benefit to ensure better delivery times and decrease construction costs, such technologies can cause social issues within a developing nation.

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Institutional Regulatory Framework and Affordable Rental Housing Delivery in Kenya

Victor Otieno Olonde(✉), Manya Mainza Mooya, and Kanshukan Rajaratnam

Department of Construction Economics and Management, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa
volonde@yahoo.com, manya.mooya@uct.ac.za

Abstract. Providing legislative and administrative instruments to promote and achieve a healthy housing sector development while protecting the environment is the core function of the institutional regulatory structure. But the regulatory framework often becomes a key restriction that prevents developers from taking part in the construction of affordable rental units. Therefore, the primary purpose of this research is to assess whether or not the existing legislative and regulatory framework facilitates or restricts the supply of affordable rental housing. This study used a qualitative research approach, consisting of in-depth interviews and document reviews. To assess the impact of the institutions responsible for regulating the housing sector on the outcome of the rental housing market, it uses primary data gathered mostly from private property developers and secondary data made up of relevant documents. The results demonstrate that land-use restrictions generate unintended underlying obstacles that increase transaction costs, with a skewed impact on the rental housing development industry. Furthermore, the legal environment is discouraging to rental housing developers because of unjust and uncertain property rights that are more beneficial to tenants than landlords, who perceive them as sources of expensive transaction costs. When compared to the one-time taxes levied against build-to-sell development, the vast majority of which are paid by the purchasers, the tax system is similarly more punishing to the rental housing industry since it is both high and lasts for the life of the endeavor. The tax system should be tenure-neutral and non-distortive to the housing market, and the approval procedure should be streamlined by unifying the process into a one-stop shop so that developers do not have to seek for approval from multiple organizations.

Keywords: Affordable housing · Housing market · Institutional regulatory framework · Rental housing

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1 Introduction

Institutional regulatory frameworks' primary function is to provide the legislative and administrative instruments necessary to foster and deliver environmentally responsible growth in the housing sector [11]. Literally, the regulatory framework refers to the "rules of the game" that mediate between policy goals and the actual attainment of the expected outcomes [3]. However, the regulatory framework often produces unfavorable results, which can skew the market and put off builders from catering to a particular sector of the housing market [11]. Therefore, the aim of this research is to examine the extent to which the institutional regulatory framework enables or constrain delivery of affordable rental housing market in Kenya. Although the regulatory framework has far-reaching implications for the entire housing sector, the paper primarily examines its effects on the affordable rental housing market. In particular, the elements of the regulations that cause more expensive production and transactions. There are significant restraints on the rental housing market due to factors like these that have an impact on the profitability of rental housing units. Therefore, one of the main goals is to research the impact that land-use regulations and taxation have on the supply of affordable rental housing. This study is part of a doctoral thesis by the first author entitled 'Affordable rental housing delivery in Kenya'.

2 Literature Review

The role of institutional regulatory framework is essential role in influencing the operation of the developers and the housing market at large. Common elements of a regulatory framework for institutions include the legal framework, land-use policies and fiscal system.

2.1 Land Use Regulations

Numerous academic works [1, 4, 12, 14, 15] examine the housing market's response to zoning, building codes, and other land use principles. All of these studies agree on one thing: the formal housing markets in developing nations are overregulated. Despite the fact that these regulations' primary purpose is to standardize land use and aid in achieving controlled urban development by shielding the neighborhood from externalities that may result from conflicting land uses [4], they can instead become the primary hindrance to developers' involvement in the delivery of affordable rental housing.

It appears that few studies actually separate the impact on rental and owner-occupied houses into separate categories. Although it is generally agreed that regulations have an impact on both the home-ownership market and the rental market, it is generally agreed that because regulatory rules by their very nature set high building standards and control densities, they have a greater impact on the rental sector by increasing the transaction costs linked to rental housing management [8, 9, 12, 15]. Most zoning restrictions limit the construction of multi-family dwelling units by lowering the allowable density in many prime zones, despite the fact that such units are the best suited for rental housing [8, 11, 14].

According to some writers, bureaucratic barriers to development have the potential to slow construction, which would in turn delay the expected rents. Since private developers may be discouraged by the prospect of a lower return on investment, this has a negative effect on the supply of rental housing [6, 13].

2.2 Legal Framework

One of the most important parts of the institutional structure that governs the rental market is the legal system. There are typically two main components of rental housing regulations: (1) regulating the essential environment for the private rental market to function, and (2) regulating the freedom of landlords to raise rent to uphold affordability and inhibit economic marginalization that could arise if rental levels surpass the renters' ability to pay [4]. Second, tenancy security improves certainty about occupancy term and simultaneously reduces risks of arbitrary ejection of renters by landlord, except for prescribed reasons [5]. In contrast, Peppercorn and Taffin [11] note that countries with a negative view of rental housing tend to have more stringent laws protecting tenants. As a result of this paradox, investors are wary of developing rental housing for fear that law enforcement will protect tenants who fail to pay their rent. However, as much as regulation in itself is not bad, but sometimes, it creates doubts and present bottlenecks to investments, while sometimes they create competitions that make rental developments by private investors unviable [15].

2.3 Fiscal Policy

Numerous authors [2, 4, 10, 11] have summed up the significance of fiscal policy in influencing the supply of rental housing. Governments are able to employ tax incentives to promote the development of rental housing [12]. Actually, the preference of owner-occupier to rental tenancy by most nations have led them to initiate favourable fiscal legislations for homeowners [7]. Accordingly, the treatment of rental housing by fiscal policy is a crucial policy guideline that affects housing market conditions, including relative rents and prices, as well as the viability of investment and rental levels [2]. For this reason, investors are discouraged by the prospect of a low return on their rental property investments due to large tax obligations. However, other research have found the opposite to be true: that tax incentives drive investments in rental housing [6, 10, 13].

3 Key Gaps in the Literature

As revealed by the literature, the majority of the information on the housing market and its institutional regulatory structure comes from the context of developed nations. In addition, research focusing exclusively on rental housing are few. It follows that there is a substantial information vacuum when it comes to the context and content necessary to understand the relationship between the regulatory framework and the rental housing market in developing nations, specifically with regard to housing for rent. In order to bridge the gap in knowledge, this research generates an understanding of the relationship between the institutional framework and the housing market, with a focus on developing nations.

4 Research Methodology

This study is qualitative in nature, employing a case study approach, and using Mombasa City, Kenya as the city under examination. Mombasa was selected because it is the second largest city in Kenya and shares many characteristics with other cities in Kenya and the rest of the developing world. As a result, it is expected that the findings of this study will be transferable to other situations with similar dynamics. A total of nineteen (19) interviews were performed using purposive sampling. Ten (10) renowned property developers in Mombasa who are engaged in substantial housing development-related activities were interviewed utilizing a semi-structured questionnaire. The major goal of this inquiry was to get insight into the developers' perceptions of the regulatory framework's effect on the housing delivery process and their reasons for avoiding the construction of rental units. In addition, one-on-one interviews were conducted with other stakeholders, as listed in Table 1, to gain a more nuanced picture of the impact of the institutional regulatory framework on the housing market.

Semi-structured interviews were used to gather primary data, while document analysis provided secondary data. To ensure the anonymity of research participants, the transcripts were de-identified and assigned codes before being loaded into NVIVO 12, as indicated in Table 1.

5 Findings and Data Analysis

The institutional regulatory framework that influences the activity of housing market actors and determines market outcomes was a primary focus of this study examination. Therefore, the analysis centers on the connections between the housing market and the various institutional regulatory framework aspects. Consequently, the study's overarching goal is to answer a research question that probes whether or not Kenya's institutional regulatory system facilitates or restricts the provision of affordable rental housing. The results of this research have been divided into three main sections: land-use laws; legal and fiscal frameworks.

5.1 Land-Use Regulations

Ideally, developers' decisions on different parts of the housing market are influenced by how they relate to or perceive these restrictions. In Kenya, county (local) governments play a significant role in development control management, working in tandem with other relevant agencies. County governments have a crucial role in regulating new construction, making sure that new buildings adhere to regulations. Permits/approvals are issued to qualifying applications, according to information provided by count government officials, who indicate that they operate in collaboration with other relevant authorities/ agencies [CGO1].

Building permit issuance is typically the initial step in development control prior to the start of construction activities, as further highlighted by information from county government officials [CGO1, CGO2]. Therefore, developers, whether building homes for sale or rentals, engage with the housing market's rules through the building approval

Table 1. Interview respondents

Respondents	Code	Nature of organisation	Title
Developer 1	D1	Property development firm	Director
Developer 2	D2	Property development firm	Director
Developer 3	D3	Property development firm	Director
Developer 4	D4	Property development firm	Director
Developer 5	D5	Property development firm	Director
Developer 6	D6	Property development firm	Director
Developer 7	D7	Property development firm	Director
Developer 8	D8	Property development firm	Director
Developer 9	D9	Property development firm	Director
Developer 10	D10	Property development firm	Director
State Actor 1	SA1	State department of housing	Director
State Actor 2	SA2	State department of housing	Assistant Director
State Actor 3	SA3	National housing corporation	Manager
County Government official 1	CGO1	County government of Mombasa	Director
County Government official 2	CGO2	County government of Mombasa	Physical planner
Housing Consultant 1	HC1	Private housing consultant	Director
Housing Consultant 2	HC2	Private housing consultant	Director
Housing Consultant 3	HC3	UN-Habitat	Housing consultant
Taxation expert	TE	Kenya revenue authority	Taxation policy

procedure. This suggests that developers place a high value on the efficiency with which building permits are issued. However, according to the developers who were interviewed, one of the unfavorable results of land-use restrictions is a persistently drawn-out approval procedure. Infrequent adherence to the established dates for approving the applications by the authorized agencies causes chronic delays and makes the entire process arduous for the developers [D1, D7].

According to interviews with multiple builders, the building approval process is subjected to multiple phases inside different institutions, and the varying rules that oversee the construction process create bureaucratic hurdles that lengthen the building application-process [D6, D7, D9]. As one county official explained in an interview, developers often have to apply for approval from multiple agencies, including the county government, the national environmental management authority (NEMA), the national construction authority (NCA), and the water resource management authority (WARMA). Each organization appears to have its own rules for conducting business, some of which may overlap with or even be at odds with those of other institutions. Even within larger organizations, such as the county government [CGO2], there are numerous departments with their own approval processes.

It stands to reason that the efficiency with which land-use regulations facilitate the process from start to finish of a development project, as well as the expenditures incurred by those responsible for its construction, are two indicators of that project's success. Both the actual money spent on the approvals and the transaction costs of any ineptitude in the process are taken into account here. Therefore, the approval procedure continues to serve as a crucial indicator of successful land-use control. Despite the process's applicability to both for-sale and rental homes, this study is concerned with how and why they have a larger detrimental effect on the supply of rental homes [D5, D7, D8].

Developers have confirmed that the lengthy bureaucratic processes involved in obtaining a building permit have a negative impact on the rental sector since they cause construction delays, which in turn cause a delay in the project's income. However, there are occasions when the regulatory tools used to achieve efficient land-use generate significant transaction costs related with navigating the lengthy procedures, which then results in negative market outcomes and limits the supply of rental housing [D5, D10].

The study was also interested in the effects of zoning laws on rental housing. The county government's data confirmed that zoning is critical in the housing market since it affects the choices made by builders [CGO2]. Nonetheless, county officials regret that sometimes the zoning rules are considered to be unfavourable to the rental housing during the approval process This is due to the fact that most of the plots in the areas deemed suitable for low-income rental residential developments [affordable housing] in Mombasa are instead zoned for single-dwelling units, implying that only one housing unit hosting one household per plot [CGO1]. This is in contrast to the general trend, which favors affordable rental housing with multi-family dwelling units. As part of our effort to gain insight into developers' interactions with zoning regulations, we conducted interviews with a cross-section of industry professionals. Our findings suggest that developers who favor single-family residential zones face a more time-consuming building approval process in order to secure multi-family residential building permits. Such conversions to permit construction of multi-family dwelling units are normally burdened with a number of obstacles, extra time, and transaction costs that make them unappealing to private developers, who would instead opt for areas already designated for high density-high or middle-income neighborhood to allow them to put up multi-dwelling units for sale [D1, D9].

In addition, a majority of respondents agree that the high costs associated with constructing a home are a direct result of the stringent standards prescribed in the building code, which come with stringent approval and supervisions and, as a result, high production and transaction costs (supervision and enforcement costs). Since low-and middle-income families are more likely to rent affordable housing, it's imperative that developers make concerted efforts to reduce the high cost of construction from the outset [D6, SA1, SA2, SA3].

5.2 Legal Framework

The legal framework is essentially more concerned with rental [lease] contracts and agreements that bestow property rights to the landlords and tenants. This study set out to investigate whether and to what extent housing market outcome is influenced by the prevailing legislative environment. According to developer interviewed discrepancies in the law may discourage some developers from investing in rental housing and instead focus on building homes for sale. Interview with housing consultant [HC2] indicates that before handing over the housing units for sale, the developer might establish a pre-sale agreement with the possible purchaser, which reduces the likelihood of future problems.

The developers who were surveyed all agreed that the high transaction costs associated with rental property management are a direct result of the current regulatory framework, which discourages them from building rental units [D3, D4]. Tenant default on rent or eviction are among examples of the kinds of management problems that might arise throughout a tenancy, causing tension between the landlord and tenant and, ultimately, driving up the transaction costs for the landlord. As a result, the landlord will frequently have to pay for the services of auctioneers. When tenants go to court to stop auctioneers and enjoin landlords from the suit, landlords have to deal with the fees of the auctioneers and the sometimes-drawn-out litigation procedure [HC2, D2]. As a result, in the eyes of the developers, the existing regulation is flimsy and vague, making it difficult to enforce against rent defaulters. The lack of precision in the rental laws regularly leads to legal battles between landlords and tenants, increased transaction costs for landlords associated with lease agreement and implementation, and unending search costs for landlords whenever vacancies appear as a result of evictions.

For a more complete picture of the legal framework, we also performed document analysis, which showed that the Rent Restriction Act Cap 296, which is meant to offer procedures for conflict settlement between landlords and tenants, is now defunct. Additionally, the Act in its current form only governs properties subject to controlled tenancies under the supervision of the Rent Tribunal. Those are homes in Kenya where monthly rents are less than Kshs. 2500/ = (about $25 USD). The interviewed developers however, were adamant that the vast majority of the apartments' rental rates were too high to qualify as regulated tenancy. This exposes one of the limitations of the Act. The law was originally passed in 1966, and since then, it has not been updated to bring its expand its pecuniary up to date with rising rents. It follows that the Tribunal is nothing more than a judicial relic with no practical application to the control of the rental housing industry. Since the Rent Tribunal may only oversee contractual arrangements for residential properties, it is safe to assume that any landlords who is aggrieved will seek legal redress courts to solve dispute. In most cases, the landlord will have to endure drawn-out legal fights with unclear outcomes and additional expenses [HC1, HC2, D1]. It is possible that the landlord's ability to collect rent could be temporarily or permanently halted by the court while the lawsuit is pending, or that the landlord could lose the case and hence never recieve the rent that had been collected. However, developers are discouraged from entering the rental housing market because they are aware of the actual and transaction costs associated with protracted legal processes, even if the landlord were to win the case. When tenants and landlords are at odds, it is usually because tenants' property rights are superior to landlords'. Developers' choices about the quality and quantity of the housing they provide are, thus, heavily dependent on the nature and form of property rights. Therefore, when the rental housing market exhibits unbalanced property rights and more tenants-centric as evidenced, the developers avoid that sector.

5.3 Fiscal Framework

Analysing the rental housing market becomes potentially deficient if the influence of the tax regime under which it functions is not well comprehended. It is expected that the way rental housing is taxed would influence investment in the sector, just as it does with other regulatory measures. According to the housing consultant interviewed [HC2], taxing is often seen as the most prominent fiscal tool for influencing the developers' decision on the sort of houses to construct and the tenure under which to deliver them. Based on our research, it appears that the tax system is not entirely friendly to the rental property market. As such, we sought to examine the developers' experiences with regard to taxation. Based on the responses, it seems that the taxation issue is still one of the most significant institutional barriers to the expansion of the rental housing market. Developers generally perceive the high tax rate on rental income as a disincentive.

The housing taxation system in Kenya is largely influenced by housing policy ideology, and as such, its advantages are more skewed towards the delivery of home-ownership schemes, as shown by an analysis of the system. It is obvious that from the outset of the project, developers' tax responsibilities for housing for sale can be predicted, calculated, budgeted for, and, all too often, shifted to the shoulders of the purchasers. But there are no any financial incentives set up to ensure the supply of low-cost rental houses. For comparison, not only are annual property taxes paid on rental properties at a high rate, but they also persist throughout the investment's duration. Developers see taxation based on gross rental income as unrealistic and unjust since it fails to account for the myriad management concerns that add expenses and transaction costs to landlords who provide rental property. As an example, what if the landlord uses the money collected to fund a large renovation? What happens if the landlord's profit is zero or negative because of lengthy vacancy or major renovations that consume a large portion of the rent? Renovations are a significant expense for landlords, yet the provision makes no mention of them. If these expenses are not taken into account during tax preparation, the burden is shifted to the landlord, reducing his or her expected returns. Given the inherent, lengthy taxation regime that will constantly burden them, most developers would be uninterested in entering the rental sector [D1; D5; D8]. Respondent developers provide a realistic explanation for why it is so difficult to plan and budget for taxes on rental housing properties: the uncertainty of voids, vacancies, and defaults in the rental income stream. In addition, unanticipated repairs might have a negative effect on earnings, and because earnings fluctuate over time, calculating how much tax will be owed can be difficult. This, as the developers point out, casts doubt on the predictability of the transaction fees that will ultimately need to be incurred. Most builders shun the rental sector because of the inherent risk involved. As it stands, the tax system is unable to stimulate rental housing supply since it does not give sufficient incentive to stir the interest of developers in the sector and instead increases transaction costs and, therefore, a constant financial burden to the developers.

6 Conclusions

The purpose of this study was to examine whether or not Kenya's institutional setting promotes the development of economically viable rental housing. In fact, it is evident from the findings that the institutional regulatory framework systematically, but inadvertently distorts the housing market by limiting supply of rental housing, a situation which is contemptuous of the common platitude that the institutional framework is aimed at providing enabling environment for delivery of adequate and quality housing for all. The framework in its current shape does not provide any substantial push towards rental housing delivery. Essentially, many biases against rental housing development have been displayed by the institutional regulatory structure. From planning permissions and zoning regulations to building codes and the construction process to post-completion responsibilities, housing developments for rent have it rough compared to those for sale. This was confirmed by the developers unanimously. Developers view the rental housing market with skepticism because of the high transaction costs caused by land-use regulations and the widespread belief in unequal property rights. The rental market is being further damaged by the tax system. The market for new construction with the intention of selling it is the primary focus of tax incentives.

7 Policy Implications and Recommendations

Despite the fact that the purpose of the regulatory framework is to make the housing market more efficient, there is evidence to suggest that in practice it has led to perverse results, such as less money being put into affordable rental housing. As a result, a major issue is how to provide incentives for new rental-housing construction within the current regulatory system. The implications for policymakers of the unintended negative market consequences caused by rules are substantial. This is due to the fact that the budgetary structure, the nature of lease agreements between landlords and renters, and the time it takes to create a certain amount of housing are all profoundly impacted by the regulatory framework. Thus, it is essential to strike a balance when dealing with regulatory frameworks so as to ensure that they do not disincentivize developers or generate high transaction costs, both of which distort the market and lead to undesirable outcomes in the housing market, whether intentionally or unintentionally. It is important for policymakers to work towards a level playing field in the housing market, but they must be careful not to undermine the current regulatory benefits in the process. Therefore, laws and agreements for renting properties should be drafted to reduce unnecessary bureaucracy and ambiguity that slow down the approval process for new construction and the resolution of tenant disputes. Landlords and developers do not feel deprived by tax systems, therefore government spending priorities should reflect the realities of the rental housing industry. However, taxes, while a significant source of government revenue, should not stifle investment in the rental housing market. Therefore, policymakers should find a happy medium between preserving the government's revenue base and ensuring that the rental housing market is not distorted by the fiscal situation.

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Project Management Practices: Importance to Delivery of Infrastructural Project

Moeketsi Horatius Mohlabi(✉) and Barend Botha

4th Floor, East Wing, 48 Ameshoff Street, Braamfontein 2001, Gauteng, South Africa
moeketsimoh@joburg.org.za

Abstract. People's last line of defence when it comes to service delivery is the local government since the services provided at this level of government have an impact on residents' everyday lives. These services range from garbage collection to water delivery to the supply of libraries to the maintenance of infrastructures like roads and sanitary systems. To facilitate operations and the achievement of their goals, local governments primarily rely on infrastructure projects and their development. This study looked at how project management techniques affected the City of Johannesburg's (CoJ) South African infrastructure projects. This study examined the relationship between project management techniques and the success of infrastructure projects using a case study of CoJ. According to the research's findings, project management techniques significantly affect whether an organisation's infrastructure initiatives are successful or unsuccessful. Therefore, the success of infrastructure projects would rise if the CoJ's project management procedures were improved. The management and leadership of the CoJ received recommendations that, if put into practice, might improve the organisation's project management and infrastructure project success.

Keywords: Project management · Best practices · Infrastructure projects · Resource-based view theory · Theory of constraints · Project management competency theory · Project success · Project performance

1 Introduction

Since the beginning of time, projects have been used as a way of attaining objectives. As a consequence, important contributions to society and culture have been made, including the first steam engine, historic Roman roads, and the Great Wall of China, among many others. Similar to the national government, local governments carry out several initiatives aimed at enhancing community life on a variety of levels. These initiatives might involve building infrastructure or even maintaining crucial and frequently critical services. Water, sanitation, garbage collection, the supply of libraries, and the upkeep of parks and infrastructure, such as roads, are just a few of these services.

The implementation of infrastructure projects requires good and effective project management, which continues to be a critical skill for the local government's service delivery agenda. The effects of service delivery issues facing various kinds of

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municipalities nationwide were examined in prior South African studies. The value of project management best practices was supported by the shared finding from this research [1, 2].

Local governments largely rely on infrastructure development and projects to support their operations and achieve their goals. The success of these initiatives, however, varies greatly, making it difficult for local governments to properly carry out their mandate. These variations in infrastructure project success, according to earlier findings, are the consequence of variations in the project management's effectiveness in creating the city's infrastructure. According to the results, project managers who are given these responsibilities learn the knowledge and abilities needed for the organization, delivery, and supervision of these services.

Local authorities in the City of Johannesburg (CoJ) recognise the value of infrastructure development in raising the quality of life, and as part of its quest for superior local governance, it has undertaken several infrastructure and services initiatives. According to research findings, it is necessary to study how the CoJ manages projects and how it affects the outcomes of infrastructure projects undertaken by the local government.

2 Theoretical Framework and Best Practice

The theories of Project Management Competency, Theory of Constraints, and Resource-Based View (RBV) have all been acknowledged as being relevant to the problems addressed by this research. The idea explains how important tangible and intangible resources affect a business's capacity to complete projects within the set time and budget parameters while maintaining the necessary degree of quality. It emphasises how performance with enough resources is likely to outperform other businesses and have a competitive advantage. Our theory is important to this investigation because it outlines the material, human, and technological resources required to enhance the efficiency of infrastructure projects. The theory also offers greater guidance on how to utilise these resources to develop customised project management skills within a particular operational environment and to meet certain project management goals.

The theory of constraints (TOC) is founded on the idea that limitations have a negative effect on any company's performance. The idea of constraints states that project managers should give appropriate management of these limitations priority [3]. The notion also pushes managers to think creatively as they look for tactics to help the business accomplish high-quality infrastructure projects despite project restrictions. According to earlier studies, the bulk of company restraints is a result of insufficient regulations and material resources [3]. The idea sheds light on the limitations that prevent road infrastructure projects from performing as planned. The limitations include the project's scope, expense, level of quality, and completion date.

The competence development framework for project management describes competency as a group of interconnected abilities, know-how, attitudes, and other character qualities that affect how a person handles a certain task. Competency and project performance are related, and both may be improved via training and staff development [4]. The idea clarifies the significance of project management skills, monitoring and assessment of development projects, and the impact of group dynamics on the success of infrastructure projects. To complete infrastructure projects within the constraints of stakeholder satisfaction, health and quality, ethical conduct, safety, environmental friendliness, time, and cost, local government construction teams must possess the technical, behavioural, and contextual competencies described in this theory [5]. In their investigation of the leadership skill profiles of effective infrastructure project managers, Ha and Tran [5] applied this theory.

The Project Management Body of Knowledge (PMBOK), Association for Project Management Body of Knowledge (APMBoK), and PRINCE2 (Projects IN Controlled Environments) are a few examples of widely used approaches, tools, and strategies for successful project management. Project management standards and guidelines that enable their execution should have these qualities as their key characteristics: relevance, usefulness, acceptability, application, significance, utility, and value. Burke [6] claims that using global norms and standards in project management has the following advantages:

1. Transfer of knowledge: A standardised project management methodology.
2. Time and cost savings: Time management is a component of project management since projects are time-dependent. The amount of time wasted re-inventing the wheel is only apparent when it is quantified.
3. A more objective and efficient audit: The auditing procedure will operate more effectively thanks to international standards.
4. Better teamwork: Teams are more effectively organised, with duties clearly defined and more productive teamwork.
5. Better communication: Project management relies heavily on communication.
6. Better market position: A stronger market position results from the use of international standards and best practices.
7. The international approach of labour: Working in a global setting is made easier by a common approach to knowledge, competency, and processes.
8. Better control and monitoring of projects: Increased effectiveness of multinational project monitoring and control.
9. Better process quality: Standards and recommendations raise the quality.

The advantages of using project management make its operations and fundamental functions easier. By directing team members toward the project objectives through smart working and integrated efficiency, project management improves efficiency while providing services. A planned, methodical strategy with distinct project deliverables has also been shown to aid in accomplishing project goals [7]. Project management is shown to guarantee higher performance and give an advantage over rivals. Additionally, it improves flexibility and leads to the team as a whole developing at higher rates of growth and development as well as finding a wiser course of action or direction for a better result. An improved risk assessment enables components of possible risk to be quickly detected before affecting project outcomes. More specifically, improving the efficacy and effectiveness of functioning and operations may improve both the quality and quantity of an organisation's output [8].

The responsibility for project management cannot be placed only on one individual. Thus, the entire team must overcome several obstacles as they adopt the project management methodology and discipline. Geographically scattered project teams pose a difficulty for project management, according to a prior study, since it is challenging to employ a centralised approach to project management when teams are working on the same project from different locations. Overusing or improperly managing resources is a problem that project management teams frequently encounter since they don't always have accurate knowledge of the resources' availability [9].

The use of incorrect tools for the completion of tasks represents another challenge to successful project management while success is also curtailed by wasting time when searching for assets or documents as well as project scope materials [10]. Spending too much time on status meetings might waste time and resources that could be used to carry out and accomplish the goals. Additional difficulties include schedule overruns, resource escalation, uncertainty and risk management, adjusting to project-specific variances, project leadership, and project strategy.

The impact of project management and associated practices on project performance has been the subject of several studies. Joslin, Müller [11] investigated the relationship between project policy, strategy, and success, as well as the impact of project leadership, using moderated hierarchical regression and component analysis. According to the study, project strategy and policy account for 22.3% of the variation in project performance, and those that were comprehensive enough to manage the project resulted in greater project success rates. The choice of project policies and tactics is influenced by project leadership as well. According to research by Blaskovics [12], project success is closely related to the technical, management and leadership skills of project managers.

Government and public organisations frequently base their conclusions on how project management affects construction time and quality on specific political and economic factors. Instructions outlining project completion dates may be provided in conjunction with such considerations. Members of the project team could be doing an impossible job to comply. According to Awuzie, McDermott [13], commercial and/or political issues appear to be the main predictors of how well building projects function. They noticed that, in contrast to unbiased assessments, planning and programming approaches are created to fulfil precise time and cost objectives. This put the project's executors under pressure, which led to generally subpar project performance.

The whole of the characteristics necessary to fulfil a certain demand, or fitness for purpose, is the definition of project quality [14]. The level of oversight, project management experience, the quality and track record of teams and managers, and the number of change orders issued all have an impact on the project's integrity. To achieve outcomes of the highest calibre, the project management team's leader must successfully coordinate these components.

Shiau [15] found that project management action was the best predictor of stakeholder satisfaction using multivariate regression and factor analysis. Communication, the client's attention to quality, and time/schedule were also highlighted as factors requiring proper consideration, in addition to the effectiveness of the construction team leader.

According to the literature assessment, there is general agreement that the success of projects is positively and significantly impacted by project management methods, including the aspects of leadership, strategy, teams, communication, and project procedures. The theoretical foundation for a project management performance model based on Zulu's work [16] was used in light of the findings from the literature and is shown in Fig. 1.

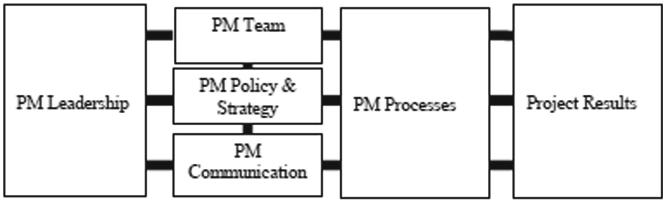

Fig. 1. Framework for theorising how project management techniques affect projects' performance [16]

3 Research Methodology

In this study, a mixed research technique was used. Because it would offer a thorough examination of the project management approach used in the CoJ and its effects on service delivery, this methodology was chosen. To understand the described phenomena, the study aimed to find relationships between the variables. A single case study technique, individually delivered questionnaires, and face-to-face interviews were all used in this study. The CoJ local government was chosen for the case study since project management and infrastructure projects are vast sectors. The case study approach was used to collect data from workers in a real-world context who reported directly or indirectly to the leaders of the component. Two projects were chosen, one of which was successful (Project A, completed on time and under budget) and the other of which was unsuccessful (Project B). The research's conclusions, however, could not be applied outside of the CoJ's framework. The study stands out for taking a comprehensive approach.

159 people working in managerial, supervisory, administrative, and operational capacities for the CoJ's infrastructure development divisions made up the study's target group. For the quantitative portion of this research, the study sample consisted of 114 individuals from the study population. This sample size of 114 had a margin of error of 5% and was significant at a 95% confidence level. This sample size made it possible to gather the information needed to carry out useful statistical analysis and enable the results to be generalised. Purposive sampling was used to choose a sample size of 10 people from the target demographic for the qualitative data collection.

To gather quantitative primary data, this study used a paper-based, structured, and self-administered questionnaire. The survey has three parts: Sections A (biographical information), B (project management effectiveness for projects A and B), and C. (success of Projects A and B). The variables and constructs found during the literature study were used to guide the design of the research questionnaire. The second research tool, a paper-based interview guide, was created to gather the information that would be utilised to create a more thorough picture of the nature and function of the CoJ's project management, as well as how it affected project success. The study's objectives were taken into consideration when creating the interview guide. SPSS 25, a quantitative data analysis program, was used to carry out the quantitative data analysis. Mean score ranking was used for descriptive analysis. Multivariate regression analysis was another method used to analyse the quantitative data using inferential statistics. The interviews that were done as part of this study were recorded verbatim using a digital recorder, entered into an electronic database for analysis, and then stored there. The existence of certain words, themes, or concepts within a given set of qualitative data was determined using content analysis, which was used to analyse the qualitative primary data.

4 Results

4.1 Project Management Practices

The descriptive portion of this research's quantitative findings about the effectiveness of project management in projects A and B are shown in Table 1.

The results of the study showed that the CoJ's project management techniques were, at worst, somewhat effective and, at best, very effective in carrying out Project A. However, in the instance of Project B, the effectiveness of project management techniques was at best mediocre and at worst terrible. These results lined up with those of the qualitative study.

4.2 Constraints to Project Management Best Practices

The study results from replies to a question about the barriers to the use of project management best practices are presented in Table 2.

From Table 2, the leading factor that constrains the application and the best practices of project management in the infrastructure project of the CoJ is noted to be limited human resources. The research findings identified a lack of personnel with the adequate training, education and skills to apply the best practices of project management in the CoJ infrastructure projects.

4.3 The Impact of Project Management on Project Success

The effect of project management on project success was specifically determined using multivariate regression analysis. Project success served as the dependent variable, whereas project leadership, project strategy, project teams, project communication, and project procedure served as the independent factors. Projects A and B of the CoJ each had a separate regression analysis run.

Project A—Project management and its components, including project leadership (APL), project strategy (APS), project teams (APT), project communication (APC), and project process (APP), were regressed against project performance to "explicitly determine the impact of project management on the performance of Project A of the CoJ". (APSC). APL, APS, APT, APC, and APP were the independent variables while

Table 1. Efficacy of project management

Project management	Project A		Project B	
Leadership	Mean	SD	Mean	SD
1. The project had clearly defined goals	3.68	0.98	2.15	1.01
2. The project manager had adequate experience	3.39	0.92	2.4	0.87
3. The project manager was competent enough to manage the project	3.36	0.85	2.4	0.82
Strategy	Mean	SD	Mean	SD
4. The project and its execution were regularly reviewed	3.68	0.86	2.34	0.91
5. The project was executed following a clear, comprehensive and effective methodology	3.32	0.78	2.75	0.79
6. The success criteria for the project were clearly defined	3.79	0.91	2.3	0.83
Teams	Mean	SD	Mean	SD
7. The team that executed the project had adequate capabilities	3.6	0.97	2.38	0.99
8. The members of the team that executed the project have adequate skill and knowledge to successfully execute the project	3.37	0.89	2.23	0.93
9. There was cooperation among the members of the team which executed the project	3.78	0.87	2.23	0.93
Communication	Mean	SD	Mean	SD
10. There was adequate communication among the stakeholders of the project	3.65	0.85	2.33	0.8
11. The communication system utilised in the execution allowed for the free flow of accurate information	3.46	0.88	2.47	0.85
12. Communication in the execution of the project was conducted frequently enough	3.68	0.82	2.25	0.84
Process	Mean	SD	Mean	SD
13. The project management processes and procedures employed in executing the research were appropriate and well implemented	3.44	0.99	2.51	0.99
14. There was a high degree of monitoring and control in executing the project	3.7	0.82	2.58	1.16
15. The implementation of project management methodology was effective and efficient done in the execution of the project	3.54	0.94	2.76	1.14

APSC was the dependent variable. As a consequence of the regression analysis, a significant regression model was identified (F (40.171) = 201.282, p 0.000), an R^2 of 0.903 was also found. The findings of the regression analysis for Project A were used to create Eq. 1.

$$0.34\text{APL} + 0.244\text{APS} + 0.304\text{APT} + 0.07\text{APC} + 0.083\text{APP} - 0.084 = \text{APSC} \quad (1)$$

Table 2. Project management best practices constraints

Constraint	Frequency (%)
Lack of suitably trained personnel	100
Mismanagement of resources	80
Limited institutional capacity	74
Bureaucratic decision-making	65
Corruption	56
Limited involvement of stakeholders	40

According to the regression model, there was a factor of 0.34 for every unit rise in APL, 0.244 for every unit increase in APS, 0.304 for every unit increase in APT, 0.07 for every unit increase in APC, and 0.083 for every unit increase in APC. It was discovered that each independent variable had a considerable impact on the dependent variable.

Participants acknowledged the major influence that bad project management had on the collapse of Project B, and the qualitative research's conclusions supported the study's quantitative findings.

Project B—Project management for the project and its components of project leadership (BPL), project strategy (BPS), project teams (BPT), project communication (BPC), and project process (BPP) were regressed against project performance to ascertain the effect of project management on the performance of the CoJ's Project B. (BPSC). BPSC was the dependent variable, whereas BPL, BPS, BPT, BPC, and BPP were the independent variables. As a consequence of the regression analysis, a significant regression model was identified (F (44.170) = 211.409, p 0.000), an R^2 of 0.907 was also found. From Project B's regression analysis, Eq. 2 was derived.

$$0.306\mathrm{BPL} + 0.204\mathrm{BPS} + 0.344\mathrm{BPT} + 0.054\mathrm{BPC} + 0.032\mathrm{BPP} - 0.09 = \mathrm{BPSC} \quad (2)$$

According to the regression model, there was an increase in project performance or success (APSC) of 0.306 for every unit increase in BPL, 0.204 for every unit increase in BPS, 0.344 for every unit increase in BPT, 0.054 for every unit increase in BPC, and 0.032 for every unit rise in BPC. The study's findings also demonstrated that the CoJ's infrastructure projects were successfully completed thanks to the project management factors of BPL, BPS, BPT, BPC, and BPP.

Participants acknowledged the strong influence that project management had on the degree of success of both Projects A and B, and the qualitative research's conclusions supported the study's quantitative findings.

5 Discussion

According to the study, the CoJ's project management techniques were between moderate and very successful in carrying out Project A. In comparison, Project B's project management procedures were at best average and at worst ineffective. The research's findings also showed that the best project management approaches are hampered by a lack of human resources, resource mismanagement, institutional weakness, bureaucratic decision-making, unfavourable political involvement, corruption, and low stakeholder participation. The results of the qualitative primary research supported and added to those of the quantitative primary research. These findings are in line with earlier studies that showed public sector organisations in poor countries usually lacked the human resources to successfully conduct project management. Additionally, the research found corruption, a lack of institutional ability, and poor resource management inside the organisation as barriers to efficient project management. These results are in line with previous research that pointed out the same challenges to efficient project management, particularly in poor countries [16].

Ineffective project management is also hampered by delayed decision-making, according to the research findings. These results are consistent with other research that has found that public organisations in developing nations share some traits that hinder efficient project management of public infrastructure projects [17]. It is accepted that public organisations' bureaucratic structures slow down project management procedures. Literature also demonstrates that government officials in underdeveloped countries sway the creation of public projects to achieve their political objectives [17]. Another obstacle to efficient project management, according to the report, is insufficient support and engagement from the government and the community. This is in line with the research, which notes that public organisations and projects include a wide range of stakeholders with many times conflicting interests who are underutilised and underrepresented.

With changes in project management techniques accounting for 90.3% of the variations in success, multivariate regression analysis showed that project management approaches had a significant and positive influence on Project A's performance. These outcomes matched those reported in the literature. The study's findings indicate that a project's success is influenced by a variety of factors, including, project procedure, project strategy, project teams, project leadership and, project communication, which has the least impact.

The outcomes of Project B were comparable to those of Project A, with variances in project management techniques accounting for 90.7% of the changes in success. The findings supported the claim that project management procedures significantly and favourably affect projects' success inside the CoJ. The results were consistent with those in the literature [11–13], which identified project management practices and its components as having a large and advantageous influence on project success. The findings show that project leadership, project teams, project strategy, project procedures, and project communication—which has the least impact—have the greatest effects on projects' success.

6 Conclusion and Recommendations

From the aforementioned findings, it can be inferred that the application of project management in unsuccessful CoJ projects is hampered by a variety of factors, including a lack of institutional capacity, a lack of institutional capacity, bureaucratic decision-making, corruption, and a lack of stakeholder involvement. However, it also shown that when project management procedures are founded on official project management techniques, greater performance may be attained. Thus, it can be inferred that greater emphasis should be placed on ensuring the use of the reliable current methods and tracking the outcomes in order to continually improve them based on knowledge and best practices.

The recommendations listed below were created based on the aforementioned information to increase the success of CoJ's initiatives.

- Spend time and money on project managers' and project teams' training and education on topics important to efficient project management.
- To expand institutional capacity, resource mobilisation, and stakeholder support for the creation of infrastructure projects, strengthen partnerships with the government, private organisations, and people.
- To ensure the uniform and consistent use of the finest project management practices across all infrastructure projects, establish a system of controls and monitoring.
- Place a strong priority on upholding the most stringent laws and regulations governing moral conduct as well as health, safety, and environmental sustainability in all activities.
- Condemnations for breaking these laws and regulations should be handled more simply.
- By utilising the current Strategic Project Management and Engineering Centre of Excellence units, centralise its project management offices.

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Housing Finance Systems and Affordable Rental Housing Delivery in Kenya

Victor Otieno Olonde(✉), Manya Mainza Mooya, and Kanshukan Rajaratnam

Department of Construction Economics and Management, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa
volonde@yahoo.com, manya.mooya@uct.ac.za

Abstract. Housing finance systems consist of a variety of market mechanisms and policy interventions aimed at facilitating the acquisition of housing capital. Housing finance, which provides the financial backing needed by developers to produce housing for rental and sale, is typically seen as a major pillar in the housing industry. However, there are instances when housing finance systems have unintended consequences, such as causing market failure in a certain subset of the housing market. It is a similar situation in the rental housing market, where supply of affordable rentals has lagged behind demand. As a result, the primary goal of this research is to find out how the housing finance systems interact with the rental housing market and how they affect market results. It primarily relies on qualitative research design, such as semi-interviews and document analyses, to obtain relevant information. It relies on primary data from financial institutions and private property developers. The results show that because rental housing development is seen as high risk, banks are more cautious and selective in providing loans for it than they are with regard to development of homes for sale. This research recommends that housing policy requirements should be integrated with the financial market system so that financial institutions become indifferent to lending to both rental and development for sale in order to increase the attractiveness of rental housing to the former.

Keywords: Housing finance systems · Housing market · Rental housing · Affordable housing

1 Introduction

Since housing is associated with strategic socioeconomic relevance [1, 8, 22, 23], most governments have kept it at the forefront of their agendas to ensure its delivery. Finance is a crucial part of housing delivery [19]. This is due to the fact that developers cannot build houses for rent or sale without the financial backing provided by housing finance [2]. In this way, the housing finance system as an institution significantly affects the decisions of the developers as to whether to provide housing for sale or rent [18]. So when the funding conditions are ostensibly favorable to the developers, they are encouraged to

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offer more housing units [12]. In essence, an effectively functioning housing system should efficiently and fairly allocate finances amongst housing investors, developing either for sale or rental [6].

Despite developers' increased efforts in the housing delivery sector, evidence suggests that the scale of affordable rental housing development remains low in comparison to the potential demand, as builders are more likely to deliver build-to-sale (BtS) projects than BtR (build-to-rent) projects [19]. As a result, the limited supply of affordable rental housing worsens the urban housing crisis since low-income households, who dominate the affordable rental housing market, are inadequately supplied [2].

Consequently, the study's primary goal is to inquire into the connections between housing financing systems and the rental housing market. Specifically, it seeks establish the loan-to-value ratios and interest rates, as well as to examine the terms under which banks will lend to developers for BtS and BtR. The central concept is that the rental housing market has been hampered by a lack of affordable options since the housing finance system has not been conducive to its growth. This study is part of a doctoral thesis by the first author entitled 'Affordable rental housing delivery in Kenya'.

2 Literature Review

Housing finance systems are the aggregation of market mechanisms and policy guidelines that together strive to provide housing financing [19]. They involve operations in the monetary and credit systems geared toward facilitating development and purchase of property [2]. Because of the nature of the housing product, housing finance is significant. Housing, as one example, is a costly good, the investment in which calls for substantial outlay of resources and a dedication to financial stability over the long term [7, 9]. Therefore, housing finance is a crucial component of the housing delivery system [8], since it serves as a source of funding for both the housing industry and its end users (both landlords and tenants). Consequently, without a well-recognized and effective mechanism in housing financing [10, 21], it is quite difficult to accomplish the policy objective in housing development.

Buckley and Kalarickal [3] acknowledge the importance of finance in housing provision and highlight the need for creating policy measures aimed at sustainable housing finance systems with the capability of boosting housing delivery at all levels. The extent to which a country's housing needs are met is greatly influenced by its housing finance system. Increasing the number of available rental properties calls for a stable housing finance system that supports both the demand and supply sides of the housing market [15, 19].

The importance of housing finance in meeting the demand for housing has been generally acknowledged [13, 20, 21]. As a result, there has been a push for new policies that will ensure the continued existence of housing financing systems that can improve the supply of affordable housing. This is due to the fact that the functioning of the housing market and the entire national economy are both dependent on the role that housing finance plays [3, 4].

The influence of housing finance systems specifically to rental housing delivery is however not well captured within the literature. Peppercorn and Taffin [17] emphasize that the nature of financial framework is significant in the development of rental housing. It is more likely that the private sector will invest in rental units if the financial instrument is structured in a way that favors the rate of return for rental housing [7].

Lawson, Hamilton, and Pawson [14] stress the significance of enticing private finance toward expanding supply across the entire rental housing segment, noting that favorable financial conditions allow for effective opportunities to deliver rental housing units to low-income families at affordable rents. They suggest that a long-term legislative framework should be put in place to guarantee the financial stability of rental housing developments in order to attract private capital. Financial institutions' lack of interest in financing rental housing has been the subject of other studies [7, 17, 18].

3 Gaps and Study Justification

The reviewed literature depicts a possible content and context vacuum for research because of the lack of data on the rental housing market in developing countries. The majority of the research articles cited are drawn from the setting of developed nations, hence the topics covered are really global in scope. This research aspires to contribute to the development of a housing data base from the perspective of a developing country.

4 Research Design

This study is qualitative in nature, employing a case study approach, and using Mombasa City, Kenya as the city under examination. According to Table 1, a total of twenty-three (23) interviews were performed using a purposeful sampling strategy. Participants were recruited based on their experience and expert knowledge around the study subject, as this is the ideal method for studying the central phenomenon via purposeful sampling. Ten (10) notable property developers were requested to participate in this study, and they were asked to answer semi-structured questions on their development efforts in Mombasa's housing market. The major goal of this study was to gain insight into the reasons behind developers' lack of involvement in the affordable rental housing market by gaining a better understanding of their interactions with housing financing institutions along the housing delivery process. Eight (8) financial organizations' representatives were purposively selected for interviews to further clarify the impact of these institutions on housing market outcomes. They disclosed their loan-to-value and interest-rate policies, as well as their loan-evaluation criteria, for various types of property developers. In addition, three (3) state actors with expertise on housing issues were sought for interviews from the State Department of Housing and Urban Development and the National Housing Corporation in order to better comprehend the housing finance policy framework. Also consulted were two (2) private housing consultants. One-on-one interviews were used to compile this data. Primary data was collected via semi-structured interviews, and secondary data was gathered by documentary analysis. To examine the information, a thematic analysis was performed. The process of spotting these new codes required open coding. NVIVO 12 was used for data management and organization to facilitate the merging of the codes into the overarching themes and categories. The transcripts were de-identified and coded with numbers before being imported into NVIVO, as shown in Table 1, to ensure the anonymity of the research subjects.

Table 1. Interview respondents

Respondents	Code	Nature of organisation	Designation
Developer 1	D1	Property development firm	Director
Developer 2	D2	Property development firm	Director
Developer 3	D3	Property development firm	Director
Developer 4	D4	Property development firm	Director
Developer 5	D5	Property development firm	Director
Developer 6	D6	Property development firm	Director
Developer 7	D7	Property development firm	Director
Developer 8	D8	Property development firm	Director
Developer 9	D9	Property development firm	Director
Developer 10	D10	Property development firm	Director
Housing finance official 1	HFO1	financial institution	Relationship Manager
Housing finance official 2	HFO2	Financial institution	Relationship Manager
Housing finance official 3	HFO3	Financial institution	Relationship Manager
Housing finance official 4	HFO4	Financial institution	Relationship Manager
Housing finance official 5	HFO5	Financial institution	Relationship Manager
Housing finance official 6	HFO6	Financial institution	Relationship Manager
Housing finance official 7	HFO7	Financial institution	Relationship Manager
Housing finance official 8	HFO8	Financial institution	Relationship Manager
State Actor 1	SA1	State Department of Housing	Director
State Actor 2	SA2	State Department of Housing	Assistant Director
State Actor 3	SA3	National Housing Corporation	Manager
Housing Consultant 1	HC1	Private Housing Consultants	Director
Housing Consultant 2	HC2	Private Housing Consultants	Director

5 Data Findings and Analysis

It is instrumental to comprehend the banks' processes and guidelines for financing different categories of housing. Since lending conditions and financial institutions' risk perception are important factors in making decisions, they formed the basis for this study's analysis. As a result, the study's focus is on how interest rates affect the banks' various client segments and how the banks' risk assessment practices inform their lending policies.

5.1 Ability to Pay Basis

This research aimed to better understand how banks and other financial institutions assess risk when providing capital for new housing development. Key highlights from the interviewed bank personnel seem to point to a standardized procedure. Banks and other lenders will evaluate a borrower's creditworthiness and the length of time it will take to repay a loan as part of their first risk assessment. Since the bank's top priority is getting its money back with interest as soon as possible [HFO1].

The developers agree that there is a significant amount of bias in the evaluation favoring the developer in both the sale and rental markets. Officials from the banks verified this, albeit in indirectly by stating that the developers' ability to repay the loan plus interests is taken into account when evaluating rental housing developments [HFO2; HFO4]. Therefore, the developer must demonstrate sufficient income from other sources without the anticipated rental income from the planned project [HFO4]. Therefore, builders of rental properties rely mostly on individual loans secured by non-rental income [D9]. However, clients who need funds to develop housing units for sale are clearly given preference, as their proposed developments are considered for project financing and the ability to pay is based on the projected income from the sale proceeds of the units, which is typically proven by pre-sale contracts with the potential buyers.

According to the results of an analysis of the mode of evaluation for ability to pay, developers of housing for sale do not need financial backing as long as the proposed development is viable. This gives developers of housing for sale an advantage over developers of housing for rent. Actually, few rental housing units could be supplied due to financial constraints because developers of such housing must have the ability to repay from revenues other than the predicted rental proceeds. This suggests that the criteria used to determine whether a developer of rental housing will be able to repay a loan are stricter than those used to evaluate the repayment prospects of the developers of homes for sale.

The bank officials were questioned about the bank's inclination to finance for-sale housing projects. The fact that banks are businesses with a focus on making a profit is implicit in the statement, but it is nonetheless worth noting. In light of this, financial institutions are risk-averse and "would not wish to have their skin in the game" [HFO6]. This means that banks want to ensure that their interests are safeguarded at all times, and this is reflected in the terms of credit that they offer.

The financial institutions therefore view rental housing market as typically associated with unpredictable incomes due to issues of vacancies, voids and rent defaults. Consequently, the actual amounts and timings of rental incomes receivable may not be certain. Yet, loan repayments entail definite amounts within specified intervals for a predictable duration. Hence, pegging repayments on projected incomes becomes tricky due to the uncertainty. The lower and uncertain rental incomes associated rental housing is assumed to cap the landlords' ability to repay the loans as projected without challenges. But one critical point that emerged from the interviewed developers is that they cannot predetermine the rate of vacancies, voids and rent defaults beforehand and therefore dealing with rental housing becomes uncertain and risky, and could potentially cause them to incur higher transaction costs arising from mitigative administrative procedure when dealing with borrowers for rental development. Subsequently the most probable rational action from the developers would be to avoid the sector or formulate stringent measures to mitigate against the high transaction costs that may result.

5.2 Payback Period Basis

The respondents indicated that banks prefer to engage in shorter and more definitive business engagements because longer periods of engagements are shrouded with uncertainties and prone to additional risks [HFO3]. One common theme among the bank representatives was that the financial institutions care more about transactions than relationships. It is fairly evident that the repayment period for a home that is for sale is going to be shorter than that of a rental, but this analysis is concerned with how this scenario affects the decision of financial institutions when reviewing financial requests for rental and sale projects. According to data compiled by financial institutions, developments geared toward sale are seen as providing shorter transactions and fewer relationships than rental housing, which is seen as leading to longer relationships and less transactions (HFO7). According to the respondents, the time frame from initial planning to selling a completed home development is typically less than three years. When it comes to financing homes for sale, banks often commit for a period of three years before moving on to other projects. This allows financial institutions to conduct more transactions over shorter time periods, reducing their risk profile. With the use of contracts requiring all financial transactions from the sale proceeds to be routed through the bank until it recoups its money, most banks are able to supervise the sale of the developed houses, thus shortening the repayment period for loans against development for sale (HFO3). This allows the bank to track their payments and automatically deduct them, cutting down on the number of defaults. Still, the fact that most of the units are sold off-plan means that full payment can be concluded by the time construction is completed, which is typically two to three years depending on the size of the project, thereby minimising risks and shortening the time frame (HFO2). Financing rental properties, on the other hand, is considered a long-term engagement because the payback period typically lasts for 10 years or more, during which time the bank and the borrower form a lasting relationship during the course of a single commercial transaction. Due to the aforementioned unpredictability of anticipated incomes, it is believed that such long-term relationships carry considerable default risks.

5.3 Property Rights and Contract Enforcement Framework

Again, we sought from the housing finance officials how they deal contract issues in loan repayment. To this, the study found out that the perception of high-risk premium in the rental housing market is accentuated by the nature of legal framework under which it operates. In fact, there is a consensus among the housing financing institutions that funding a house for owner-occupation [for sale] is more secure than rental since in the former, the bank directly deals with the end user while in the latter, a number of parties could be involved some of whom have no contract with the bank. For example, explanation from the HFO5 reveals that the overarching concern is in regard to the complex legal challenges for financial institutions in administering a rental unit in case of a dispute. Usually, when advancing finance for rental housing development, a Rental

Deed of Assignment is usually signed between the institution and the developer to compel the later to remit an agreed amount of rental to the bank monthly failure to which the bank takes over the premises and appoints their own agent a to collect rent on their behalf.

The banking officials were also asked how they deal with contracts issues. However, they pointed out that the notable weakness of the contract instrument is that it lacks a legal framework for enforcement in case of breach. To enforce it, the banks have to go to court and get a court order, but this involves protracted litigation which may end up favouring either party, and huge litigation costs. This is more so due to the fact that the property rights structure is seen to contribute to the uncertainty in a number of ways. Primarily, the concern is elicited by the fact that the financial contract exists between the bank and the landlord, and therefore if the latter's grip on the property is weakened, then recovery of the loan may be jeopardized. The banks have no contract with the tenants. Therefore, in the event of default by the landlord and the bank opts for foreclosure, the rights of the tenants cannot be wished away. Such scenarios increase the risks to the banks and in effect daunt them from financing rental housing development. This scenario points to an implication of lack of properly laid down property rights. Essentially, unclear property rights increase transaction costs. In this scenario, the anticipated transaction cost of navigating the disputes and litigations is perceived to be high by the bank and therefore, they avoid or minimize their financial engagement with rental housing developers. This in turn limits the developers' financial ability to deliver more rental units.

5.4 Loan to Value Ratio

Banks use the Loan to Value [LTV] ratio approach to limit the amount of risk they take on by lending money to developers. As a result, knowing the percentages of bank loans given to different types of house construction is essential for evaluating the banks' role in the housing market. Despite the generally set Loan to Value [LTV] ratios, developers are worried that banks would analyze them further and alter the ratios to suit their judgments based on the type of project [D1, D7, D5]. Because all the banks in the sample provide smaller loan percentages to rental properties than they do to homes for sale, the ratios accurately illustrate the systematic bias against rental properties. Constructing with the intent to sell implies a greater access to capital than would be the case for a developer constructing with the intent to rent.

5.5 Lending Rates

The developers indicated that even if interest rates have dropped from 18 to 21% to the current cap of 13.5%, there is still a shortage of rental house builders because of the strict financing criteria, which are especially prevalent in the rental housing sector. They state that most housing development loans have interest payments beginning before the construction is even finished. Since most developers view rental housing as a long-term investment, they may be dissuaded from developing for rent in favor of for-sale housing [D4, D6, HC1]. Housing building is a high-risk endeavor that requires a sizable initial investment, and the developers who were surveyed all agreed that banks are a necessary component of the industry. However, the financial system is designed in such a way that the total amount paid is proportional to the time period during which the payment is made [i.e., the shorter the time, the less is paid and the longer the time, the more is paid] [HC2]. More interest is accrued for a longer payment term, and likewise for a shorter term. Interest payments typically begin before a building is finished being constructed. The financial commitment required to build rental housing is lengthier than that required to build for sale, which is why the latter generates more demand.

6 Key Discussions

The foregoing examination not only demonstrates the value of housing financing in new construction, but also demonstrates how the financial system as an institution has consistently prioritized the construction of homes for sale over the construction of homes for rent. The data analysis shows that banks have strict and limited lending criteria for rental house construction. However, it is clear that the banks' perception of the risks connected with rental properties, as opposed to for-sale properties, is to blame for the current dire circumstances. When comparing the two types of developments (rental and sale), the rental housing performs worse due to a number of factors. These include lower and more uncertain returns, a longer payback period, and incomplete property rights, which can lead to ambiguous and unenforceable contracts. While this study agrees with Peppercorn and Taffin [17] and Chiquier and Lea [7], it disagrees with a number of studies, including Garnett and Perry [10] and CAHF [5], which have looked at finance from the perspective of households (consumption finance), and shown how low-income earners have been systematically shut out of the housing finance market due to stringent lending requirements. As important, the monetary side of housing provides a difficult policy challenge. This is due to the perception that the rental property sector is a high-risk, unpredictable market for financial transactions. This research, however, agrees with Malpezzi [15] that this kind of risk cannot be pinned squarely on the rental housing itself as a commodity, given that a large part of it stems from the unfavorable institutional setting. Because both housing products and the housing market are complex in many ways. As such, a number of distinct but interconnected institutions are involved in housing production and market operations. This means that the actions of one institution can have repercussions in another. In this light, the results of the ineffective regulatory system are seen to have a bigger impact on the attitude of financial institutions towards the housing market.

7 Conclusions and Recommendations

This study confirms the importance of housing finance to the housing market, as it serves as a key enabler of the home delivery process. However, financial institutions are business driven and strive to reduce risk. Since banks view rental housing development as high risk, they apply stricter lending standards compared to building for sale, as evidenced by the results. Banks prioritize the volume of transactions over the longevity of customer relationships; thus they favor short, clear-cut agreements. The unwillingness of lenders to finance the construction of rental housing, in conclusion, tilts the balance in favor of builders' focusing on building homes for sale. Alternatively, because of the perceived high risk and uncertainty that veils loan recovery in rental construction, lenders tend to favor development for sale. To make rental housing more attractive to financial institutions, housing policy regulations should be woven into the fabric of the financial market system in such a way that banks become indifferent to lending for both rental and construction of for-sale properties. Furthermore, the strategy should attract institutional investors due to the high capital expenditure required for housing developments. Attracting corporate or institutional investors with strong financial muscles is necessary to supplement the small number of private investors currently engaged in rental housing delivery in order to meet the demand for mass affordable rental housing. For this reason, future research ought to investigate how corporate institutions, particularly pension institutions, might be tapped as a source of funding for the supply of affordable rental housing.

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Investigating Construction and Demolition Waste Management Practices Among Building Industry Professionals in Lagos, Nigeria

Oluwole Alagbe, Akintunde Onamade(✉), and Opeyemi Asaju

Department of Architecture, Caleb University, Imota, Lagos, Nigeria
{oluwolealagbe,akintunde.onamade, opeyemi.asaju}@calebuniversity.edu.ng

Abstract. Building construction activities is one of man's most influential activities on natural resources and the environment. Cities in the phase of rapid economic development, urbanization and migration thus resulting in construction activities to accommodate the teeming population are generating construction and demolition waste (C&D). Nigeria, as a growing country, must implement an innovative approach to on-site management that includes waste capture and segregation to address the linked concerns of C&D waste affecting the construction sector and adversely affecting the environment. This study assessed the level of awareness and adherence to on-site innovative C&D waste management (re-use and re-cycle) practices by building industry professionals (BIPs) to protect the environment. A quantitative sampling method was used in the collection of data from 180 building industry professionals (BIPs) respondents drawn from BIPs in Lagos. The result revealed that the bulk of C&D waste was disposed of at landfill sites while the level of awareness of innovative use (re-use and re-cycle) of C&D waste is low among BIPs practising in Lagos. Thus it is recommended that massive enlightenment be engaged to increase awareness level among BIPs. Furthermore, priority should be given to adherence and monitoring of construction and demolition waste management practices by government agencies and professional bodies.

Keywords: Building industry · Professionals · Construction and demolition waste · Innovative · Waste management

1 Introduction

The current environmental challenges in the building industry are becoming alarming, building construction activities are one of man's most influential activities on natural resources and the environment, and the processes involved in construction create severe impacts on the environment [1]. Researchers have described the construction industry as one of the biggest consumers of energy and natural resources that depletes the environment in a way that environmental sustainability becomes in-practicable [2–4]. Horsley et al. [5] posits that the building process evolves over a variety of timescales from the extraction and processing of raw materials used in construction, through the duration of

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the construction process, the operation of the building, up to the eventual demolition of the structure at the end of its operative life.

The recent rate of building collapse in the study area has become a serious concern in construction and demolition waste generation. Since there is a great need for building development to accommodate the rapid economic development, urbanization and migration to cities, construction activities became inevitable for the teeming population. Given these decisive measures, programs must be put in place to reduce the volume of C&D waste generation. Invariably, overpopulation has placed a demand on the demolition of older buildings and construction of new ones thereby generating construction and demolition waste (C&D). Consequently, construction and demolition waste management has become a major environmental problem in the cities [6–9].

The environmental impact of mismanagement is often considered a localized impact without any reference to its global effect [10]. Combating construction and demolition waste management which is on the increase involves management strategies, input and commitment from different professionals in the building industry and government agencies (stakeholders). However, efforts have been ongoing striving to do more with less by reducing waste at all stages of construction. The assessment of professionals who forms the core of decision making and executioner of building project becomes very critical in issues of investigation of construction and demolition waste. It is against this background that this study sought to investigate construction and demolition waste management practices among building industry professionals to minimize wastage in Lagos, Nigeria.

The specific objectives of this study are to:

i. Investigate the effectiveness of C&D waste management practices in terms of re-use and re-cycle as a means of waste reduction among BIPs in Lagos, Nigeria.
ii. Assess the level of involvement of BIPs in C&D waste management.
iii. Examine the frequency of waste evacuation from selected construction sites in Lagos Metropolis Nigeria.

The novelty of this study is the revelation of the extent to which building industry professionals in Lagos practice and their level of involvement in innovative construction and demolition waste management practices and as well as the frequency of waste evacuation on environmental quality.

2 Review of Relevant Literature

2.1 Understanding Waste Generation and Classification

Waste generation has existed since the dawn of time, and it is the consequence of human consumption and production [4, 6]. It is often defined as substances or materials that have lost their value or utility to their creator, as well as substances or materials that have been thrown away or are about to be thrown away by the owner or generator [7]. Waste is often classified into two types non-hazardous waste and hazardous waste. Non-hazardous wastes are normally harmless and denote no immediate threat to humans or the environment and are also referred to as general waste. This category includes household wastes, C&D wastes, commercial waste, and garden waste, however, if they are not adequately controlled non-hazardous waste can become dangerous to both the environment and humans [10]. Hazardous waste can be defined as substances or materials that are injurious or harmful (even in low concentrations) to human health, animals, plants and the environment [11]. They include flammable liquids, flammable solids, Poisonous-Acute, corrosive, toxic waste with Radioactive properties etc. This study focuses on construction waste which is classified as non-hazardous waste and it includes all materials generated during or after construction or demolition activities, which could include new construction (of buildings, bridges, roads, etc.) or renovation/remodelling, whole demolition or partial destruction.

2.2 Waste Management Concept and Strategies

Waste management encompasses all human efforts, including the storage, collection, transportation, recovery, processing, and disposal of all substances or materials no longer required by the original generator [9]. This process of waste management can be defined as human behaviours such as designing, planning, organizing, staffing, leading or directing, and regulating an organization or system to achieve a set of objectives. These set objectives may include reduction of the negative impact of waste on human health, prevention of air, land and water contamination to engage in continuous improvement of the aesthetic value of the environment and finally recover resources for further usage [8, 11]. One of the most often used waste management concepts that are widely accepted is the waste hierarchy, it involves 3Rs (Reduce, Reuse and Recycle) [4]. This is well promoted and supported by the United Nations with waste management techniques and ideas to promote or encourage Zero Waste and getting the maximum output from a product while generating the least amount of waste. However, further arguments posit that beyond the 3Rs, there should be a Rethink towards waste, while disposal at the landfill is avoided and dumping and burning should be discouraged (Fig. 1).

Fig. 1. Showing waste management hierarchy. *Source* https://r7rx7211eooyolghipkh81cx-wpengine.netdna-ssl.com/wp-content/uploads/2020/08/22561928_web1_200831-Impress-ACRD-Waste_3.jpg

2.3 Construction Waste, the Industry and the Built Environment

The construction industry while attempting to contribute to the overall socio-economic development, turned out to be a major exploiter of natural non-renewable resources and continue polluting the built environment [12, 13]. Kabirifar et al. [14] agreed to the fact that this exploitation endorses environmental degradation through resource depletion, energy consumption, air pollution and waste generation. Furthermore, the construction industry is one of the top sources of air pollution, especially on construction sites where diesel equipment is used which always compromises the overall air quality. The natural ecosystem is affected substantially thereby causing habitat loss, biodiversity extinction, green fragmentation, and deforestation which all affect climate change [6].

2.4 Sustainable Construction and Demolition Waste Management Practices

The practice of waste management for construction activities has gained the attention of researchers to protect the environment [15, 16] and recognise that C&D wastes contribute significantly to the polluted environment [17]. Furthermore, an integrative and holistic process of construction that proposed to create harmony between the built and the natural environment calls for sustainable construction [18]. This increasing awareness of the environmental impacts of construction wastes has led to the development of waste management as an important function of construction project management [18]. However, beyond addressing C&D waste management other studies have delved into sustainable construction waste management practices identifying key indicators for effective practices [17, 19]. These indicators include waste segregation techniques, identification of causes of waste, reuse and recycling of waste and cost-benefit analysis which is applied to evaluate gains of reuse and recycling of waste [20]. Environmental sustainability is of great importance globally. The United Nations (UN) World Commission on Environment and Development, gave definitions and clarifications stating that environmental sustainability is about acting in a way that ensures future generations have the natural resources available to live an equal, if not better, way of life as current generations [14]. Environmental sustainability is responsible for the conservation of natural resources and protection of global ecosystems to support health and wellbeing, now and in the future [13]. It is now advisable that waste management should involve a procedure in which waste production is controlled and minimized by expert in order to achieve sustainable construction waste management practices.

2.5 C&D Waste Management and Legislation in Nigeria

In Nigeria, C&D waste management is still evolving, only a few multinational construction companies can treat or recycle their C&D waste, majority of the construction waste generated is still at the elementary level and is currently being undertaken on an informal basis [19].

The Environmental Management and Protection Law 2019 gave some legal backing to effective collection and disposal of C&D waste in Lagos as described in Section 79 of the law is titled: Domestic or Bulk waste. These provisions gave the guidelines required for effective management, however, the construction and demolition are leaving the traditional way of collection and disposal to a more effective innovative modern practices which makes waste management effective and seamless.

3 Study Area and Population

Lagos State was reported to have a landmass of 2797.72 km^2 and a water area of 779.56 km^2 and a population density of approximately 4193 persons per km^2 as well as a landmass of 1171.28 km^2 with an average population density of over 20,000 persons per km^2 [21]. Presently, the state is experiencing a daily influx of people as they attempt to take the advantage of multiple industries, massive commercial activities and technological advancements to seek employment in the highly competitive labour market of Nigeria (Fig. 2).

Fig. 2. Map of metropolitan Lagos State showing the 16 local Government areas. *Source* http://www.nigerianmuse.com/20100527092749zg/sections/pictures-maps-cartoons/maps-of-various-states-and-their-local-governments-in-nigeria.

3.1 Research Design

A quantitative sampling method was used in the collection of data from 180 building industry professionals (BIPs) respondents drawn from the active members of their professional bodies in Lagos who had worked in different capacities representing client's organizations, consulting firms and contracting firms. This sampled (BIPs) includes; Architects, Builders, Engineers and Quantity Surveyors representing different stakeholders in the industry. The BIPs under consideration are registered professionals whose practice is situated in Lagos and who have executed projects within Lagos. The data was analyzed and presented with descriptive statistics (Table 1).

4 Results

4.1 Socio-demographic Characteristics of Participants

The respondents consisted largely of males, comprising 67.8% of the total retrieved data sample and females comprising 32.2%. The building industry professionals (BIPs) comprising of Architects, Engineers, Quantity Surveyors and Builders have varying work

Table 1. Showing building industry professional respondents.

Professionals	Active in Lagos chapter	Sampled size
Architects	1200	60
Engineers	900	56
Quantity surveyors	750	45
Builders	500	19
Total	3350	180

experience which only 8.9% fall below 5 years, 6–10 years account for 20% while 36.1% are between 11–15 years, also 16–20 years has 23.9% of the entire sample population. However, respondents with work experience of 21–25 years and 26-above have 5.6% each (Table 2). Consequently, BIPs below 5 years of experience only account for 8.9% while 91.1% are BIPs with more than 5 years' experience this is further described in Table 3.

Table 2. Effectiveness of C&D wastes for re-use and recycling

Effectiveness of C&D for re-use and recycling	Frequency	Percentage (%)
Slightly effective	41	22.7
Not effective	55	30.4
Moderately effective	63	34.8
Very effective	11	6.1
Not reported	10	6.1
Total	180	100.0

Table 3. Years of experience

Year of experience	Frequency	Percentage (%)
Below 5	16	8.9
6–10	36	20.0
11–15	65	36.1
16–20	43	23.9
21–25	10	5.6
26-above	10	5.6
Total	180	100.0

4.2 Awareness and Involvement in C&D Waste Management

Of the respondents, 36.7% were partially involved in waste management while the remaining 63.3% are not involved, in other words, no one is taking full responsibility for C&D waste management as shown in Table 3. However, findings from Table 4 show that 66.1% claim that C&D waste management is effective while 20% are not of the effectiveness whereas 13.9% clearly stated its non-effectiveness. From Fig. 3, assessing the response to sorting of waste at the point of generation and collection 26% said no sorting is done at generation source while 37% were not sure in their response and another 37% responded that sorting is done at generation point and its well collected. Similarly, on the effectiveness of waste tracking shows that 24% of the valid respondent says it's slightly effective, 32.4% says it is not effective and 37.1% agrees that it's moderately effective while 6.5% says it's very effective as shown in Fig. 4 (Table 5).

Table 4. Showing BIP's involvement in waste management

BIPs involvement	Frequency	Percentage (%)
Partially involved	66	36.7
Not involved	114	63.3
Total	180	100.0

Table 5. Showing effectiveness of C&D waste management.

Effectiveness	Frequency	Percentage (%)
May be	20.0	8.9
No	13.9	20.0
Yes	66.1	36.1
Total	180	100.0

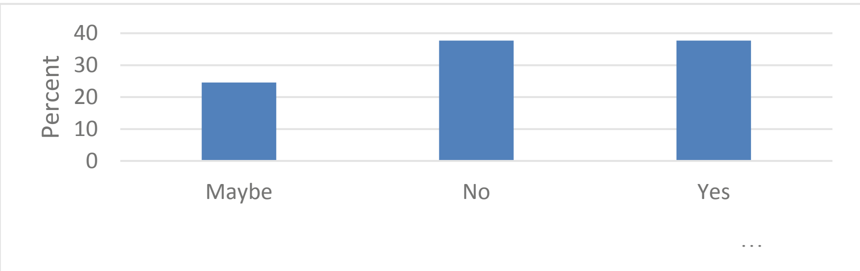

Fig. 3. Showing waste sorting done at generation time and collected

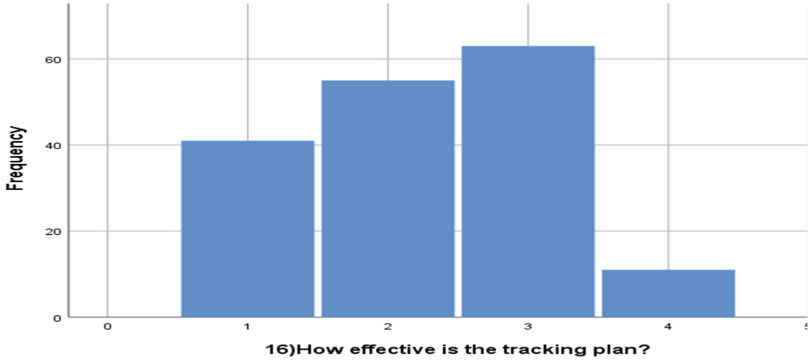

Fig. 4. Showing waste tracking effectiveness

Figure 5 presents the Building Industry awareness of on-site recycling processing equipment, the majority said No and Maybe representing 78% and 17% respectively only 5% gave a Yes answer.

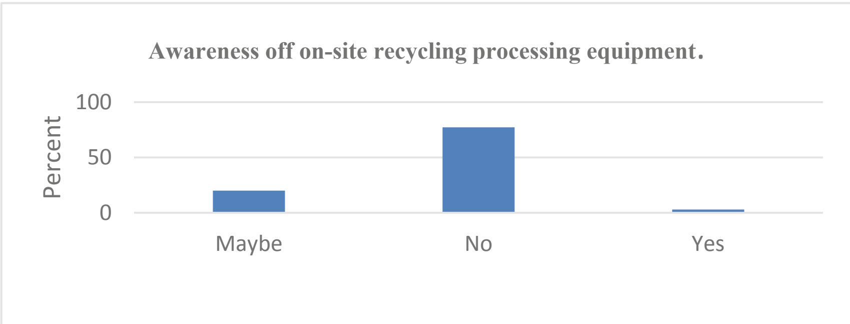

Fig. 5. Awareness of on-site recycling processing equipment

5 Discussion of Findings

This study investigated the construction and demolition waste management practices among building industry professionals to minimize the wastage of resources in Lagos, Nigeria. Results of the survey have generated some specific issues that are calling for attention in the construction industries in Nigeria. The first issue relates to the effectiveness of construction and demolition waste management practices in terms of re-use and re-cycle as a means of waste reduction among building professionals in Lagos, Nigeria. The results of the survey data revealed that the majority of the participants generally agreed that the re-use and re-cycle of construction and demolition waste have not been very effective in the control of waste management in Nigeria. Notably, this result can be explained based on the submission by previous authors [5, 8, 22] indicating that a massive loss of resources had occurred to resource management due to the inability to effectively manage construction and demolition wastes in Nigeria.

The second issue from the results deals with the level of involvement of building industry professionals (BIPs) in construction and demolition C&D waste management. The present study has shown that despite the present campaign for sustainable construction waste management, most of the participants involved in this study have not been involved in handling construction waste. Just a few numbers of the participants have been partially involved in construction waste management. This shows that in most of the projects they handled, they usually left the waste management to other people to handle for them.

The third issue is related to the frequency of waste evacuation from selected construction sites in Lagos Metropolis Nigeria. Our survey data revealed that evacuation of wastes is often done on most construction sites in Lagos state but the wastes are being evacuated to other dumpsites without quality tracking systems. The tracking systems should have assisted to monitor if the waste evacuated is disposed of properly or otherwise as supported by previous authors [6, 9, 11] on effective waste management systems to achieve a sustainable environment. This implies that the drive of C&D towards environmental sustainability is still far from the threshold required if BIPs who should be the custodian and regulators demonstrate non-involvement and ineffective tracking and disposal despite regulations that enable them.

6 Conclusion and Recommendations

This study investigated the construction and demolition waste management practices among building industry professionals to minimize the wastage of resources in Lagos, Nigeria. Three distinctive conclusions were derived from the findings. The first conclusion is that the re-use and re-cycle of construction and demolition waste have not been very effective in the control of waste management in Nigeria. The second one is that most of the participants involved in this study have not been involved in handling construction waste, instead, they prefer that another contractor handle this aspect of work for them. Lastly, despite the non-effective re-use and re-cycle of construction and demolition waste, evacuation of wastes is often done on most construction sites in Lagos state but the wastes are being evacuated to other dumpsites without quality tracking systems.

From these findings, Construction and Demolition waste management in Lagos is still not at a satisfactory standard, because C&D waste is mainly disposed of at landfills and burned at the site. Whilst reuse and recycling activities are less practised onsite. The population of BIPs studied cannot be taken as an adequate representative of the sample also the result may differ if ongoing projects were evaluated. Therefore, this study recommends more awareness campaign strategies that make building experts have more detailed ideas of how to handle construction wastes properly. The government should equally make available more facilities that can effectively be accessed for waste evacuation and management from most construction sites.

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An Appraisal of Construction Health and Safety Practices in Privately Owned Small and Medium-Sized Construction Firms in Nigeria

Nzoputa Blessed Madueme[1], Obianuju Akuabia Anwara[1,2](✉), and Uzor Onyia[1]

[1] Department of Civil Engineering, University of Nigeria, Nsukka, Nigeria
{nzoputa.madueme,obianuju.udodi,uzor.onyia}@unn.edu.ng
[2] Centre for Environmental Management and Control, University of Nigeria, Nsukka, Enugu, Nigeria

Abstract. The construction industry is recognized for both its crucial role in economic growth and its precarious characteristics. Construction site accidents have disastrous consequences for property and employees' lives, as well as disrupting project completion on schedule and budget. The purpose of this research was to conduct a quantitative study using a well-structured questionnaire to appraise the construction health and safety practices in privately owned small and medium-sized construction firms in Nigeria. A convenience sampling approach was used, and 100 questionnaires were obtained out of the 150 sent out. The data was analyzed by descriptive statistics with the aid of SPSS 25 to reveal that poor Health and Safety (H&S) practices are evident in privately owned small and medium scale Nigerian construction firms, such as: the lack of an adequate system to monitor substance abuse on-site, lack of adequate government policies on construction health and safety, lack of Communication of health and safety procedures to construction personnel on-site, nondenial of work to construction personnel under the influence of drugs or alcohol among other factors. The findings suggest that to considerably increase the safety performance objective on construction projects, the priority given to elements impacting safety performance must be re-aligned and re-balanced. These findings will be used as a reference for government agencies, construction regulatory bodies, and construction site supervisors in improving construction health and safety.

Keywords: Accidents · Appraisal · Construction · Health and safety · Hazards

1 Introduction

The importance of the construction sector in Nigeria and other areas of the globe cannot be understated, as it is one of the country's greatest and most dynamic economic generators, employing millions of people [1]. Small and medium-sized privately-held construction enterprises, in particular, are a source of economic growth due to their

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large-scale creation of jobs, wealth creation, and innovation through adopting competitive tactics that set them apart from other firms [2]. It has been noticed that the job opportunities they provide benefit a large section of a country's population. Regardless of its benefits, construction's intrinsic qualities also result in a significant probability of site accidents, dangers, and deaths [3]. As a result, the construction sector is noted for its economic importance as well as its risky nature. Because of the severity of construction accidents and hazards, relevant research is required to provide stakeholders with the information they need to better understand and decrease site accidents and risks by improving construction health and safety.

No construction project is risk-free, and managing the health and safety aspects of every construction project is vital to its success [4]. In the construction industry, a lot of studies have been done to determine what elements contribute to poor H&S management. Many developing countries, on the other hand, have noticed that there appears to be a disconnect between research and real health and safety regulations seen on construction sites. Many countries have legal responsibility for enforcing construction health and safety regulations, with specific government offices tasked with H&S inspection and monitoring. This has resulted in an increase in litigations in the construction industry when H&S rules are faulted, highlighting the significance of a concerted effort and dedication to improving the industry's H&S level. It has also led to the creation of cost-effective H&S processes that include subcontractor selection and management to reduce injuries and deaths on the building site [5].

However, there is a need to enhance H&S awareness in developing nations, because construction operations in developing countries like Nigeria are more labor-intensive than in many industrialized countries, and even more so in privately owned small and medium-sized construction firms. As a result, accidents are more likely to occur in these areas. Hence this study sets out to make an appraisal of construction health and safety practices in privately owned small and medium-sized construction firms in Nigeria.

2 Literature Review

2.1 Construction Health and Safety Management

Construction is unique in that it is both dangerous and difficult due to a variety of construction procedures that involve working in hazardous conditions and relying heavily on heavy machinery and equipment [6]. Construction workers are routinely engaged in accidents and are subjected to dangerous situations such as working at heights, getting entangled and stuck in machinery and equipment used in construction, and are regularly involved in accidents [7]. The notorious nature of the construction has wreaked havoc on productivity, which is often assessed in terms of cost, quality, and timeliness [8]. This problem involves not just monetary losses, but also the loss of valuable human lives, disease, brilliant workers, and hefty compensation payments [9].

In the previous decade, researchers were particularly concerned with safety management. Construction safety management is the process of overseeing safety requirements, practices, and procedures on a construction site [10]. According to [8,] proper safety planning is one of the most crucial elements that might impact the success of any construction project. According to [11], H&S planning is still carried out separately from project planning, and accident during construction may result from this lack of integration. Workers are more susceptible to unknown dangers, and if hazard identification is not carefully addressed as part of project preparation, they could sustain catastrophic harm [12]. As a result, integrated health and safety planning is now recognized as one of the factors that, if not properly implemented, may lead to death. Several academics have pointed out, however, that present safety procedures rely heavily on human safety judgements, knowledge, experience, and cognitive capacity to detect dangerous situations [13–15].

2.2 Causes of Accidents on Construction Sites

Accidents are described as uncontrolled events that result in personal harm or property damage [16]. Occupational accidents occur in the workplace, and the most typical result is an injury to the individuals involved. Accident avoidance necessitates a detailed grasp of accident causes. Gaining a better knowledge of the primary reasons responsible for of workplace accidents may also will promote the advancement of accident prevention strategies. According to the literature analysis, the causes of construction site accidents may be divided into seven categories: (i) Negative attitudes and behaviours; (ii) Insufficient ability and competency; (iii) Environment of work; (iv) Level of knowledge on construction health and safety; (v) Work System; (vi) Stakeholders interactions in assuring construction health and safety; and (vii) Sanctions, Incentives, and Reward [17].

Communication issues, individual habits, and talents are all influenced by worker and work team factors. There are issues at work, such as a lack of welfare facilities, limited working space, and ground features such as undulated and dangerous terrain, as well as the unstable ground. Dusty working conditions, low illumination and sunlight reflection on concrete, and bad weather are all aspects to consider [18]. Changes in the quality of construction materials, the way they're delivered, their availability and suitability, a lack of knowledge about how to use materials and equipment, and the use of contaminated materials can all result in accidents and risks caused by materials and equipment. The major causes of accidents and hazards are thought to be work design and project management approaches [19]. A recently constructed structure may fail and collapse due to defective designs and a lack of construction supervision, bringing about hazards and mishaps. Likewise, disputes over the project's authority between consultants and contractors can result in workers receiving contradictory instructions, which can lead to poor performance and on-site dangers and accidents. Furthermore, in unforeseen situations, working space is frequently restricted. Due to a lack of working space, the amount of space available for storage, paths, transportation lines, and workshop locations is restricted [20]. Employees' hazardous behaviors, workers' reactions to risky situations, and unsafe settings are the three key causes of construction accidents and hazards, as identified by [21]. They pointed out that a number of worker and pedestrian deaths and injuries are caused by dangerous situations including open-sided floors, inadequate ladders, sticking-out reinforcements, improperly built scaffolds, unprotected explosive items, and exposed trenches.. Furthermore, regardless of the working environment, a worker's unsafe deed causes accidents and risks. Workers who don't have the right attitude toward safety don't take responsibility for their personal personal safety while working. Workers who overlook established safety requirements, such as failing to wear personal protective equipment, risk endangering themselves and others on the job. According to [22], the most common causes of construction site accidents and risks are a lack of protective equipment and improper use of safety equipment. Unsuitable equipment and working platforms, a poor safety mentality, and poor housekeeping are all factors that lead to construction accidents and risks, according to [23]. Workers and even passers-by are exposed to accidents, dangers, and injuries as a result of insufficient equipment use and a lack of safety concerns. A lack of adequate supervision and monitoring, as well as a lack of appropriate processes and safety regulations, can result in on-the-job accidents and dangers.

2.3 Adoption of Health and Safety Practices in the Nigerian Context

To improve its health and safety performance, the construction sector has explored a variety of strategies. According to [24], the level of commitment to safety by senior and middle management of a typical Nigerian construction company is far below acceptable global standards. This commitment is determined by corporate safety leadership, risk management, safety training, operational control, and effective response as safety variables. According to [25], a shortage of personal safety equipment (PPE), failure to use PPE, the use of inferior instruments, and an inability to secure and warn against inherent risks are the main causes of accidents on Nigerian construction sites. Additionally, the majority of Nigerian construction companies lack the expertise to identify all potential risk factors and hazards before or during construction [24]. This indicates that there is no realistic way to anticipate accidents or lessen their effects. Similar reports claim that more than 70% of construction employees in Nigeria do not obtain on-the-job safety training [24]. It is clear from this that higher management and authorities lack accountability and concern [26]. This led to the discovery that senior and intermediate management in the majority of Nigerian construction enterprises seldom adhere to any health and safety plans during construction [27]. Given the preceding description of the poor level of H&S precautions utilized in Nigerian construction, a research was conducted to investigate the problems in more detail and determine what might be done to enhance procedures in the nation.

3 Study Methodology

A quantitative research approach was used to successfully satisfy the goal of this study, which was to examine the degree of construction health and safety practices in privately owned small and medium construction firms in Nigeria. Researchers employ this technique to offer answers to preset research objectives and questions by analyzing the relationship between various variables using a tool for collecting data that is either experimental or not (survey), yielding numerical results that can be analyzed using statistics" [28]. The study focused on privately owned small and medium-sized construction firms in Enugu State, Nigeria because of the researcher's location and accessibility. Hence, a well-structured questionnaire was delivered to the respondents by hand through the convenience sampling approach. Construction practitioners who either owned, worked in, or with privately owned small and medium-sized construction firms were approached as respondents. Primary data was collected using a standardized questionnaire with a 5-point agreement Likert scale (strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, and strongly disagree = 5) that was delivered to the respondents. Because the data was mostly ordinal, it was treated and scaled to produce the variables strongly disagree = 0, highly disagree = 0.25, neutral = 0.5, agree = 0.75, and strongly agree = 1. It should be highlighted that the survey participants received a total of 150 questionnaires, whereas 100 questionnaires were returned.

Cronbach's alpha was utilized to determine the data's reliability and validity, and the result was 0.89. The statistical technique is reliable and has excellent internal consistency, according to [29], with a Cronbach's alpha value ranging from 0.70 to 0.95. Mean Item Score (MIS) was used to assess the data, which is the most used approach for ranking variables based on respondents' agreement with individual components. The variables are given in decreasing order, with the greatest mean value first, then the next highest value, and so on. The Statistical Program for the social sciences (SPSS) 25.0 statistical software was deployed for the data analysis.

4 Data Analysis, Findings, and Discussions

4.1 Profile of the Background of Respondents

Out of the 150 questionnaires distributed and administered to respondents by hand, 100 were returned yielding a response rate of 67%. From the analyzed data, 24% of the respondents were engineers, 24% were surveyors, 18% were architects, 14% were consultants, 8% were government agency, 6% of respondents were town planners, and 6% were project managers. Respondents whose highest educational qualification was a Bachelor's degree made up 64%, whereas 20% had a Master's degree, and 4% had a doctoral degree. 10% had a higher national diploma (HND), while only 2% of respondents had an ordinary national diploma (OND). It was also discovered that only 2% of the total respondents had less than a year of work experience, while 12% had one to five years. It also indicated that 36% of respondents had 6–10 years of industry experience, 30% had 11–15 years of experience, 10% had 16–20 years of experience, 4% had 21–25 years of experience, and 6% had more than 25 years of industry experience.

4.2 Main Analysis and Findings

Construction H&S Practices in Nigeria

Table 1 summarizes the averaged mean scores as well as the degree of agreement between the responses. All of the variables' scaled mean indices had a minimum score of 0.105 and a maximum score of 0.29. According to [30], a measure of inter-rater agreement is interpreted as follows: Poor Agreement is represented by 0, "Slight Agreement" ranges from 0.1–0.20. "Fair Agreement" is between 0.21 and 0.40. "Moderate Agreement" ranges from 0.41 to 0.60, "Substantial Agreement" ranges from 0.61 to 0.80, and "Almost Perfect Agreement" ranges from 0.81 to 1.00. This means that a minimum score of 0.105

indicates a very low level of agreement, whilst a maximum score of 0.29 indicates a very modest level of agreement. As a consequence, the overall findings show a low level of agreement among the respondents in terms of the interpretation of the evaluation of the factors. This indicates that the respondents' practical judgment based on their experience indicates that the aggregated mean ratings of construction health and safety procedures in the Nigerian construction sector are in a terrible state.

The standard mean error of any statistical measure, according to [31], indicates a sample's likelihood of being representative of the population, boosting the generalizability of statistical conclusions. In this scenario, a large standard mean error indicates that the sample and population means are significantly different, but a small number suggests that the sample well reflects the population [31, 32]. Table 1 demonstrates that all of the mean scores' standard mean errors were extremely near to zero. This suggests that the sample used is typical of the entire population, and so the findings and conclusions are a realistic reflection of reality, providing credibility to the study's findings, interpretations, and generalizations. Table 1 summarizes the findings and reveals that the majority of health and safety measures are disregarded in privately owned small and medium scale construction firms in Nigeria.

Based on the findings, it can be deduced that while all the assessed variables of construction health and safety as practiced by privately owned small and medium-sized construction firms were found wanting, the most significant variables are "adequate systems to monitor substance abuse on-site" and "proper maintenance of mechanical equipment" as they had a mean of 2.16 (SM = 0.29, R = 1) and 1.96 (SM = 0.24, R = 2) respectively. Also, the major variables which require critical attention include "Denial of work to construction personnel under the influence of drugs or alcohol", and "inclusion of health and safety policy during tendering", as they have the lowest means of 1.46 (SM = 0.115, R = 11) and 1.42 (SM = 0.105, R = 12) respectively. The various accessed variables are presented in Table 1. The variables selected have a combined mean value of 1.74 (SM = 0.185). Considering that this value is well below average and falls in the region of slight agreement, it can be deduced that construction health and safety practices are at their infant stages in privately owned small and medium-sized construction firms in the Nigerian construction industry.

This is consistent with research from other developing nations, such as Pakistan [33], where it was determined that Pakistan's building sector had weak health and safety standards, resulting in human and financial losses that harmed the country's economy. This was mostly due to people's reluctance to record and report incidents on the job, as well as several fundamental cultural behavioral factors impacting health and safety. According to [34], employees in the Indian construction sector are exposed to 16.4% of worldwide occupational risks. This was mostly ascribed to a lack of sufficient communication, the failure to wear personal protective equipment, incorrect work, and job activity postures, a lack of training, a lack of safety orientation and culture, and challenges relating to compliance with applicable legislation. In Norway, [35] cites a lack of competency, a lack of prioritizing, and a lack of consequence as the key factors contributing to the country's poor construction health and safety. Osei-Asibey et al. [17] in Ghana highlights the Ghanaian construction industry's poor health and safety practices, proposing as possible solutions improvements in attitude and behavior, working environment, management's

Table 1. Health and safety practices.

Heading level	Mean	Std. deviation	Scaled mean (SM)	Standard mean error (SME)	Rank
Adequate system to monitor substance abuse on site (FC16)	2.16	1.293	0.29	0.129	1
Proper maintenance of mechanical equipment (FC10)	1.96	1.082	0.24	0.108	2
Provision for the identification and handling of injuries and accidents on site (FC3)	1.88	0.686	0.22	0.069	3
Presence of health and safety committee on construction projects (FC2)	1.88	0.591	0.22	0.059	3
Contractor is involved in health and safety of construction personnel (FC14)	1.86	0.603	0.215	0.060	4
Communication of health and safety procedures to construction personnel on site (FC4)	1.84	0.545	0.21	0.055	5
Client is involved in health and safety of construction personnel (FC12)	1.82	0.520	0.205	0.052	6
Proper maintenance of electrical equipment (FC11)	1.82	0.821	0.205	0.082	6
Consultant is involved in health and safety of construction personnel (FC13)	1.76	0.955	0.19	0.095	7

(*continued*)

Table 1. (*continued*)

Heading level	Mean	Std. deviation	Scaled mean (SM)	Standard mean error (SME)	Rank
Provision of supports during excavation works (FC8)	1.76	0.767	0.19	0.077	7
Availability of Personal Protective Equipment (PPE) on site (FC6)	1.74	0.895	0.185	0.089	8
Provision of safety nets when working at heights (FC9)	1.58	0.727	0.145	0.073	9
Adequate regulatory agencies to monitor health and safety on project sites (FC7)	1.58	0.855	0.145	0.085	9
Construction personnel receive compulsory health and safety training (FC1)	1.58	0.638	0.145	0.064	9
Adequate government policies on construction health and safety (FC5)	1.50	0.644	0.125	0.064	10
Denial of work to construction personnel under the influence of drugs or alcohol (FC17)	1.46	0.989	0.115	0.099	11
Inclusion of Health and Safety policy during tendering (FC15)	1.42	0.855	0.105	0.085	12

dedication to construction health and safety, understanding of construction health and safety, and the right tools and equipment [36] emphasizes the recurrence of poor health and safety practices in the construction industry in Malawi, which is mostly due to health and safety is viewed primarily as the responsibility of site managers. In South Africa [37] indicated that although health and safety on South African construction sites are regarded as a high priority, there is still a need to build a good health and safety culture at all levels of the business, as well as changes in the Department of Labour's inspection and enforcement of health and safety rules. This is consistent with [38], which claims that while there is a high degree of awareness of numerous safety requirements in South Africa, there is still an issue with implementation and enforcement.

5 Conclusion

Through a survey of experts currently working in the construction sector in Nigeria, this study assessed construction health and safety procedures in the Nigerian construction industry. The study suggests that the construction health and safety procedures available in privately-held enterprises operating on small and medium-sized construction projects in Nigeria are at an unacceptable level, with a high level of contempt for numerous health and safety standards, based on the findings. The implication is that, while the health and safety of construction personnel working on large government projects have improved over time, most day-to-day construction personnel working in cities, towns, and villages across the country are exposed to occupational hazards and dangers caused by contractor negligence. It also means that the duty for health and safety in these privately owned enterprises relies primarily on the construction people in the field, with little provision or preparation by the firm. This is consistent with prior research since it has been established in several journal studies that the accident rate in SMEs is greater than in LEs [39].

The study's findings disclose new information that broadens our understanding of the situation of construction health and safety in privately-held enterprises in Nigeria that operate on small and medium-sized building projects. The findings are critical for policymakers in the building industry, such as the Nigerian Council for Regulation of Engineering Practice and the government.

However, because of several limitations, caution should be exercised when extrapolating the conclusions of the study. The first is the possibility of selection bias in the study's sample. More research can be done with a wider population of construction professionals with a diverse perspective on construction health and safety, rather than just those in private practice, as in this study. Furthermore, because it was done in Enugu State in Nigeria, the current study's geographical reach was limited. To obtain a bigger sample size, more studies might be done in various states around the country.

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User Experience of Health and Safety Provisions for Women in Construction

Aghaegbuna Ozumba(✉), Kathryn Wray, Destiny Johnson, and Riyaadh Moolla

School of Construction Economics and Management, University of the Witwatersrand, Johannesburg, South Africa
Obinna.ozumba@wits.ac.za, {600034,670225, 536622}@students.wts.ac.za

Abstract. The aim of this study is to examine the issues around the provision of gender-sensitive health and safety (H&S) measures, for female operatives on construction sites, from a user experience perspective, using the local context of South Africa. The study was executed through review of purposively selected extant literature, complimented with field work through a mix of case study and survey strategies. The key findings suggest that there is a considerable level of gender sensitivity to site H&S provision but an appreciable variability in user experience, which indicate significant need for substantial improvements in the provision of gender-sensitive personal protective equipment, and sanitary facilities for female workers. An emergent pattern that needs further examination is that there is more user satisfaction with H&S provision for female site workers on public project sites, compared to commercial development sites. Results highlight the dynamics and variability of user needs which should inform design, and the need for more user focus and gender sensitivity.

Keywords: Construction · Gender · Health and safety · Operatives · Women

1 Introduction

The research interest here centres around the gender sensitive provision of health and safety (H&S) measures for women or female operatives working in construction sites, in the face of global gender mainstreaming efforts in all sectors of human life. Though gender mainstreaming has been theorised and practiced globally to a substantial extent, there are variations and sometimes, major gaps in historically male-dominated sectors such as construction, and in emerging economy contexts such as South Africa [1–3]. The dynamics and many issues regarding women and work and the specific area of occupational health and safety are well documented in literature such as: [4] on gender ideologies, hegemonic masculinity [5]; male chauvinism, female self-discrimination, and gender neutralisation [6]; perceived general negative psychological ambience in construction [7]; human factor issues [8]; and lack of gender sensitivity in provision of PPE for construction site work [2, 9]. The challenge of providing for their need of women in construction has been associated with the increase in their representation in

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the industry [2, 10]. This could be probably due to a lack of empathy, poor understanding of the requirements for female site workers, lack of preparation, etc.

Due to the anatomical and physiological makeup of women, it is arguable that they have unique H&S needs in comparison to their male counterparts. While construction workers on a site may generally face H&S issues, female operatives arguably face other different health and safety hazzards. Apart from musculoskeletal diseases, they suffer from reproductive problems, higher risk of infections, and gynaecological diseases. It is therefore necessary to highlight such issues and advocate for the H&S needs of women at work [2]. Therefore, the provision of personal protective equipment (PPE) and sanitary facilities, among others, need to be addressed with gender sensitivity.

PPE consists of all that is designed to be worn on the body, for protection from H&S hazards in construction environments. These include hardhats, overalls, safety goggles and fall harnesses [11]. Inefficiencies in this area have improved but there is still a gap in PPE and sanitary provisions, specifically designed for women. The anatomical differences between males and females are not well provided for [11], and ill-fitting PPE expose women to many hazardous risks [12]. Being historically male-dominated, PPEs for construction work were designed for men [2], though recent studies have substantiated serious impacts resulting from the anatomical differences between males and females [2, 11]. In addition, the anthropometrics used in the design of PPE is based mainly on male populations from some parts of Europe and North America, such as Germany, France, and the USA [2]. As such Women still struggle with H&S provisions due to lack of fit [11, 13]. The lack of proper fit for females in construction is also evident in the design of tools, which disregards the ergonomics for females [2, 10].

There is a similar situation in the provision of sanitary facilities, which is generally not sensitive to the needs of women on site. There is poor provision, distant and obscure locating of such facilities, and abuse of such facilities, which pose more risks to female operatives. The result is avoidance of toilets and drinking water outlets in many cases, which results in dehydration, heat stress and other health problems such as bladder and kidney infections, and vulnerability to heat strokes and heat exhaustion. There is also the lack of concentration which affects safety consciousness at work, thereby increasing the risk of injuries and accidents [2]. Inadequate sanitary facilities increase the risk of contracting gynaecological diseases and transmission of infections from unwashed hands [8]. Furthermore, there is the issue of providing for the management of menstrual cycles in women at work. Though a normal occurrence in a healthy woman, poor provision for managing monthly cycles is known to constitute a major threat to the performance of women at work [13]. The need to provide for such issues arising from more inclusion of women in the workplace has been highlighted in earlier writings such as [14]. There are physiological and psychological issues related to the female monthly cycle, which could be complicated further due to insensitivity to such needs [13–16]. It will require the supply of water, clean and safe sanitary facilities with adequate privacy and access control, affordable menstrual hygiene materials and disposal units, education, etc. [13].

In South Africa, the current legislation and construction charter acknowledge that working conditions on construction sites are extremely poor. Ill-fitting PPE, inadequate sanitary facilities and reproductive hazards all contribute to a negative picture for female entrants and the currently employed [17, 18]. However, there is scarcity of information on the specificity of gender-sensitive site H&S provision, from the experience of users. Very little data has been captured from the South African context, which could inform on the specific experience of the South African female operative on a construction site. As such a deeper and more contextual approach is necessary.

Literature established the perceived risk to women's health, vulnerability to sexual harassment, and an expectation to work within the patriarchal model. This notion of the patriarchal model as well as hegemonic masculinity has further been established by literature to be a cause of more dangerous practices and mentalities on site, all of which fueled by the lack of sensitivity to specific needs of women on site. A combination of such issues and more, create barriers and vulnerabilities that affect the business case for women in construction, and particularly the experience of the female operative in construction. While these issues still plague the construction industry at various levels in different regions, there is a dearth of data on the user experience of the issues of PPE and sanitary provisions for female operatives, and women's health on site, from the local context of South Africa. As such more empirical data was needed to draw a baseline of contextual understanding of the experience of female operatives in relation to H&S provisions.

Based on the findings at this stage, the identified key problem was poor gender sensitivity in H&S provisions for female operatives on South African construction sites, which could result in greater vulnerability to incidents, leading to accidents, and long-term health implications. The ultimate outcome would be the perception of construction as an undesirable work environment for women. As such the aim of the field study was to investigate the identified problem through lens of the user, in this case, the female operative. The lines of inquiry were as follows: To determine the general adequacy of H&S provisions for female workers on site, and the H&S implications of the current state of provisions, all from user perspective. Therefore, the pertinent question was, "What is the experience of the female construction operatives regarding the provision of H&S and sanitary facilities on site?

2 Materials and Methods

Findings of the literature review generated many themes about H&S provision on construction sites. However, the current paper is limited to a primary focus on the following themes: General perception of H&S provision for women on site, provision of appropriate PPE for female site operatives, provision of sanitary facilities for female site operatives, including menstrual cycle issues. Although there is an appreciable body of knowledge on women in construction, ample room was allowed for the specific area of study and the context, especially the emphasis on user perspective. Therefore, the strengths of case study and survey were exploited in the design of materials and methods for the study [19, 20]. In terms of the time horizon, cross-sectional study was adopted due to institutional constraints of time on the project. While there was little room for a longitudinal study of cases, the mix of case study and survey strategies was applied to derive substantial data within a shorter timeframe. Based on what is generally known about women in construction, an explanatory study was undertaken where it was deemed necessary to gather data, through semi-structured questionnaires. In so doing, the fundamental qualitative nature of the data could be exploited, while numerical strengths of responses could also be used to further cross validate results. In summary, a largely interpretivist view was used on an existing knowledge base, through a mixed method approach [21].

To keep within manageable limits, the study was geographically scoped within the greater Johannesburg boundaries of the Gauteng region of South Africa. The study population was primarily female site operatives, who firstly identified themselves as being females between the ages of 19–65 years and having some experience of working on construction sites. The study was able to secure six case study sites, from which 32 female operatives participated. The second sub-group in the population was the managerial personnel of each construction site, who had at least three years of site experience. They are, however not covered in the current paper. The sampling approach adopted was non-probabilistic, through the snowballing technique, which serves well when the target population cannot be determined [19]. Construction companies within Johannesburg, with live projects, who employed female site operatives were identified. Referrals were used to identify subsequent companies. See Fig. 1.

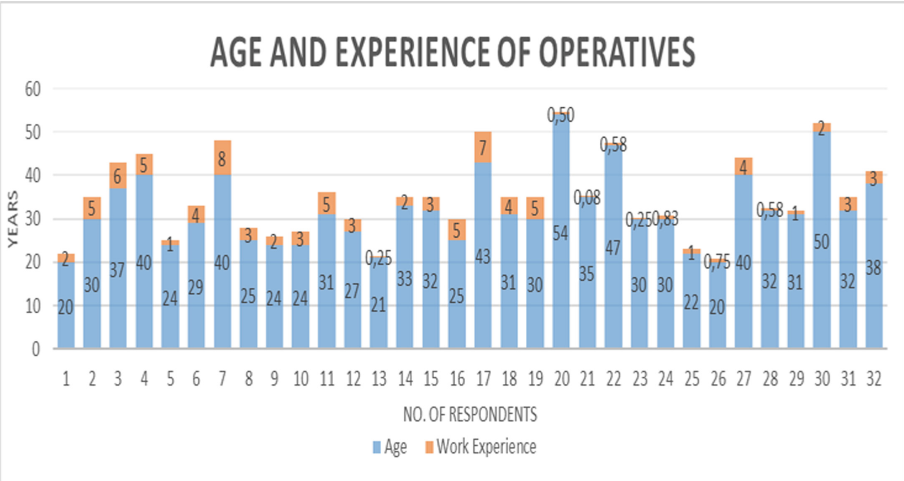

Fig. 1. Demographic data on age and site experience of survey respondents.

To obtain data in a professional and ethical manner yielding as many valid and reliable responses as possible, a defined procedure was followed, where permission to access the various construction sites and conduct the study with employees was acquired by email after forwarding introductory letters. Researchers were required to be on site before the commencement of the day's work, preferably during the registration and preparation period of the morning prior to the commencement of works, to hand out questionnaires to the maximum number of female operatives available. Furthermore, researchers had to undergo safety inductions before entering each site, for each day of the visit, and ensuring they were properly kitted with PPE. Questionnaires were distributed and respondents completed and returned them anonymously to one physical repository on site, while preliminary analysis of survey responses was performed on the same day.

In the design of data collection tools, the survey was focused on female operatives. Data collection was carried out through a self-administered semi-structured survey questionnaire aimed at female site operatives [19, 20]. For validity and reliability in the study [19], Effort was made to attain the maximum number of participants possible. Details of the study were explained to potential respondents in a very comprehensive manner, to ensure proper understanding. Furthermore, the questionnaire was translated into a local language, IsiZulu, which was understood by the operatives, in cases where respondents did not understand English well enough to give proper responses. In addition, all relevant institutional ethical protocols were observed. Results are presented according to the themes.

In terms of analysis, respondent data from the raw questionnaire was transferred to MS Excel and organised in spreadsheet format, to correspond with the derived lines of inquiry, which now form the research objectives. A primary numerical approach was taken initially to arrive at general deductions on the objectives. Then content analysis of respondent data was used to understand the meanings of responses further in order to enrich the findings and discussion following.

3 Results

3.1 Profile of Respondents

The participants were made up of female operatives and site management representatives. The site managers were all of three years site experience and played a representative role in their responses. A total of 32 female operatives participated in the study with the youngest participant being 20 years old and the oldest participant being 54 years. Their site experience ranged between 1 month and 8 years of experience. Thus, the average age was 32 years, and the average years of experience was 3 years. These provided adequate coverage for the cross-sectional study. Furthermore, six case study sites were split between public infrastructure projects, and commercial projects.

3.2 General Perception of H&S Provision for Women on Site

A substantial portion of participants (65.63%) felt that women health and safety needs were treated with priority on construction sites. This is despite their position that more sanitary facilities need to be provided, in addition to more female hygiene products and disposal units. Furthermore, perceptions seemed to vary between female operatives on infrastructure project sites and those on commercial retail development sites. Majority of women on civil construction sites were positive in their overall perception of H&S provision for women on site. This contrasted with the more negative perceptions of most female operatives on commercial project sites.

3.3 Provision of Appropriate PPE for Female Site Operatives

For this theme we looked at the appropriateness in terms of good fit, for the PPE issued to female workers, and the occurrence of any incident leading to an accident and injury, from poorly fitted PPE and safety equipment on site. About 53.13% (17 out of 32) participants from the five sites, indicated that they had proper fitting PPE and Safety Equipment. This leaves out almost half of the sample (46.87%) who did not feel comfortable with their PPE issue. About 68.75% (22 out of 32) had not experienced any injury due to ill-fitting PPE or inappropriate Safety Equipment, nor seen or heard of such. While that is somewhat positive, about 31% had experienced or heard of injuries accruing from wrong and poor fitting PPE.

3.4 Provision of Sanitary Facilities for Female Site Operatives

The With regard the need for separate sanitary facilities for males and females respectively, all respondents agreed to the necessity. Two key reasons were highlighted, specifically the need for privacy and female unique health needs and hygiene requirements. Other questions under this theme focused on adequate provision of female sanitary facilities on site, cleanliness of site sanitary facilities, quality of the sanitary facility in terms of disposal equipment for women and proper access and privacy control for female users. More than half of respondents (56.25%) experienced unclean sanitary facilities, while (78.13%) participants indicated that they had not avoided using sanitary facilities on site due to unhygienic conditions. The result could indicate some degree of cleanliness of site sanitary facilities. It also highlights the possible degree of exposure female operatives could be facing to unhealthy conditions, which could have long term health impact. This is arguable, considering above 50% of them had experienced unhygienic conditions in site sanitary facilities.

3.5 Menstrual Cycle Issues

While majority of respondents (84.38%) did not avoid work due to menstruation, many felt that there was inadequate of hygiene products and disposal units to use during their monthly cycles, and in case of any such emergencies. About half of respondents (50%) indicated that sanitary facilities were under equipped with hygiene product and disposal units/equipment.

4 Discussion

In general, there is the notion that the construction industry has lagged in H&S provision globally. It is also arguable that the industry has performed poorly with regards to health and safety, and in the provisions for female workers on site. In the local context of South Africa, regulations have emerged and are extensively reviewed [22]. Despite the introduction of many regulations and legislative frameworks in South Africa. the industry H&S performance also lags here. One major causative factor is sheer non-compliance [22]. Literature alludes to the fact that most, if not all, PPE utilised within the South African construction industry are specifically designed for men. They are designed to accommodate the anatomical and physiological makeup of males [2, 10]. Literature establishes that such designs cause limitations to mobility, productivity, and safety of workers [11]. However, findings from the study do not follow extant literature fully due to the variations in the results. Appreciable proportions of respondents had positive and negative experiences respectively, with H&S provisions. Some of the experiences also seem to be influenced by the nature of the project and site. While it is not significant at this stage, and not explored further in the current study, the female workers from public projects seemed to have a higher level of satisfaction with H&S provisions, compared to the commercial project workers. However, this is speculative at this point and suggested as a focus for future studies.

Furthermore, where majority of correspondents reported positive experiences, it was accompanied by other complaints. For example, findings show that majority of sanitary facilities on the case study sites were demarcated according to gender. However, (31.25%) of respondents indicated that many female operatives complain about their male colleagues deliberately using the female toilets, against site rules. Such complaints accompanying otherwise positive results point to the influence of social factors on the overall outcomes, regardless of the level of provision. Extant literature placed emphasis on improving provisions for hand wash facilities, disposal units, and demarcation of sanitary facilities according to gender [2, 8]. In this regard, there is a significant relationship between existing literature and findings from the current study. Literature also shows women having difficulties with sourcing adequately fitting PPE and experiencing various health hazards because of ill-fitting PPE [2, 11]. In slight contrast, the current study shows majority of respondents as being provided with adequately fitting PPE that did not make them vulnerable to harm. However, this majority, just as in most results from the current study, are accompanied by a substantial proportion indicating a negative experience. Since H&S is the parent subject of the study, any appreciable proportion of respondents from a study of six sites, indicating negative experiences, was viewed as significant.

5 Conclusion

The current study is informational on the level of gender-sensitive site H&S practice in a local industry case such as South Africa. It takes a user experience research approach to build an initial understanding of the provision of personal protective equipment and sanitary facilities for female workers on site in South Africa. Overall findings suggest that women's health and safety is provided to an appreciable extent, and possibly more on public civil construction sites than on commercial construction sites. While the provision of H&S for female site operatives has improved, the experiences of the women have not all been positive. They struggled with the inadequacy of PPE and sanitary facilities and equipment. It was also indicated that social and cultural issues cannot be divorced from the H&S experience of female site operatives. Similarly, there are social and health impacts of poor provisions for women at work. In general, the provision of gender-sensitive H&S for female operatives on construction sites, has increased appreciably. However, the increase is not necessarily uniform across all project types and sites.

The current study is an attempt to present a baseline of understanding, and the initial contextual picture of the user experience of H&S provision for female operatives in construction. Conjectures drawn here are informed by the experiences and perceptions of female construction site operatives, who are classified as the user population in this study.

The synthesis of results with extant literature, highlights the probable need for gender-sensitive policy or regulations, to drive more improvements to the status quo. Considering variations in the results, emergent patterns of responses, and some commonalities in responses, there is a need to drive more empathy and user-centeredness in designing site provisions for women in construction projects.

Currently, the main conjecture from the study is that H&S provision for women on site, is driven by nature of the project and attitude of management. With the entrance of more women into the construction industry, there is a need to shift towards a user-centred approach, where all user types and their peculiarities are better considered and accommodated in site H&S provision. Social factors, though subtle in some cases, are known to have high impact, as in the case of male violation of ablution spaces on sites. It points to deeper social and cultural issues, which still present a threat to health and safety of female operatives on site. Such issues would require more education and the change of attitude, in addition to stronger regulations, policies and their enforcement. In conclusion, considering the limitations of the current study in the number of relevant themes, sample size, geographical scope, research approach, future studies are suggested as follows: A wider sample at a national level, future including other aspects of H&S provision for female construction workers, bringing in the male perspective and user experience, and applying other research strategies. It would be informational to benchmark the South African experience against other countries of Africa and the world.

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Climate Change—An Exacerbator of Human Health Problems in Coastal Areas

Thobile Zikhathile[1](✉), Douglas Aghimien[2], and Harrison Atagan[3]

[1] Faculty of Natural Sciences, Mangosuthu University of Technology, Jacobs 4026, P.O. Box 12363, Umlazi, KwaZulu Natal, Republic of South Africa
Thobile@mut.ac.za

[2] Department of Civil Engineering Technology, Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa
daghimien@uj.ac.za

[3] Institute for Nanotechnology and Water Sustainability College of Science, Engineering and Technology, University of South Africa, Pretoria, South Africa
atagahi@unisa.ac.za

Abstract. Climate change (CC) has continued to have a devastating effect on the earth's sustainability. The impact on the environment, economy and society has continued to gain significant attention among countries worldwide. Coastal areas are not exempted from the adverse effect of CC. This study, therefore, assessed the impact of CC on human health in coastal cities. This was done to showcase the determinantal effect of man's activities in the ecosystem and how these activities are now impacting negatively on the health of individuals living in coastal cities. The study adopted an interpretivist approach, using the review of extant literature to unearth the key health issues associated with CC, particularly in coastal areas. The study found through a scientometric that CC has an impact on (1) water resources and management, (2) vulnerability and health risk of humans due to rising sea levels, (3) environmental pollution impacting on human health, (4) urban growth, and (5) public health. With specific attention to people's health in coastal areas, CC can be detrimental to human health in terms of the emergence of water and vector-borne diseases, respiratory diseases and allergies, mental health, loss of life and injury, and other health issues.

Keywords: Climate change · Coastal cities · Human health · Health impact

1 Introduction

The issue of climate change (CC) has continued to be of immense concern to countries around the world [1]. In recent years, the impact has grown exponentially in cities worldwide, and those within the coastal regions are no exceptions. The continuous increase in urbanisation of cities has brought about a significant increase in greenhouse gas emissions because these cities generate a significant amount of CO_2 [2]. Worse is the case of coastal cities, which faces a greater increase in population, urbanisation, and industrialisation. This is due to land-ocean interaction, which results in massive urban

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developments and investments that provide better access to food, transportation, ports, and work and leisure opportunities. They are also the sites of various economic activities and the majority of industries [3].

CC has environmental, economic, and health impacts [4]; hence it is termed a global challenge [1]. However, while the economic and environmental impacts have garnered significant attention, the health dimension has received less attention in most practice and academic discourse [5]. Based on this observation, Thomas et al. [6] noted that it is essential to develop effective health strategies for adapting to or mitigating CC issues. The impact of CC on health requires immediate attention because it is predicted to cause a "global health catastrophe" in the near future [7]. More so, the vulnerability of coastal cities due to their highly dynamic, geomorphologically complex, and extreme weather events make it important to pay special attention to the impact of CC on human health in coastal cities [8, 9]. Studies have continued to note some societal and health issues associated with CC. For instance, Paavola et al. [10] stated that CC could expose people's vulnerability, pre-existing medical conditions, sensitivity, and adaptive capacity. More so, the majority of the population in cities, particularly in developing countries, are vulnerable due to poverty [11, 12]. People in these areas lack adequate housing, basic services, and affordable healthcare systems [9]. This situation has led to several health challenges within such areas [13, 14].

Based on the knowledge that less attention is given to the impact of CC on human health, particularly with respect to coastal cities, this study was designed to fill in this gap in the literature. The aim of the study is to explore the human health impact of CC, particularly in coastal cities around the world. This was done to further showcase the determinantal effect of man's activities in the ecosystem and how these activities are now impacting negatively on the health of individuals.

2 Methodology

This study follows an interpretivist stance using an inductive approach with a review of extant literature review. The scientometric review—a branch of the bibliometric review which uses a text-mining of scholarly publications to draw logical conclusions on the trend in a research area, was adopted [15]. This approach has been widely accepted in recent social science studies [16] because it gives a visual perspective of diverse aspects of existing scientific studies [17]. The scientometric approach makes it easy to identify leading authors, countries, funding organisations, journals, and collaborations within a field of interest [18]. The scientometric review follows a search protocol using relevant databases. Studies have shown that several databases tend to overlap in terms of articles indexed in them [17, 19]. For this study, the Scopus database, which has been noted as a more recent and fast-growing database, was adopted [20, 21]. The keyword searched plays a pivotal role in the number of extractions and the quality of findings in a scientometric review. As a result, care must be given to the selection of the keywords to be searched [16]. Since the study is designed to unearth the impact of climate change on human health in coastal cities, the article search was done using TITLE-ABS-KEY "Climate Change" OR "Global warming" OR "Climate crisis" OR "Extreme weather" AND "Coastal area" OR "Coastal region" AND "Human health"

OR "ill health" OR "public health" OR illness OR disease. The search timeline was set for ten years (from 2012 to 2022) to maintain recency. The initial search gave 180 documents, and the search criteria were further refined. In refining, the language of publication was set at English only. The document type was also restricted to journals, book chapters and conference proceedings, as recommended in past studies [22, 23]. The subject area was refined using environmental sciences, social sciences, engineering, agricultural and biological sciences, and earth and planetary sciences. Based on these set criteria, the number of extracted documents was reduced to 75 documents and were exported for further analysis. The extracted documents were analysed for their year, publication type, countries, sources, authors, citations. Furthermore, VOSviewer was used to develop a co-occurrence map showing the network of major keywords and a visualisation of the trends of keywords. The choice of using VOSviewer against other visualisation tools was premised on its ease of usage, availability and better pictorial view of knowledge areas [16].

3 Result and Discussions

3.1 Publication per Year

The 75 extracted documents were analysed for their year of publication. The result in Fig. 1 revealed that the year 2021 and 2019 had the highest number of publications (frequency (f) = 16 and 14). Scant publications were extracted from 2012 to 2018, while the year 2022 revealed just two publications. It is pertinent to note that the search for this study was done in March 2022. Therefore, there is the possibility of more studies emanating within the year. These publications were extracted from journals (f = 53), book chapters (f = 16) and conference proceedings (f = 6).

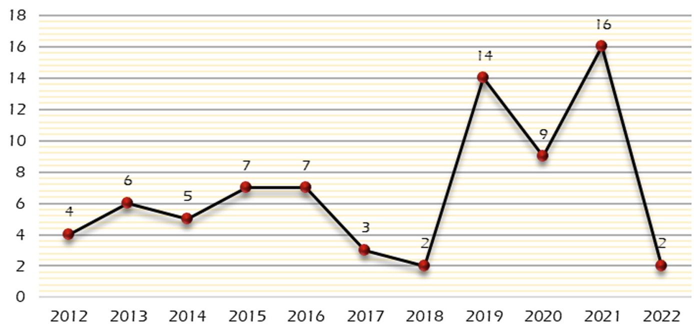

Fig. 1. Publication per year

3.2 Publication per Country

The extracted publications emanated from 39 countries. Figure 2 shows the map of countries with at least two documents published. From the figure, it is evident that the majority of the publications emanated from Europe, American and Asia. The United States of America (USA) is at the forefront of CC issues as it relates to human health. The country has the highest number of publications (f = 22) as well as citations (f = 690). Next is Bangladesh (f = 14), China (f = 8), United Kingdom (f = 8) and India (f = 5). Based on the refined data adopted, it is evident that there is a paucity of studies emanating from Africa, as only one country (Tanzania) was within the 'two documents' threshold. With several coastal cities on the continent, researchers can take the opportunity to explore the impact of climate change on the health of people living within the cities on the continent.

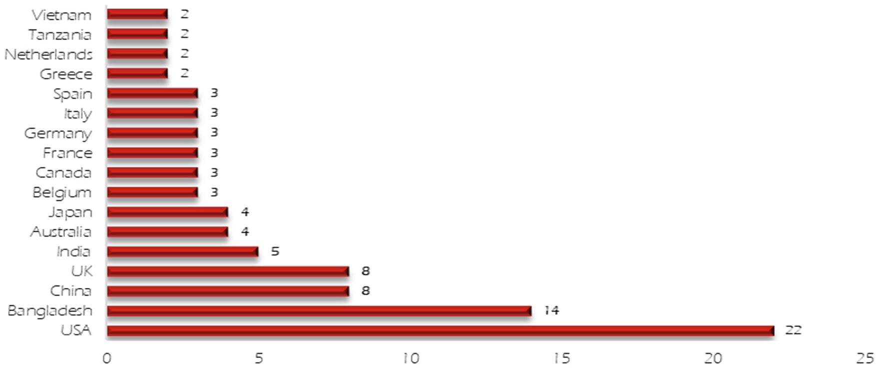

Fig. 2. Publication per country

3.3 Most Cited Publications

Citation count is an important parameter that shows the scientific contribution of an author or article to the body of existing knowledge. As a result, the citation counts of the extracted documents were assessed to determine the contribution of the extracted documents to the existing body of knowledge. Table 1 shows the ten most cited documents with at least 35 citations. In one way or the other, these studies have measured the effect of climate change on human health and the survival of people. From the table, the works of Berdalet et al. [24], which assessed harmful algal blooms by exploring the challenges and opportunities in the 21st century, had the highest citation of 189. The paper was published in the journal of the marine biological association of the U.K. Also, Baron et al. [25] explored the effect of CC on the water body by assessing the effects of high nitrogen and CC on aquatic ecosystems in the USA. This paper has garnered 117 citations. The studies of Gobler [26] and Moftakhari et al. [27] are also worth mentioning as they have been cited 86 and 83 times, respectively. While the latter focused on nuisance flooding along with coastal areas due to increased sea level, the former beam its searchlight on harmful algal bloom and CC. Finally, the document at the bottom of the table is the work of Yue and Unger [28], who assessed the radioactive effects of aerosol pollution in China. The study was published by Atmospheric Chemistry and Physics and has been cited 35 times.

Table 1. Most cited publications

Document	Title	Citations
[24]	Marine harmful algal blooms, human health and wellbeing: challenges and opportunities in the 21st century	189
[25]	The interactive effects of excess reactive nitrogen and climate change on aquatic ecosystems and water resources of the United States	117
[26]	Climate Change and Harmful Algal Blooms: insights and perspective	86
[27]	Increased nuisance flooding along the coasts of the United States due to sea level rise: past and future	83
[29]	Agricultural research in an era of climate change	59
[30]	Living with harmful algal blooms in a changing world: strategies for modeling and mitigating their effects in coastal marine ecosystems	58
[31]	Climate change, extreme events and increased risk of salmonellosis in Maryland, USA: evidence for coastal vulnerability	55
[32]	Extreme weather and air pollution effects on cardiovascular and respiratory hospital admissions in Cyprus	42
[33]	Drinking water vulnerability to climate change and alternatives for adaptation in coastal South and South East Asia	40
[28]	Aerosol optical depth thresholds as a tool to assess diffuse radiation fertilisation of the land carbon uptake in China	35

3.4 Past Research Focus on Climate Change Impact on Human Health

The network co-occurrence of keywords was used to determine the key area of concentration of the extracted publications. This assessment was done using VOSveiwer. All the extracted documents had 950 keywords. There has been no agreement in past studies regarding the ideal number for the minimum number of co-occurrence of keywords when using the VOSviewer [20]. However, it has been noted that adjustments should be made to the set threshold until a clear and visible map is attained [34]. As a result, this study adopted a minimum threshold hold of three for the co-occurrence of keywords retained. Based on the adopted threshold, 62 keywords were extracted and clustered into five major groups, as seen in Fig. 3.

Cluster 1—arbitrarily named "*CC impact on water resources and management*" is seen in the red nodes in Fig. 3. This cluster has 19 keywords, including; climate change, coastal zone, portable water, drinking water, surface water, water management, water source, water quality, seawater, health, adaptation, adaptive management, disaster, among others.

Cluster 2—arbitrarily named "*CC leading to vulnerability and health risk of humans due to rising sea levels*" is represented by the green nodes on the map and has 14 keywords. Prominent among these keywords are vulnerability, storms, coastal zones, flooding, floods, sea-level change, sea level, sea-level rise, storm surge, health risk, bacteria disease.

Cluster 3—arbitrarily named "*environmental pollution impacting human health*", *is represented by the blue nodes on the map and* has 14 keywords. Chevies among these keywords are atmospheric pollution, environmental exposure, environmental monitoring, extreme event, heat, carbon, ecosystem, human, precipitation.

Cluster 4—arbitrarily named "*CC impact on urban growth*" is represented by the yellow nodes on the map and has nine keywords. Prominent among these keywords are land use, mortality, urban growth, future prospect, climate modelling, heatwave, high temperature, summer.

Cluster 5—arbitrarily named "*CC impact on public health*" is represented by the purple nodes on the map and has six keywords, including public health, global warming, policymaking, harmful alga bloom.

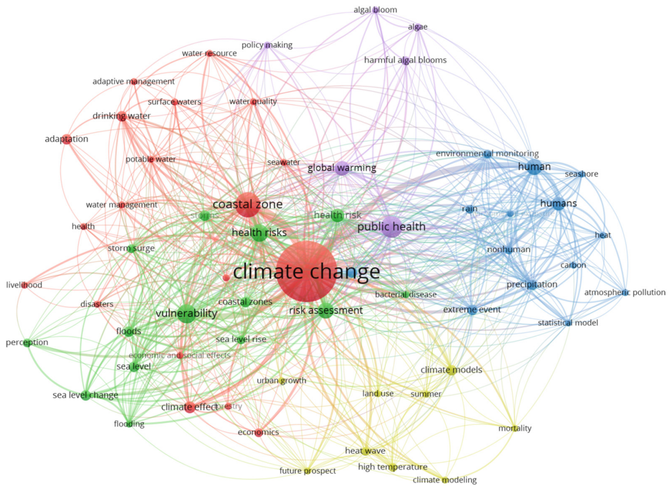

Fig. 3. Network visualisation map

3.5 Trends and Areas for Future Studies

Figure 4 shows the map overlay visualisation of the extracted keywords. This map helps identify the trend in research by highlighting the most recent areas of discourse. From the figure, it is evident that research focus from 2016 to 2017 on CC as it relates to human health in coastal areas has been majorly on issues around the sea-level rise, alga boom, mortality, heat, among others. These are seen in the purple nodes on the map. However, between 2017 to part of 2018, the research trend spreads across numerous areas such as floods, disasters, bacterial diseases, atmospheric pollution, public health, vulnerability, harmful algal boom, adaption, livelihood, among others. This shows that the idea of CC creating harm to man became prominent in academic discourse within this period. More recent focus from 2019 has been on areas such as global warming (total link strength (TLS) = 60), water management (TLS = 19), surface water (TLS = 24), water quality

(TLS = 27), economics (TLS = 19), heatwave (TLS = 24), and high temperature (TLS = 22). These are represented in yellow nodes on the map. While global warming is still a common topic in recent times, it has garnered significant attention based on its TLS derived. However, the TLS for the other recent keywords is low, thus implying that while these areas are recent, they still have not gained significant attention and, as such, are worth exploring.

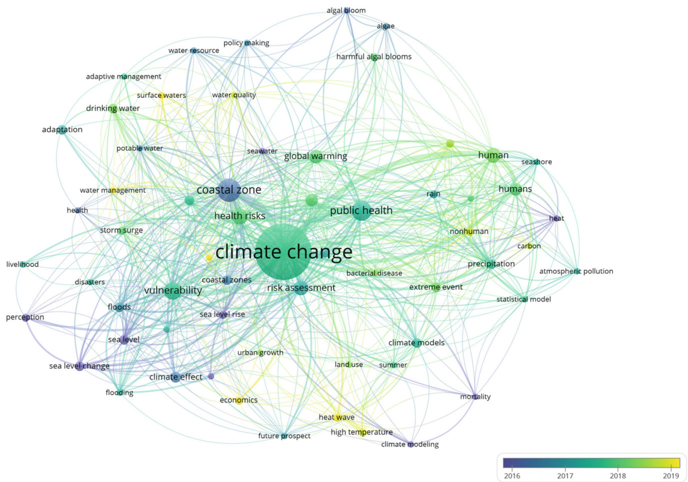

Fig. 4. Overlay visualisation map

3.6 The Impact of Climate Change on Human Health in Coastal Areas

To augment the findings from the scientometric review, an exploration of past works was conducted to unearth the impact of CC on human health, particularly in coastal cities. Based on the generic review, it was noted that the dire impact of CC could be felt in terms of (1) water and vector-borne diseases, (2) respiratory diseases and allergies, (3) mental health, (4) loss of life and injury (5) other health issues.

i. **Water and vector-borne diseases**
   It has been noted that in coastal areas, sea level rise results in saltwater intrusion into coastal water resources [35]. The resultant effect is dire to both the quantity and quality of available water, leading to serious health effects for coastal communities [36]. These health effects include pre-eclampsia, hypertension, skin illnesses, acute respiratory infections, diarrheal diseases, and vector-borne diseases such as malaria and bilharzia [35, 36]. According to the U.N.'s [37] report, water-borne diseases such as cholera and vector-borne diseases such as malaria are extremely climate-sensitive. There is a considerable association between temperature and diarrheal disorders that has been discovered. Thus, CC has a significant impact on the distribution of water-borne diseases. Within optimal climatic circumstances, vectors,

diseases, and hosts all thrive and multiply. Temperature and precipitation are critical factors in the growth of malaria vectors. Warmer temperatures accelerate mosquito development, allowing them to reach adulthood more quickly. This also increases mosquito activity and biting rates, as the odds of survival have been raised [38]. Increased warmth, rainfall, and humidity accelerate vector geographic distribution, prolong disease transmission, and amplify seasonal disease peaks.

ii. **Respiratory diseases and allergies**
The emergence of CC has been connected to respiratory disorders, as ozone density increases with increasing temperatures [38]. Additionally, drought has a detrimental effect on air quality by creating dust storms. Wind transports airborne infectious pathogens such as Mycobacterium tuberculosis, the causative agent of tuberculosis, over greater distances, infecting more people than would have occurred without the high wind. Tuberculosis has been noted as the leading cause of death in coastal areas such as Durban in South Africa [13]. Allergy-related respiratory disorders such as asthma and sinusitis are also on the rise. According to research, coastal locations have a higher prevalence of sensitivity to house dust mites than inland areas [38].

iii. **Mental health**
Gifford and Gifford [39] warn that the impact of CC on mental health may be more than anticipated, as it may occur before, during, and after a climate-related crisis. The prevalence of mental health problems substantiates this assertion. The number of people experiencing anxiety due to impending environmental change has increased. The amount to which a person's mental health is compromised is determined by the way the environment is altered or endangered. Losing property and loved ones can be a terrible experience, resulting in mental health problems for some people. Following a calamity caused by climate change, shock and mourning are followed by long-term psychological trauma such as sadness, despair, and post-traumatic stress disorder [39]. Bambrick [38] corroborates this assertion by noting that there is a higher rate of hospitalisation for mental health problems during the summer months, and an increase in suicide is associated with dry seasons.

iv. **Loss of life and injury**
CC-induced sea-level rise poses a serious threat to people who live along the coast. Heavy rains, strong gusts, and extreme temperatures hinder visibility and degrade driver abilities and vehicle performance. Additionally, about 23% of accidents in the United States are weather-related [40]. Heavy rainfall may trigger severe storms, resulting in floods [41], a fast rise in river levels, and dam overflow [38]. This puts people immediately at risk of being washed away by floods and wounded by fallen trees. Flooding caused by storms can risk people's lives, particularly those who live in substandard homes. Displaced individuals resulting from property destruction may become victims of violence and criminality [38].

v. **Other health issues**
Temperature fluctuations are detrimental to health and promote the proliferation of pathogenic organisms. Excessive heat for an extended period damages the respiratory and cardiovascular systems and exposes them to vectors that transmit encephalitis. On the other side, low temperatures increase the risk of infection from infectious organisms that cause Lower Respiratory Infection [38]. Kim et al. [42] have also noted that excessive heat may be connected with rabies epidemics. According to

the study, excessive heat forces wild animals to seek water from human inhabitants. The result of this action is the outbreak of diseases such as rabies, as noted in some coastal cities [43]. The World Health Organization expects that the impact of CC will exacerbate, putting more strain on an already precarious situation and resulting in major increases in illness and death [44].

4 Conclusion

Conclusively, man's activity has continued to create harm to the environment and changes in the natural climate have become obvious. These changes continued to have a devastating effect on the earth's sustainability and an adverse repercussion on human health. Based on the scientometric review conducted, it is evident that CC impacts water resources and management, vulnerability and health risk of humans due to rising sea levels, environmental pollution impacting human health, urban growth, and public health. With specific attention to health issues of people in coastal areas, the continuous adverse changes in climatic conditions can be detrimental to human health in terms of the emergence of water and vector-borne diseases, respiratory diseases and allergies, mental health, loss of life and injury as well as other health issues. Thus, to address these issues, there must be policies to checkmate adverse activities that contribute to changes in climatic conditions. While the sustainable development goal has inculcated the need for countries to address the issue of CC, countries must also drive this goal through proper legislation. It is also necessary to improve the health care sector, particularly in coastal cities that are more vulnerable to the adverse effect of CC on people. Future scholars seeking to help combat the effect of CC on coastal areas can also explore areas suggested for future works from the scientometric review conducted. These areas have received less attention in the CC impact on human health discourse, and they are water quality and management, economics, heatwave and high temperature.

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Prevalence of the Hand-Arm Vibration Syndrome (HAVS) Among Construction Workers in South Africa

Mariam Akinlolu[1(✉)] and Theo C. Haupt[2]

[1] Faculty of Engineering, Mangosuthu University of Technology, Durban, South Africa
Akinlolu.mariam@mut.ac.za

[2] Department of Construction Management and Quantity Surveying, Nelson Mandela University, Durban, South Africa

Abstract. HAVS affects the physical abilities of construction workers as time progresses. This study sought to identify the presence of HAVS among construction workers in South Africa. Data was obtained through face-to-face, structured interviews on two construction sites. 196 construction workers participated in the study. Criterion sampling was used to select construction workers who used vibrating tools and equipment during construction activities. A content analysis technique was then used to assist capturing of responses, determining statistics, and drawing conclusion. The findings indicate HAVS is a problem within the construction industry. Construction workers displayed clinical symptoms suggesting that they were exposed to HAVS.

Keywords: Construction workers · Musculoskeletal disorder · Vibrating tools · White fingers

1 Introduction

Notably, musculoskeletal disorders have a high prevalence in industries such as construction. Musculoskeletal disorders such as Hand-arm vibration syndrome (HAVS) are common in construction workers with at least 63% of the workforce possibly being affected [1]. In the context of the construction industry, hand-arm vibration is the term used to describe vibration that is transmitted into the hands and arms of construction workers that are using mechanical hand-held power tools or processes while carrying out construction work activities [2–7]. The vibrations are transmitted by various vibrating tools into the hands of workers. Such tools include, for example, jackhammers, power chain saws, pneumatic drills, concrete vibrators and concrete levelers, angle grinders and compactors [2].

HAVS is a recognisable problem globally and studies in several countries have confirmed its prevalence such as Malaysia [8], Sri Lanka [9], Canada [2], United Kingdom [5], Norway [7], and the United States [3]. To date very little research has been conducted on HAVS on construction sites in South Africa.

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Hand-arm vibration syndrome causes irreparable and debilitating damage to the muscular skeletal, neurological, and vascular system and in the case of this study of construction workers using tools that have high levels of vibration [5]. The prevalence among exposed workers has been estimated at 50% and varies by intensity, duration of vibration exposure and climate conditions. Due to the presence of white fingers which is a common feature of HAVS and provoked by low ambient temperature, the condition is easily recognised in temperature zones [10, 11]. The prevalence of HAVS is not well documented in warm countries because VWF is typically provoked by cold weather conditions, and literature in warm countries is minimal [12] (Figs. 1 and 2).

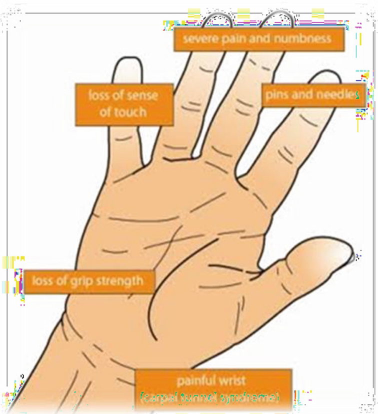

Fig. 1. Symptoms of HAVS

Fig. 2. White fingers

An overview of epidemiological studies reveals that HAVS has vascular, neurologic, and musculoskeletal features [2]. Its vascular component, also known as vibration-induced white finger (VWF), is a type of secondary Raynaud phenomenon because of attacks of well-demarcated finger blanching [13], and the most well-established manifestation of HAVS [14]. During an attack the fingers might feel ‘numb’ and a sensation of ‘pins-and-needles’ may also be experienced. A more progressed state of VWF can be triggered by a less significant reduction in temperature and if left to progress even further through ongoing HAV exposure and/or no medical intervention the condition will ultimately lead to increased numbness, increased tingling, and a significant decrease in manual dexterity of the hands [15]. In the most severe cases, damage to blood circulation may become permanent [16] causing fingers to turn ‘blue-black’ in colour. In the most exceptional of cases, gangrene may result [6].

In South Africa, the onus is on the employer to deliver a safe and acceptable working environment for all employees. The Occupational Health and Safety Act 85 of 1993 (OHSA) communicates that the general duties of an employer include “taking such steps as may be reasonably practicable to eliminate or mitigate any hazard or potential hazard to the safety or health of employees, before resorting to personal protective equipment.” Therefore, according to clause 8 of OHSA an employer is compelled to take corrective action when the daily exposure action value and/or the daily exposure limit value is exceeded [17]. The daily Exposure Action Value (EAV) is the amount of vibration exposure that an employee can safely encounter for one day. The limit is 2.5 m/s^2, above which it is crucial for employers to implement corrective action to eliminate the risk and/or reduce the amount of vibration [18]. The daily Exposure Limit Value (ELV) indicates the maximum amount of vibration that an employee can absorb in one day. This limit is 5m/s^2, above which employees should under no circumstances be exposed.

The general lack of proper and timeous diagnosis of HAVS and referral are major reasons for delays in treatment [19]. Further, the lack of awareness by workers and their employers and fear of repercussions by their employers are also barriers [2]. Early recognition and management of this condition are crucial for preventing progression and improving prognosis. Little is known about the effects that vibration exposure to handheld tools can give on the ability to perform activities of daily living [20]. The key to effectively managing this risk is to employ optimised working practices and risk mitigation and control measures that limit exposure to vibration energy. Against this contextual backdrop, a sparse number of reputable contractors have attempted to implement risk control measures but often fail to understand the basic problem they face—namely, identifying a hierarchy of which working practices pose severe vis-a-vis modest exposure to hand-arm vibration using field observations.

Given the prevalence of HAVS in construction, this paper seeks to investigate its prevalence in South Africa, where it is misunderstood and ignored despite the negative health impacts of the occupational disease.

2 Methodology

A cross-sectional study of two construction sites managed by one main contractor was conducted. All plant operators involved in general operations and construction work were recruited to participate in the study. The participants were involved in activities such as bricklaying, woodwork, drilling and concrete breaking, and therefore had direct exposure to vibrating tools and equipment to fulfil their job requirements. Questionnaire interviews were administered to a total of 196 respondents. The interview schedule included questions on participants demographic, awareness of HAVS, type of vibrating tool used, experience of any symptoms of HAVS and indication of other work during breaks and duration of exposure. Respondents were required to specifically recall and report this information as accurately as possible. Responses obtained from the interviews were analysed through a content analysis and were categorised into relevant themes.

To conform to the accepted ethical research standards, the study ensured that appropriate ethical considerations were made in the conduct of this research. The participants were contacted, and consent was obtained through an informed consent form distributed to all participants with all the research information. Implications of their participation in the study were clearly stated. Further, gatekeeper's permission was obtained from the employer before the interview of the respondents.

3 Data Analysis

3.1 Familiarity with HAVS

Respondents were requested to indicate their familiarity and extent of awareness of HAVS. Figure 3 shows that 52% of the respondents had not been aware of the existence of such a condition prompting an explanation by the interviewer. Once the characteristics of HAVS had been communicated the respondents, then understood the basis and significance of the study.

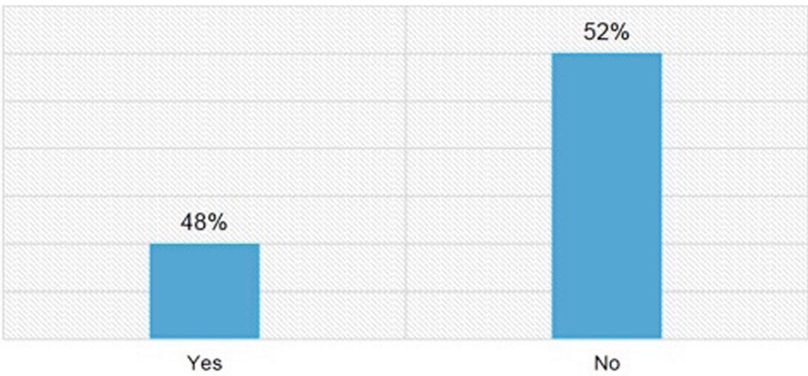

Fig. 3. Familiarity with HAVS

3.2 Type of Vibrating Tool/Equipment Used

Figure 4 indicates the different types of vibrating equipment used by the respondents. The concrete breaker is evidently the most used equipment.

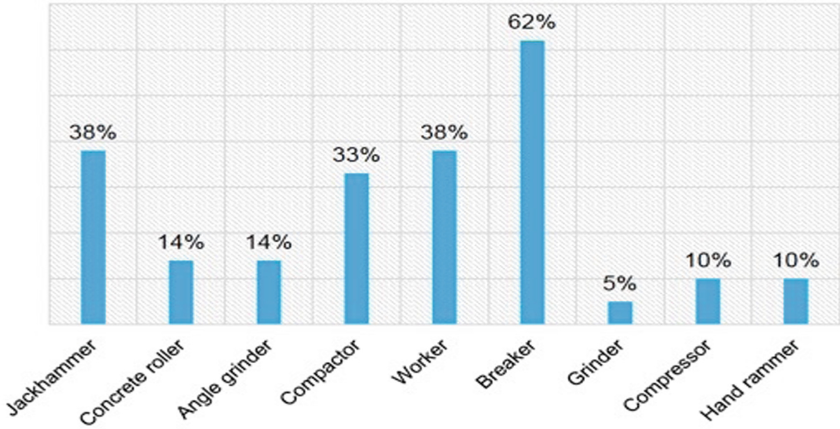

Fig. 4. Type of vibrating tool/equipment used

3.3 Indication of Other Work and Duration of Breaks

Figure 5 indicates that many of the respondents had indicated that activities involving the use of vibrating equipment had been the only work activity expected to be completed by them. These individuals, as well as those who also complete other work activities which do not involve the use of vibrating equipment, are allowed a 15-min tea break and a 30-min lunch break in one working day.

Ten percent of the respondents had indicated that there is no standard duration for their breaks. These individuals typically work from 07h00 to 09h00 and thereafter wait until there is another task which requires their attention. Other respondents explained that in the event of a job needing to be completed in a short period of time no breaks are allowed to the construction workers.

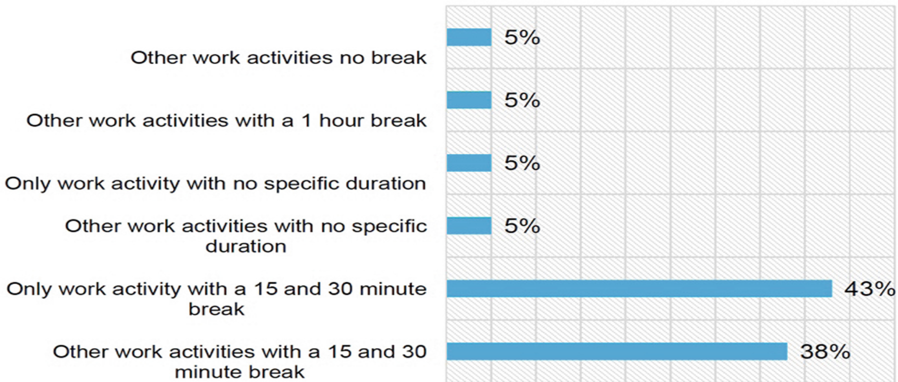

Fig. 5. Indication of other work and duration of breaks

3.4 Experience of Numbness/Tingling of Fingers

Figure 6 illustrates that 81% of the respondents experience a numbing or tingling sensation in either their fingers or hands. Fifty two percent of these individuals experienced numbness specifically. A further 5% of the respondents had experienced numbness for a short while only after using the equipment.

Only 14% of the respondents had experienced no numbness or tingling in their fingers or hands.

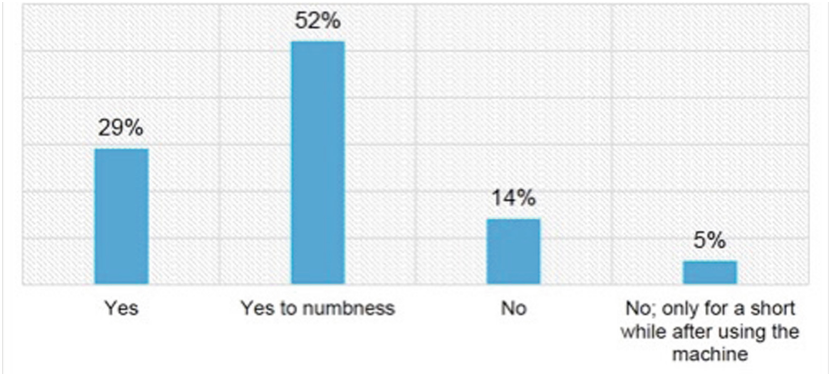

Fig. 6. Experience of numbness/tingling of fingers

3.5 Experience of White/Swollen Fingertips

Figure 7 shows that 71% of respondents had noticed their fingertips becoming white. Twenty four percent had no such experience with 5% explaining their belief that the use of gloves during the operation of the equipment prevents this occurrence.

3.6 Difficulty in Picking/Holding Objects

Figure 8 shows that a mere 29% of respondents had no difficulty in the holding or picking up of objects; the rest of the respondents had in fact had trouble with this. Five percent specifically explained that the difficulty only arises when their finger and/or hands are numb after using the equipment and another 5% had indicated that difficulty arises as the requirements of the job changes.

3.7 Effect of Symptoms on Working Abilities

Figure 9 shows that 10% of respondents only feel tired if the magnitude of work is greater than usual. This then causes them to rely on energy boosters which they describe as being unhealthy for them. Five percent had stated that their abilities are affected to the extent of the task needing to be handed over to a colleague.

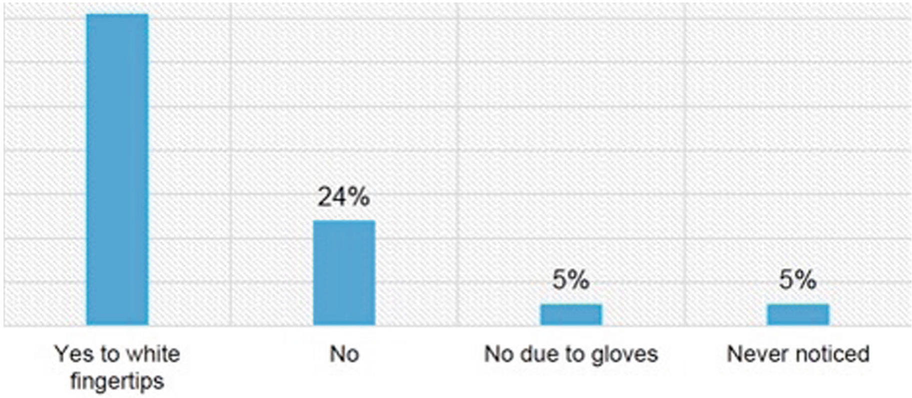

Fig. 7. Experience of white/swollen fingertips

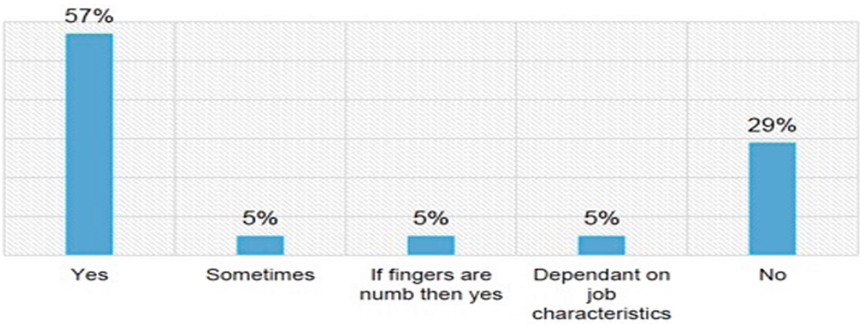

Fig. 8. Difficulty in picking/holding objects

Just less than a quarter of the respondents (19%) explained that they are forced to take short breaks to relax before they resume the task. However, 5% of these individuals indicated that their working abilities are not compromised. Fourteen percent of the respondents expressed that they feel unwell but because it is their only job they are compelled to work and pull through.

3.8 Protection Mechanisms Against HAVS

Figure 10 reveals that most respondents were unable to suggest measures which should be implemented to protect them from HAVS. However, 10% explained the need to modify the features of a concrete roller such as installing a steering wheel which will make it easier to change its course. Other respondents believed that a single individual should not use the equipment for too long; the task should be divided among other workers and workers should be allowed to take short ten-minute breaks in-between using the equipment.

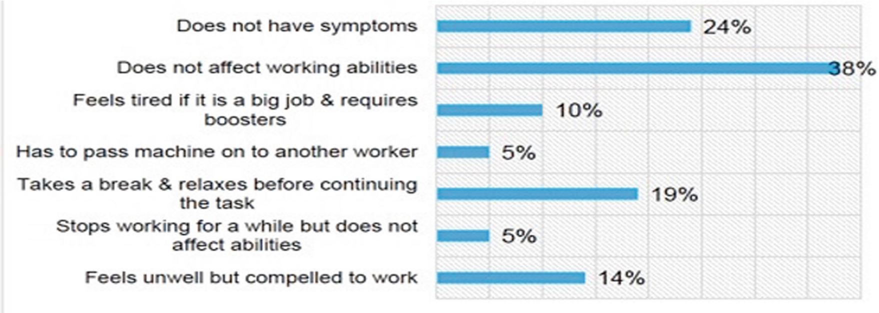

Fig. 9. Effect of symptoms on working abilities

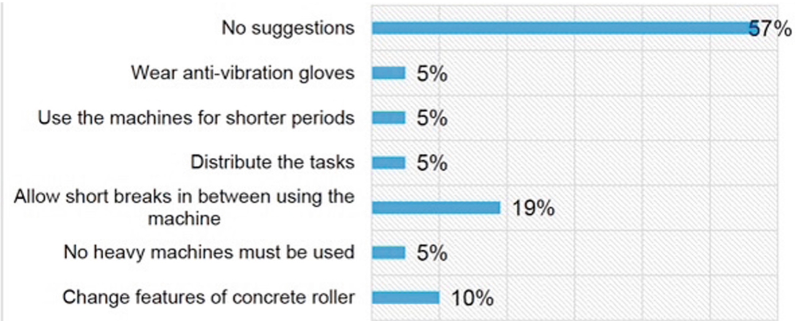

Fig. 10. Suggested measures to safeguard construction workers

4 Discussions

Previous studies have explored HAVs related risks and suggested that there is a high prevalence of HAVS in construction work [8, 21, 22, 24]. However, there is limited investigations in Construction workers in South Africa. The exact prevalence of HAVS in this study is undetermined. While most of the construction workers were not aware of such condition, a considerable number displayed some knowledge of HAVS. This indicates that there is still a gap which needs to be bridged. Although many of the workers were not familiar with HAVs, they were aware of side effects caused by the vibrating equipment that is used. These individuals were simply aware that the use of the equipment saw themselves and colleagues being affected physically in terms of shaking hands, hand, and back pains. The superintendents are aware of these effects as well. They had explained that in addition to hands, the workers' legs and back also get affected using this vibrating equipment.

Most of the respondents revealed an experience of HAVS related symptoms, however, these symptoms did not appear to be in their extreme stages. This provides a justification as to why their work activities are completed despite the presence of these symptoms. Project performance is therefore not greatly affected despite the impact on their health and wellbeing. Moreover, the study found similar patterns of symptoms in previous studies [8, 23]. The respondents experienced a numbing sensation in their finger and had noticed their fingertips becoming white coupled with a difficulty in picking up or holding objects. Apparently, the construction workers desire changes to be made to safeguard their health and safety. A few of the respondents believe that modifications to the equipment, increased number of breaks and division of labour could be possible solutions to the issues faced due to the equipment used. Specially designed anti-vibration gloves could be introduced and worn by construction workers to protect against vibration emitted by the equipment.

Construction workers should be expected to use the vibrating equipment for a specific amount of time each day. Consequently, several individuals should be trained and qualified to operate the equipment thereby ensuring successful division of labour. Workers should also be allowed to use the equipment in intervals as opposed to continuous exposure. A few construction workers from the sample population had suggested the features of the equipment be modified to make the equipment more user friendly and less hazardous.

5 Conclusion

Since symptoms are present in the sample of construction workers, Hand-Arm Vibration Syndrome appears to be a severe problem in South Africa. The current study supports the findings in similar previous studies on construction workers exposure to HAVS in warm climates. Since this study sampled a limited group of construction workers, a further extension of the study should consider a larger sample to better examine the extent of HAVS in high-risk occupations such as construction and mining.

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Rethinking Density: Design and Planning for Healthy Informal Settlements Post COVID-19 in Sub Saharan Africa

Christiana Ekpo(✉) and Alizera Moghayedi

Department of Construction Economics and Management, University of Cape Town, Rondebosch, Cape Town 7700, South Africa
Christiana.ekpo@alumni.uct.ac.za, Alireza.Moghayedi@uct.ac.za

Abstract. COVID-19 pandemic has raised very significant attention to improving the detestable state of informal settlements and the relevance of health interventions in design and planning of cities is emphasized. Cities' sustainability, resilience and health is achievable if the planning and designing of human habitats consider the lives and heterogeneity of residents of informal settlement in addition to the respect of their environmental integrity. Therefore, post COVID-19, radical changes are required in city planning and building designs, as informal settlements are currently diverted from mainstream infrastructure and interventions, including housing. A Critically Appraised Topic literature review was carried out, using relevant keywords and themes in the review of different articles. This study contributes to knowledge by identifying that there is a missing convergence of the tri domain disciplines of planning, building and health in all papers reviewed and very essential for further studies. The findings revealed that the studies on designing and planning with space in mind that prevents disease transmission are very limited and this is a major gap identified. The work draws attention to the relation between Architecture, Urban planning with an eye on Informal settlements space, and Human health. The study indicates that all authors' emphasis is placed on rapid change, societal reform and transformation for a more sustainable, resilient, equitable, and diverse healthy society. And so, the convergence of these tri-domain disciplines should be explored in future studies.

Keywords: COVID-19 · Density · Design · Informal-housing · Urbanization

1 Introduction

Plagues have been known to adversely affect human population and have conversely helped in shaping cities too [1–4]. Subsequently, the Covid-19 uproar compelled lockdowns across cities that halted usual busy lives schedules globally which are currently relaxed with the easing of restrictions. This elicited a boost in creative rethinking of urban design and planning. Increasing evidence that exists suggests that architecture, planning and the built environment in general, significantly determines health. Therefore, increasing attention is drawn by the United Nations and World Health Organisation universal

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agencies, to member states, stakeholders and other role players, for greater integration of built environment and public health [5, 6]. Many authors agree that a significant gap exists on the extent to which the built designers and planners observe health concepts in design and planning and so, their practices must be adjusted in a way that enhances the delivery of healthier urban environment argues that the built environment design is an indicator of a community's health and so, a greater need arises for increased synergy between these tri-disciplines [6–8] and this include informal settlements upgrades [9] being recommended.

The integration of urban planning, design and health professions had existed once, especially during the emergence of threatening health situations and speedy industrialisation era [9, 10]. These professions had common origins in the nineteenth century in order to prevent infectious disease spread especially in densely and unhealthy conditions attributed to expanding industrial cities [5]. Objectives have however changed and agendas shifted over time, especially with the advancement in technology towards pathogens and drug research; while design and planning considered possible spatial constraints mitigation for financial growth while adopting a zoning approach, which demarcates residential areas from industrial zone; public health on the other hand, preserved the medical professions instead [5, 10, 11]. In 1986, the WHO Ottawa Charter that Promotes health supported the shift in discourses that encouraged healthy policies across sectors, including housing, and healthy environments [9]. The contemporary planning, designing and health agendas and sustainable development goals recognised these and their determinants as very essential in addressing informal settlements particularly in Sub Saharan African (WHO, 2016, 2018).

Density implies building structures concentrations within a geographical location that aims to raise population density in terms of their coverage, height, and floor area ratio (FAR). The zoning and building regulations use these policy measures to indicate the allowable land use which further manifests a variety of urban form. So, correct densities relate to both parallel and perpendicular usage [12]. However, a fundamental challenge that confronted urban planners and designers now is the glaring friction between modern densification and integration concepts of contemporary cities, identified as an essential component for environmental sustainability enhancement and the advocated disintegration, which entails special and populations spread, used as key measures to impede Covid-19 transmission [2]. Density concerns and the overall informal settlements unkempt environmental wellbeing are constantly emphasized because they provide the needed human resources for most Sub-Saharan African Cities. This suggests that the infection transmission risk increases in such settlements and constitute risk for other areas in the urban precinct.

Apparently, the World Health Organisation (WHO) recommended relevant safety practices; facial masking, social distancing, regular hand washing and sanitising, general good hygiene, among others as ways to prevent spread [9, 13–15]. However, these precautionary measures became a very challenging concern for informal settlers who could not be easily isolated from each other due to their housing forms. Wilkinson, et al. [16, 17] argue that the problems confronting most third world countries in sub-Saharan Africa especially, during COVID-19 era are complex because of the presence of informal settlements. Their housing is usually unregulated, unplanned, and basically constructed with substandard materials in a haphazard fashion, and sometimes occurs because of land grabbing, poverty and competition for space, where homes are closely built together with unplanned streets [17–19]. Therefore, the observance of the WHO's precautionary actions of social distancing simply became too difficult and almost useless in some densely populated informal settlement. The city becomes more endangered when the demographic challenges of informal settlers are constantly disregarded, and this is partly reflected in their housing and health formations.

Policy changes that enable upgrade of informal settlement that allows formal planning and designing for improved health is suggested by experts [9]. The thrilling procedures and plan of action designed to ameliorate informal settlements' challenges, should not just observe and manage informal settlements as short term dwellings that are merely transient and do not need viable appropriate infrastructures [9]. Interestingly, the international consensus increasingly favours on-site reconstruction or development over resettling dwellers, except where there are ecological and security threats and other concerns [20]. Oftentimes, evacuation and resettlement of dwellers of informal habitats to periphery areas of the City are the policy technics applied when they ought to be reformed rather, to provide dwellers with different chances to live better lives [20]. Enhancing informal settlements should be comprehensive enough from a perspective of equipping dwellers with opportunities instead, than treating them as a huge dilemma. Such kind of upgrades are possible when planning and building regulatory policies are observed and applied and the upgrade could portray as economic impetus for funding and socio-economic development, which encourages job creation too.

The study therefore aims to review the challenges that are affiliated with informal settlement density that built designers and planner for health must be acquainted with. The study interrogates whether high population density inherently raises vulnerability of informal settlers to pandemic surges. The objective of this study is to examine the convergence of design, planning and health and the gaps therein. This work intends to help the researcher to explore new discoveries in handling density in an epidemic situation. This will help the research to establish what a sustainably viable, all-inclusive, irrepressible spatially structured, and hygienically healthy upgraded informal settlement should consist of for a more justifiable future.

The paper is splitted into five sections. This introductory section is preceded by the drivers of informal settlement in Sect. 2 and the section introduced the methodology in Sect. 3 which is preceded by findings and result in Sect. 4, followed by the discussion in Sect. 5 and conclusion in Sect. 6. The next section therefore highlights the major challenges that should be considered and possibly addressed while rethinking density and health of informal settlements in environmental design and planning.

2 Drivers of Informal Settlements

Density caused by Urbanization: The more humankind advances uninterruptedly, the more urbanization is but-tressed to increases exponentially in the 21st century [21], and ceaselessly challenged with perilous catastrophize and emergencies [22–24] like the current pandemic, disasters, war and conflicts [25]. The more urbanized Cities are, the more substandard and denser informal habitations become. This has become a common challenge plaguing almost every Sub-Saharan Africa City. COVID-19 thus heightened the major challenge of managing urbanization in these Cities. The density challenge in Informal settlement are partly urbanization related, because, the heavy population triggers substandard informal spatial formations and inappropriate land conversions, grabbing and adaptations [8]. Consequently, informal unstructured, unkemptly compact, unaerated spatial formations, are the likely common features that encourage disease spread in such habitations. So, when informal settlement upgrades are granted, the designer and planners must be abreast of these challenges while designing and planning such urban space.

Planning and building planning regulatory challenges: Angignu and Huchzermeyer [26] argued that illegal land tenancy for informal habitat breaches conventional and formal land use management and planning regulations. Accordingly, King et al. [20]; Ekpo [29] argues that policies meant to manage land and urban sprawl are pivotal in addressing housing issue as urbanization is known to be a crucial impetus for land-use shifts [27, 28]. The policies are manifested in the modern concepts of promoting integration and density which further promotes congestion issues that encourage disease spread. Promotion of conversions around less/unused land and buildings found around inner cities for affordable housing development becomes vital [29] that can help to reduce housing need and informal settlement. Government land is identified as one of the greatest possible sources that land is made available for housing development for the poor. The fundamental human right to health requires one to having healthy environmental access and the utility of health-promoting areas fundamentally hinges on acquiring legal property rights as well [20]. Therefore, just as spatial structural configuration is very significant component in achieving social distancing, so should getting appropriate land use and planning rules equally be of vital importance. Furthermore, history has shown that diseases epidemics can assist in correcting occupancy limits [30, 31].

Inadequate housing: Many scholars characterize informal settlements as poor housing Therefore, supporting a sustainably spacious city through design and planning ought to be an essential component of a viable regulatory policy that built experts must incorporate which concomitantly targets the promotion of affordable housing and healthy communities. Although regulations sometimes restrain professionals from achieving spatial designs. Creatin communities with well delineated spaces are very vital to prevent heavy densities that will instead provide healthy access to well-incorporated spaces that enhance social interrelations [32, 33].

Lack of Sustainable Communities: Sustainability, that promotes community resilience, in the socio-economic-environmental terms, should be the watchword in designing and planning for health, when upgrades and restructuring of informal settlements are allowed. The built environment is thus expected to play a transformative role in leaver creative thinking that apply innovation in planning and designing building that are environmentally responsive and friendly [34–36]. Again, this can help avert carbon emissions pollution from informal habitats acknowledged to be heavy contributors of pollutants to the environment from their different survival activities. The poor housing formations attribute greatly to high in-house gas emissions and environmental pollution.

3 Research Methodology

An archival research method is employed in this paper to basically scrutinise existing pedagogical works using the relevant themes and this is done within given time frame; hinged on an identified benchmark [37] to identify gaps in literature. It is essential to stress here that this work explores a contemporary research area that is relatively current, and many investigations are still underway to advance the fundamental subjects on COVID-19 implications which is an inter disciplinary subject.

Review of existing research: This work is established from 48 papers relating to themes on density of informal habitats, urbanization, population, housing, land, planning, design, and sustainability together with poverty, Health and wellness themes. These themes are searched using appropriate keywords, key authors in the themes, reading abstract and then tabulated to enable easy research of the topic from the identified and designated journal articles. The pertinence and content of the topic determined how the 48 papers were evaluated and analyzed.

Criteria and Procedure: The papers from the respective Journals were gathered from online scholarly bibliography from Elsevier, Emerald and SAGE, Taylor and Francis and so on high impact journal datum employing google scholar and Mendeley tools and every reviewed paper went through a standard scrutiny to authenticate the inclusiveness and relevance to the rudimentary measures applied to this subject. As a multi-faceted subject, Informal settlement topic have alluring recognition from academics in varying disciplines for decades unlike and COVID-19 that is a relatively new subject. In order to accomplish the paper's aims, the articles on informal settlement chosen for this review were selected from 2000 to 2022 and a study form 1986 was also considered due to its relevance. The informal settlement topic has evolved way back, is way older and surpasses the contemporary COVID-19 topic, whose studies, only emerged in December 2019 and is still in progress. So, consideration was paid to high impact journal papers between 2019 till date.

Analysis and Quality Assurance: This work is mainly a guiding paper to further studies. It is in this context that complete quality evaluation is of great essence here. The scrutiny of articles garnered for this paper is established from factual study methods, which Welman, Kruger and Mitchell [37] admits that, the theme or topic, period of article and its significance are perfect pedestal for research. A chronological and moderate process is utilized for cross-checks. This includes (1) documenting applicable articles to the topic, (2) evaluating each and every article, (3) sorting to disqualify or qualify articles as an integral part of investigation (4) validating the fundamental details contained in the chosen articles (5) and using the quality assurance pass to evaluate and tabulate the study principally from the validated journal papers [37] (Fig. 1).

Addressing the research problem investigated: The density caused by urbanization, sufficient housing and land use issues, sustainability and cities resilience were considered as important variable to be considered in design and planning for health. The study design aids the researcher to achieve set out objectives, which is identified gap that exist in the integration of health and wellness in design and planning of the built environment and more light shed on drivers of informal settlements that the planner

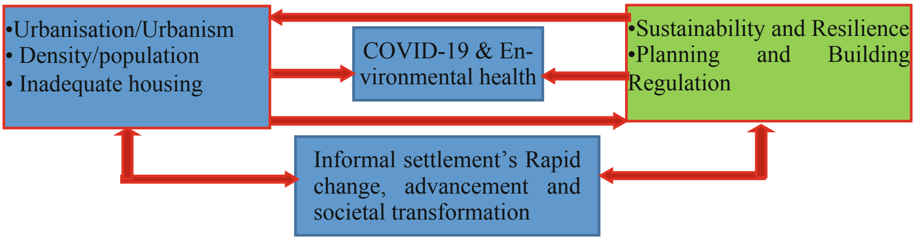

Fig. 1. Theoretical research framework

and architect must note, for a healthier environment, from review of various literature. The researcher also ascertained that all 'qualified' papers are applicable and published in certified and admissible databases for quality endorsement and affirmation. The adopted timespan is intended to secure a broad coverage of the investigated topic that resulted in the findings and outcomes. In conclusion, the written evaluation, figure and table provide sufficient discourse on this topic. The themes considered include Density/population, urbanization/urbanism, housing, sustainability/resilience, Planning/building regulations, COVID-19, poverty, Health, Rapid change and societal transformation.

4 Findings and Results

Table 1 shows the findings on the topic on focus. The classification of relevant themes in accordance with the study's appraisal reveals that (1) Both Informal settlement and COVID-19 was heterogeneous and multidisciplinary in character with researcher's interest especially emphasized on Density/population, urbanism/urbanization, housing sustainability and resilience, of cities as well as the overall health. (2) Informal settlement COVID-19 connotation with concentration on density was investigated using 40 of the articles; (3) Informal settlement COVID-19 implication with concentration on housing, land and health was centered on 21 of the articles; and (4) the goal of Density and Health variables of informal settlements in this work is meant to strengthen viable spatial formations that are adaptable and environmentally healthy for informal dwellers through creative planning and designing when informal settlement upgrades are allowed (5) 25 studies suggested possible solutions that can help designers and planners design and planning for better outcomes.

Implications of Density: This paper allows for the understanding of Poor Density with COVID-19 implications. The table below presents the challenges of informal settlements that becomes the focal themes that a designer, planner, policy maker, must consider while planning and designing for environmental health. These themes are applicable while narrating the possible inference of density problem while designing and planning in a pandemic era. It introns the theoretical framework indicated in the preceding section (Table 2).

Table 1. Themes and frequency

Themes	Frequency
Density	33
Urbanism (urbanisation)	29
Housing	16
Sustainability and resilience	25
Planning/building (land-use)	24
Covid-19	13
Poverty	20
Health	31
Rapid change and societal transformation	36

5 Discussion

In all the reviewed papers a significant gap that exists is that scholars are unable to establish the convergence of design, planning and health. This once existed, so, moving forward, planning and Design focus should integrate environmental, social, and economic factual truths meant to addresses health challenges. Innovative and sustainable approaches in education, training, design and urban planning, policy interventions are needed to provide the statistics and quality of housing required, to meet up the demands of the current informal settlers' populations and the expected urbanization, post COVID-19. Governments should together with city planners and designers think of informal settlement reforms and upgrade in a way that addresses health and hygiene issues. In situ upgrading of informal settlements should be adopted which generally requires, housing improvement, provision of infrastructural amenities and services and granting safe tenure rights.

The study indicates that all authors' emphasis is placed on rapid change, societal reform and transformation for a more sustainable, resilient, equitable, and diverse healthy society, The Regulatory amendment should consist of pragmatic regulations and standards that permits informal housing improvements and construction that allows readjustments in land use management and development processes and observed building codes to fit this class of citizens Land grabbing and. Misused metropolitan land, underspent lands and buildings should be changed to affordable housing too to reduce overcrowding and enhance healthy cities across Sub Saharan Africa.

A need therefore arises to integrate COVID-19 mitigation measures with continuous climate change reduction and adaptation measures. Governments need to assist in well-organized energy retrofits when upgrading informal habitats through enormous refurbishment and reconstruction for sustainability and assist accelerated construction of low and zero-energy buildings via informal settlements upgrade. Provision should be made for green Energy generation and conservation that would impact the environment positively and also improve the living conditions and health of this vulnerable class as well. Green incentivizing interventions then become very crucial.

Table 2. Themes reflecting informal settlements

Density challenges	Health, design/planning challenges	Implication for informal settlement design and planning
Impractical/inadequate Housing + Environmental Health = Informal Settlement		
Density caused by Urbanisation and migration challenges	Poverty/natural and health disasters (interdisciplinary)	Informal settlement is partly driven by poverty, that gives rise to high density Government interventions for trans-formation becomes relevant
Density/population control	Housing sustainability and Resilience	Conscientious comprehension of societal economic and eco-logical concepts for transformative shift is needed for responsive design and planning of dwelling of informal settlement upgrade
Adequate affordable housing for all	Appropriate land policies, planning and Building regulation	Well guided policies that guide land use and development will help to improve the health situation of informal settlers through aptly responsive designs and planning
Rapid change, and advancement	Societal transformation	Planning and designing skills that are channelled towards space, spreading out and health. These can then deal with trans-formation and speedy advancement for overall societal good

6 Conclusion

COVID-19 creates a chance to invest in centralized health networked solutions appropriated for high density settings through design and planning in upgrading of informal settlement in an urban precinct. This study contributes to knowledge by identifying missing convergence of the tri domain disciplines in all papers reviewed and very essential for further studies. Cities' sustainability, resilience and health is achievable if the planning and designing of human habitats consider the lives and heterogeneity of residents of informal settlement in addition to the respect of environmental integrity of such human settlement in human-space relationship with land. Targeted environmental improvements will boost the capacity of planers and designers of communities to react to disease outbreaks and health that aims curtailing in transferal pathways to germs. Informal settlements upgrade can possibly transform into a more enhanced functional and lively habitat with an involvement of dwellers themselves and create employment for them through different activities therein.

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A Delphi Approach on the Challenges of Human Resource Management Practices Implementation in the Nigerian Construction Industry

Helen Ifedolapo Babalola[1,2](✉), Clinton Aigbavboa[2], and Wellington Thwala[2]

[1] Department of Project Management Technology, The Federal University of Technology Akure, Akure, Nigeria
hibabalola@futa.edu.ng

[2] SARChi in Sustainable Construction Management and Leadership in the Built Environment, Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa
caigbavboa@uj.ac.za

Abstract. More attention should be given to the implementation of human resource management practices (HRMPs) as these practices influence the workforce (HRs) activities and overall project delivery in the construction industry (CI). Therefore, this study identified the challenges facing HRMPs implementation in the Nigerian construction industry (NCI). The Delphi approach data collection method was utilised to achieve the stated objective. Delphi experts, engineers, architects, builders, quantity surveyors, project managers, and HRs in the built environment, research institutes, academic of higher learning were engaged in the study. The challenges of HRMPs were evaluated by identifying the influence of each challenge on HRMPs; these factors were measured from 1-no impact to 10-very high impact. Mean item scores and interquartile deviation were means by which data collected were analysed in this study. Based on different challenges evaluated through the Delphi technique, the study found that for effective management of HRs and HRs activities through HRMPs implementation in the NCI, priority must be given to issues such as political interference during the recruitment process and employee layoff/downsizing. These factors had a very high impact. The study contributes to the body of knowledge in the area of major challenges faced in implementing HRMPs as there is a lack of studies despite several studies conducted on HRMPs.

Keyword: Challenges · Construction industry · Delphi approach · Human resource management practices · Political interference

1 Introduction

Globally, the construction industry significantly contributes to the country's economy through its workforce [1–3]. However, recent construction projects delivery has suggested the need for effective management of HRs (skilled, semi-skilled, or unskilled),

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enhanced HRs performance, and HRs capability [4]. These have resulted in the implementation of varied HRMPs needed to attract, develop, and retain a capable workforce in the construction industry (CI). The workforces are the internal part and the workgroup difficult to manage within an organisation compared to other physical resources such as costs, materials, and others. Inability to effectively manage them, can impair firm growth [5]. To manage HRs in the CI, different organisations across the globe have suggested varied HRM practices. [6] identified sixteen practices and argued that high performance workforce result from combination of compensation, planning, selection and the likes, thereby achieving competitive advantage. Also, [7] maintained that HRM practices implementation is achieved through the combination of compensation, training, empowerment, and appraisal system. These practices help in employee retention.

Despite implementing these practices, the CI is constantly faced with the problem of managing and getting the appropriate HRs. [2] explained the case of the NCI, which is characterised by uncertainties associated with high rates of employee turnover, thereby resulting in labour shortage. [4] noted that getting the required skill is not always an easy task, hence the need to effectively manage them in the CI. [8] indicated that various stakeholders in the CI, including unions and politicians, influence the implementation of the HRM practices compared to other sectors. Thus, this often results in an interference involving sentiments in the recruitment process. Further, [9] opined that different bundles of HRMPs implemented are not motivation-enhancing practices. This implied that organisations only focus on HR practices capable of strengthening employee opportunities and abilities to carry out organisational activities rather than financial incentives that may benefit HRs and may displace firms intrinsic motivation [9]. Based on these highlighted inadequacies, there is a dearth of studies showing that attention had been given to HRMPs implementation issues in managing its workforce. As such, [2] corroborate the assertion that there is a paucity of literature on HRMPs in the NCI. Few available studies identified HRMPs and their drivers; successful implementation of these practices for HRs performance within the NCI seems difficult if associated problems surrounding HRMPs implementation are not adequately identified. Based on this, this study assessed the challenges facing HRMPs implementation in the NCI with a view to identifying the challenging areas needed to improve on and that will influence HRM activities and overall project delivery in the construction industry.

2 Related Works on the Challenges of Human Resource Management Practices

Emerging changes in the construction organisation confer several challenges affecting the HRM function in achieving its goals. [10] assert that to manage HRs in the CI, well-structured HRMPs should be developed and implemented. However, [11] added that the industry is constrained by challenges that hinder the implementation of HRMPs. As reported by [12], one of these challenges is political interference in the recruitment process without following due process. Socio-cultural issues that center on sentiments by political and influential personalities in government distort the recruitment process based on applicants' skills and technical abilities. This interference affects the recruitment activities in selecting the right HRs for better construction work. Likewise, the place of fairness and equity in the recruitment process have been taken over by godfatherism [13]. In a similar manner, [14] and [15] noted downsizing/employee layoff as an organisational challenge to HRMPs implementation. For instance, in the United States, a temporary contract has been linked to job insecurity, unbalanced work-life, job dissatisfaction, and not staying long on the job, which eventually results in employee layoff [16]. The failure of the government to provide regulations and policies such as rights and responsibilities of HRs in the workforce affects HRMPs implementation [14] and [17]. These regulations control organisation activities that preserve HRs essential to construction activities whose duties cannot be replaced by machines [18] and [2].

In addition, dwindling economic condition is an issue that poses a challenge to HRMPs implementation [17]. Economic conditions such as global recession and financial crises have resulted in mass unemployment and downsizing in the workforce [19]. Aside from the above challenges, discrimination among employees has been noted as a challenge to HRMPs implementation. [20] asserts that HRs in the CI find it difficult to report the incidence of discrimination as they view it as a target that may lead to future occurrences. Similarly, [21] stated that environmental issue like globalization retards HRMPs implementation. Changes in HR can trigger an increase in globalisation, thereby expanding interest in innovation and sustainability as well as increasing generational diversity [22]. Also, lack of organisation strategy, influence of unions, poor management system impacts the type of HRMPs implementation [23] and [24]. In the same vein, [25] noted that the partial recruitment and selection process may cause HRMPs implementation due to a lack of feedback on factors that will enhance the process.

3 Methodology

The study's objective is to assess the challenges of HRMPs implementation in the NCI through a Delphi technique. According to [26], the Delphi technique is a quantitative methodology but employed also for qualitative research where research participants are engaged in a natural sense of conversation, unlike the laboratory type of research. It is a qualitative study because it explored the views of selected construction professional experts in the NCI with diverse experience in the management of HRs and its practices. The role of the experts in this type of study is to analyse critically the attributes underlying the subject being investigated (HRMPs implementation challenges) and give their opinion based on their past and various experiences to reach an agreement. The Delphi approach was adopted because there is need to provoke debate on the challenges of HRMPs implementation in the NCI in this study. Hence, a research process that could generate and encourage the discussion of varied expert opinions to ensure relevant issues were identified, validated and consensus on the subject matter was advocated for in this study [27]. Based on this, the study does not utilise one-off questionnaire which could only elicit opinions but not encourage exploration of opinions; the Delphi method was adopted.

Furthermore, Delphi method was utilized because of its robustness for rigorous experts' query. Its strength lies in the rounds of questioning (iterative process) used, which allow initial and collation of feedbacks as well as distribution of collated feedback to participants for additional review [28]. According to [29], this process of group communication centres on the strength of the Delphi method. Also, the cost of the research, time constraint, and location of experts ruled out a series of individual or focus group interviews; hence a Delphi method was utilised for this phase of the PhD study. Therefore, this study employed Delphi survey to identify and solicit experts' opinion on HRMPs implementation challenges in the NCI. Two rounds of Delphi process were conducted to reach consensus among the experts on the questions sent. Statistical Package for Social Sciences (SPSS) version 27 software program was used for this study, while the statistical tools were mean, median, standard deviation, and interquartile deviation.

3.1 The Delphi Technique

Delphi technique has been described as a systematic and interactive research process in which the researcher purposefully selects respondents with the experience and knowledge appropriate to provide insight into the subject being investigated [30] and [31]. According to [31], these respondents are independent experts. They remain unknown to each other during the iterative process of carrying out the Delphi study but are in contact with the researcher; they are asked a series of questions. The views of the experts are analysed by the researcher and returned for further comments. This series of processes is repeated over a number of rounds, called iteration, which allows the experts to alter or retain their views in response to others' views, thereby generating consensus [30] and [31]. Therefore, a Delphi study is characterised by anonymity, repetitive process, and statistical response [32].

In line with the above discussion, this study, therefore, attained consensus on the challenges of HRMPs implementation in the NCI. While forming consensus among the experts' panelists of the Delphi study, [33] posit that researchers should determine in advance actual meaning of consensus for a study utilization (Table 2). Furthermore, [33] inform that it is important to accept over 50% higher rating by experts over pre-determined number and remove vigorously opposed statements. Hence, the study adopted the median, mean, and interquartile (IQD) score analysis for consistency and consensus.

3.2 Identification, Selection, and Validation of Experts' Status

[34] indicated that the list of expert panelists prepared can be endorsed by experts who help identify other experts. This study provided the demographic characteristics of pre-qualified experts to show level of knowledge and experience in contributing to the subject under investigation. In terms of their designations, academics, professionals in the built environment (engineers, quantity surveyor, project manager, builder, architect), and human resource/personnel managers from the Nigerian construction industry were identified. They were registered members of different professional bodies and believed to have significant experience on the field and possess considerable knowledge of the construction industry HRMPs. Additionally, the experts selected cut across major Southwest cities in Nigeria; Lagos (6), Osun (1), Ogun (2), Ondo (4) States including the Federal Capital Territory (2). This helps to enrich the study by seeking varied opinions and knowledge across these cities in Nigeria. Notably, [35] recommended a diverse expert panel size for a Delphi study. Initially, nineteen (19) experts willingly started the Delphi

study; thus, for the first round, nineteen (19) copies of questionnaire were sent out. The clear objective of the study and the required role from the respondents were clearly stated. The Delphi questionnaire were sent through WhatsApp messages, emails, and a follow-up through telephone calls. Seventeen (17) experts responded to the first-round, while in second round, fifteen (15) returned. However, 21.05% of the experts were not interested and recorded in the study. This indicates that 78.94% were sufficiently interested and involved in the investigated subject, representing a high commitment response rate.

Experts' educational levels show that 79% had a master's degree, while 27% had a PhD degree in construction-related fields. In terms of members of the professional bodies experts belong to in the NCI, the majority (35%) of the respondents were members of the Council for the Regulation of Engineering in Nigeria, while members of the Quantity Surveyors Registration Board of Nigeria followed making up 25%, members of Chartered Institute of Personnel Management came next, followed by the members of the Nigerian Institute of Architects, and Council of Registered Builders of Nigeria completing the list at 20% and 15% each respectively. Regarding years of work experience in the NCI, about 48% of the experts had 6–10 years of work experience. At the same time, 27% of the experts had between 11–15 years' experience, while 25% had over 16 years of experience in the built environment. In one way or the other, all experts had been involved in construction projects involving HRM practices in the NCI. Additionally, experts were drawn from different institutions in the NCI. Lecturers at the universities make up about 30%, with the research institutes and CI constituting 30% and 40% respectively. Therefore, the study experts are qualified as having the required experience and knowledge to provide adequate responses.

3.3 Data Collection Through Delphi

[28] opined that answers to Delphi study issues are achieved by utilising sequences of survey rounds to obtain iterative responses, while [35] mentioned no specific guidance the optimal number of rounds in a Delphi study. From the foregoing, several rounds had been advocated by different authors based on the literature review. For instance, Table 1 depicts the rounds utilized by various authors.

Further, [32] and [42] opined that due to the rigorous nature of the Delphi study, there is a drop off in the number of experts at the end of the second-round. Likewise, [43] suggested that only when there is stability in data collection, Delphi process should stop. Then consensus is only achieved when stability occurs in data collected and analysed. This is in line with [43]. The Delphi was carried out to achieve consensus in the experts view on the challenges of HRMPs implementation in the NCI. Through an electronic method, the Delphi questionnaire was sent to all the panel members who were asked to respond to the questions based on their experience and ability. The Delphi questionnaire was developed based on the literature reviewed to achieve study objective. Thus, the Delphi method used in this study involved two rounds of the iterative process because data collection was stable. Each round took almost a month. A questionnaire was designed for round two based on the responses from the first round. However, based on the study literature review, the first-round questions were developed. These were arranged both in structure and construct to frame the first round of the Delphi study. As such, Delphi

Table 1. Number of rounds in a Delphi iteration

Authors	Number of rounds
Dalkey et al. (1970) [36]	Two
Woudenberg (1991) [37]	Two to ten
Critcher and Gladstone (1998) [38]	Two to five
Loo (2002) [39]	Three to four
Aigbavboa (2013) [40]	Three
Ameyaw et al. (2016) [35]	Two to six
Somiah (2019) [41]	Three

Source: Researcher's compilation

surveys round one was intended to be a brainstorming exercise used to produce a list of empirical attributes on the challenges of HRMPs implementation in the NCI.

In the Delphi study round 1, open and closed-ended questions were used. The first-round responses were analysed, and the results formed the basis of the second round. Frequencies were used to measure the degree of consensus reached in the participants' opinions concerning the challenges of HRMPs in the NCI. The second round of the Delphi questions was the final round aimed at allowing the expert panelists to review and comment on the challenges of HRMPs implementation in the NCI, which the expert panelists proposed in the Delphi round 1. In the round two, open-ended questions were utilised to investigate the expert panelists' comments expressing agreement, disagreement, or clarification concerning the challenges of HRMPs implementation in the NCI. The very nature of the open-ended questions should have aroused participants' reactions, but there was no reaction from any of the participants based on the analysis from the first round. Frequencies were used to measure the degree of consensus reached in the expert responses regarding HRMPs challenges. For each response on each of the challenges of HRMPs, the group median was calculated. The group median was the appropriate measure of central tendency utilized in this study. This is because it was found to be more suitable for the type of information that was being collected.

Accordingly, [28] informed that measuring central tendency through the median, eliminates bias, consider outlier responses, building consensus and making notion more reasonable. However, [28] mentioned that utilisation of mean only consider outlier responses in measuring central tendency. A probability scale ranging from 0 to 10 representing 0 to 100% was used. Interval ranges were also set and used at 10-point ordinal scale ranging from 'no impact' to 'very high' impact. Furthermore, in the second round, group median for each element was computed and sent back to the expert and were asked to either maintain their first-round response or change their response based on the group median of round one. However, The Delphi process was terminated after the second-round response had been analysed and consensus determined. In this study, the anonymity of participants was maintained to avoid undue influence on other panel members as it is crucial to the results' credibility.

3.4 Reaching/Determining Consensus

In the Delphi study, determining consensus among expert panelists is a contended area. Literature has established that no single consensus was agreed on regarding the best adaptable methodology in reaching consensus [28] and [35]. However, researchers have used several methods to assess agreement or determine consensus in Delphi study. For instance, [44] utilised frequency distribution based on the criterion of at least 51% response rate to any given question; [45] used percentage response with an increase in percentage agreements; [46] used arithmetic mean. In the present study, consensus was evaluated by computing various responses central tendency to all questions from the expert panelists. As observed in this study, all responses group median (M), standard deviation (σx), mean ($\overline{x}$), and interquartile deviation (IQD) were computed. In achieving consensus, the deviation of all group median responses was determined not to be more than one (1) unit, likewise for the IQD. This is suitable as the scale that was used for probability (influence), agreement, and the impact was 1 to 10. This method had been utilised by a number of researchers in their various studies, including [47–49] and [50]. Thus, Table 2 shows the scales of consensus for this study. The Statistical Package for Social Sciences (SPSS) version 27 software program was used for the analysis.

Table 2. Adapted scales of consensus

Consensus	Median	Mean	Interquartile deviation (IQD)
Strong	9–10	8–10	$\leq$ 1 and $\geq$ 80% (8–10)
Good	7–8.99	6–7.99	$\geq$ 1.1 $\leq$ 2 and $\geq$ 60% $\leq$ 79% (6–7.99)
Weak	$\leq$ 6.99	$\leq$ 5.99	$\geq$ 2.1 $\leq$ 3 and $\leq$ 59% (5.99)

The above scale was based on a 10-point impact scale ranging from 1 "no impact" to 10 "very high impact". Notably, studies had mentioned difficulties in attaining validity and reliability of the Delphi process [40]. However, in this study, experts were provided with clear definition of terms; understanding of the Delphi process for valid and reliable responses; and clear instructions on how to answer the questions. This helps to reach common understanding of the Delphi questions. Based on this, consensus was reached at the round two of the survey.

4 Findings and Discussion

Due to the qualitative nature of the Delphi process, its reliability and validity have been questioned by different researchers. Further, judgement is based on the opinion of various experts with regards to their knowledge, thus making it difficult to ascertain its validity. However, in this study, the validity was determined. The study ensured a comprehensive understanding of each factor under discussion by the expert panelists. Also, as discussed in Sects. 3.1 to 3.4, the validity of the Delphi process was also determined in terms of experts' educational level, members of professional bodies experts belong to, years of work experience, and location across cities in Southwestern Nigeria for varied opinions.

Delphi Round 1

This is the exploration phase [33] of the Delphi study, where respondents look into the question and new questions are added. In this round, it took one month to complete the Delphi questionnaire by the experts, and two (2) experts raised only two questions based on the questions sent. These are validity of Delphi questionnaire and should answer be based on the level of management of the employee in the implementation of HRMPs. Answers were provided to these promptly by sending responses to individual experts. Further, each expert was contacted individually to inform them to add new questions that have not been captured or omitted and are relevant to the study. This is the essence of the Delphi study as it is an avenue for discussion. Where there is a need for clarification, the experts were helpful to send emails and WhatsApp calls as the need arises. The round one Delphi questionnaire has thirteen (13) identified HRMPs challenges attributes. A total of nineteen (19) copies of Delphi questionnaire were sent to experts who agreed to participate in this study. In this round one, thirteen (13) experts responded promptly, whereas the other six (6) experts were sent messages as a reminder. [51] opines that the level of care, attention, and time taken by experts to answer the questionnaire depends on the level of motivation by the researcher. After round one, fifteen (15) experts responded, and the researcher analysed their responses. The results revealed the group median, the mean, standard deviation, and interquartile deviation. The remaining four (4) experts never gave reasons for not participating, even after several calls and emails. They were therefore excluded from this study. Additionally, feedbacks of round one with their rating highlighted in yellow, and the group median in a separate column highlighted in red of the round 2 Delphi questionnaire were sent to the experts.

Delphi Round 2

In round 2, experts were given the option of changing their rating if need be. Being an iteration process, the experts were expected to provide reasons for any change. All the experts agreed with the group median and non-fell out of the group median in this study. In this round, all the expects responded promptly but with the constant reminder by the researcher. The Delphi survey result is shown in Table 3. The result from Table 3 revealed that all the factors are challenges of HRMPs implementation as they all obtained a median range of 8 and above. The findings from the Delphi survey also revealed that consensus was achieved for all the listed factors as the IQD scores achieved the cut-off score for the study (IQD $\leq$ 1) (Table 1). From the findings, the impact score rating revealed that ten (10) out of the challenges had a very high impact (VHI: 9.00–10.00), while three (3) factors were scored high impact (HI: 7.00–8.99) by the experts. However, none was found not to be a challenge facing HRMPs implementation in the NCI.

In terms of mean scores ranking, political interference in the recruitment process and downsizing/layoff was jointly ranked first, while union actions and involvement were ranked 13th among the challenges. It is important to note that the researcher should not impose on experts for responses to attain consensus to achieve a good Delphi result. This act may lead.

To force consensus, which consequently affects the Delphi result validity. In the present study, experts are allowed to make decisions based on their knowledge and expertise on the subject under discussion. Further, the researcher affirmed the result in

Table 3. Challenges of HRMPs implementation in the Nigerian construction industry

Sub-attributes	(M)	($\bar{x}$)	(σx)	(IQD)	(R)
Political interference in the recruitment process	9	9.00	1.00	0.50	1
Downsizing/layoff	9	9.00	1.07	1.00	1
Government regulation	9	8.80	0.94	0.50	3
Inappropriate recruitment channels	9	8.67	1.18	0.50	4
Dwindling economic conditions	9	8.67	0.98	1.00	4
Discrimination among employee	9	8.60	1.40	0.50	6
Absence of internal and external recruitment system	9	8.60	1.12	0.50	6
Lack of good leadership development program	9	8.60	0.91	1.00	6
Globalization	9	8.47	1.46	1.00	9
Poor organisational strategy	8	8.47	0.83	1.00	10
Partial recruitment and selection processes	8	8.33	1.35	1.00	11
Poor organisation management	8	8.33	0.98	1.00	11
Union actions and involvement	9	8.33	1.23	1.00	11

M = Median, $\overline{X}$ = Mean, Σx = Standard Deviation, IQD = interquartile Deviation, R = $\bar{x}$ Ranking

the 2nd round by sending individual emails to the experts presenting a third-round Delphi questionnaire. Their responses were maintained and unchanged.

As shown in Table 3, the study identified the challenges facing HRMPs implementation in the NCI. Out of the thirteen (13) related factors, ten (10) had a very high impact (VI: 9.00–10.00), while three (3) elements were scored high impact (HI: 7.00–8.99) by the experts. However, none was found not to be a challenge facing HRMPs in the study area. [12, 52] and [17] recognized interference that involves sentiments in the recruitment process by the political office holders and highly placed individuals as well as union actions involvement as a challenge of HRMPs. Similarly, [53] and [20] argue that discrimination among employees is a challenge facing HRMP. [54] identified wrong recruitment and selection practices as a challenge of HRMPs. According to this study, wrong recruitment and selection could be classified as recruitment channels, absence of internal and external recruitment systems, and partial recruitment and selection processes. Further, [54] gave the assertion that poor organization management as a challenge of HRMPs. Therefore, the above findings confirm the assertions by the various scholars. In addition, the scores agree with the assertion that government regulation and policies, globalization, and downsizing/layoff, are challenges facing HRMP [14, 21, 55] and [17]. Moreover, the study agrees with the finding that dwindling economic conditions is HRMP challenge [17]. Also, poor organizational strategy has been identified as a challenge of HRMP. [56] and [57] emphasized the implication of this finding that good organisational strategy/objectives can influence the choice of HRMPs.

5 Conclusion and Recommendation

The study identified the challenges facing HRMPs implementation in the NCI. Based on this, the study utilised a Delphi technique which is inductive to knowledge dissemination. Regarding the Delphi results, a good consensus was reached in both rounds amongst experts on set criteria for the study. Notably, out of the initially invited nineteen (19) experts to the Delphi study, only fifteen (15) concluded the study within reasonable time frame. The study evaluated thirteen (13) challenges and according to the findings from this study, factors such as political interference in the recruitment process, downsizing/layoff, government regulation, inappropriate recruitment channels, dwindling economic conditions, discrimination among employee, absence of internal and external recruitment system, lack of good leadership development program, globalization, and union actions and involvement were ranked by the experts as the most significant challenges to HRMPs implementation with group median of 9. Other factors were also found to be significant with a group median of 8. It can be concluded from the study that top challenges to HRMPs implementation are interference in the recruitment process by the political office holders and downsizing / layoff of the workforce in the industry which does not encourage/ makes it difficult to implement these practices. However, the findings of this study are constrained in terms of the Delphi study. Only fifteen (15) experts out of the nineteen (19) experts invited completed the study in this study. There is a likelihood that the findings could have been presented differently if all invited experts participated in the Delphi study. Likewise, the study experts were from the Southwestern part of the study area including Abuja, the Federal Capital Territory; thereby making it difficult to generalise the results for the entire country. Also, the study findings view the challenges of HRMPs from the perspective of construction professionals and HRs in the industry. The practical implication of this study will give a better understanding of HRMPs for the construction managers, professionals, and HR practitioners within the construction industry on the numerous challenges to HRMPs implementation. This understanding will identify areas where improvement should be focused or which improvement will bring about the result.

Furthermore, based on the difficulties encountered during this study, recommendations from the study are as follows: the structured Delphi questionnaire should be short, clear, and easily understandable for a high response rate. Also, the instruction to experts on the Delphi process should be concise. Additionally, experts should be constantly reminded before the closing date of the submission for responses. Further, if experts need an extension of time by experts, extra time should be allowed for a new submission date. Finally, where there is a need to achieve consensus such as HRM practices studies to identify challenges to HRMPs implementation, the study encouraged the Delphi approach.

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Assessment of Compensation Mechanisms for Construction Related Occupational Accidents in Oyo State, Nigeria

Akintayo Opawole[1,2](✉), Kahilu Kajimo-Shakantu[1], and Bisola Martha Olafare[2]

[1] Department of Quantity Surveying and Construction Management, University of the Free State, Bloemfontein, South Africa
tayoappmail@gmail.com, kajimo-shakantuk@ufs.ac.za

[2] Department of Quantity Surveying, Obafemi Awolowo University, Ile-Ife, Nigeria

Abstract. The purpose of this study is to assess the compensation mechanisms that are put in place for accidents victims in the construction industry based on experience from Oyo State Southwestern Nigeria. The methodology is quantitative with in-depth literature synthesis serving as the basis for identifying the variables that were analyzed using structured questionnaire. Forty four (44) respondents distributed as 13 quantity surveyors, 4 architects, 17 engineers, 2 project managers and 5 other management officials responded from 50 randomly selected firms out of 117 registered construction contracting organizations in the study area. Data collected include types of compensation mechanisms that the firms have implemented as well as issues affecting the implementation of the Nigerian compensation Act 2010. Data collected were subjected to descriptive analysis including percentage, mean, standard deviation and Kruskal Wallis H test. The finding indicated that the employees were not satisfied with the adequacy of the country's compensation system but concluded that the level of implementation of the existing compensation Act in Nigeria is progressive and satisfactory. Results of this study will provide management of construction firms with better insights on how to improve their compensation systems and achieve better project performance and organizational objective.

Keywords: Accidents · Building · Compensation · Injury · Projects

1 Introduction

The construction sector is characterized by a variety of hazards and dangers to workers, all of which have the potential to cause injury or death [1]. Construction accidents can result in damage to human and properties both with adverse implications on the image and profitability index of a construction firm. The injury and fatality rate is regarded as higher in construction than any other industry [2]. Construction accidents negatively affect workers as victims may likely be temporarily unfit to work at some points due to serious injuries or health concerns. Such workers may suffer financial loss, depression and become psychologically traumatized [3], especially when injury is sustained in the

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workplace without commensurate compensation. Most disheartening is the fact that some victims are usually laid off when they are considered unfit any longer as a result of the fatality suffered. Labour has a significant influence on cost, quality and time objectives of projects, and management of social interactions between employees and the workplaces could be a determining factor in improving productivity.

The Workmen Compensation Act 2010 was enacted in Nigeria as instrument to manage employees' welfare in workplaces and also include for compensation of construction accidents victims [4]. This Act applies to both public and private sector organizations and ensures that employees who suffer from occupational accidents and injuries at work or in the course of their employments receive proper compensation. Therefore, employers of labour are expected to adopt the Compensation Act 2010 as a basis for the administration of compensation of workplace accidents victims.

Compensation of accidents in the Nigerian constructions appears unsatisfactory and little empirical evidence on this concept has not enabled the development of robust procedure and mechanisms. Despite the fact that the [4] establishes a general system of compensation for employees and their dependents in the event of an injury, death, disability, or sickness arising out of or in the course of employment, there appears to be low level of compliance by all parties that are involved (employers and employees).

The purpose of this study is therefore to assess the methods and mechanisms adopted in compensating construction accidents victims in the study area with a view to enhancing labour performance. There is imperativeness of more awareness of construction accidents compensation in order to actively involve both the employers and employees to ensure compliance to the provisions of cCompensation 2010. Understanding of the mechanisms in place and how these have been implemented is expected to bring into focus the information to enhance sustainable enforcement of appropriate compensation mechanisms by the construction firms. This knowledge will also provide implications for enhancing the productivity of the construction firms.

2 Literature Review

Earlier study like Christopher and Bulah [5] had established a strong correlation between employees' compensation for work related accidents and productivity. Cglar et al. [6] indicated occupational injury as comparatively high in the construction sector in developing countries which had attracted huge social costs. A case study conducted by Christopher and Bulah [5] on Mayfair Insurance Company Limited in Kenya indicated a positive significant association between compensation and employees' performance. The aspects of victims' mental, physical, social, and familial well-being are affected by compensation level, financial status, and family indebtedness. Compensation of accidents victims and social protection in construction organizations had been established to be generally low in Nigeria. A comparison of per capita GDP to social protection expenditures for six Sub-Saharan African countries, including Nigeria, shows that despite being the richest of the six, Nigeria spends a lower proportion of GDP on social protection [7].

The issue of poor compensation of accident victims amongst construction organizations has been much explained by poor policy implementation and corruption in Nigeria [8]. The economic conditions and corruption practices in Nigeria gives little room to fully implement and enforce a total compensation system, therefore employers use these as excuses. The institutions in charge of enforcing proper compensation for victims of accidents also appear ineffective. In ministries where compensation is a goal, it is not a top priority. Most of the institutions lacked mechanisms for their sustainability and effectiveness in carrying their responsibilities under compensation Act 2010. Employers are discouraged by the escalating expense of medical treatment and insurance, which leads to under-reporting of incidents to legal authorities. However, construction accidents have been considered as one barrier of innovation and development of the construction industry in many countries. It brings so many complexities in many ways. Construction accidents influence variables such as project success, quality of construction works, labour productivity and psychology of workers [9–11].

An organization is said to be good if it can compensate its employees in the long run. Despite the robust provision of the employees Compensation Act 2010, there has not been adequate evidence of the satisfactory implementation mostly by the Nigerian construction industry's operators. Several problems are associated with compensation systems and it includes that accident victims are not usually compensated and mostly left unattended to or relayed off work. Among the aims of workers' compensation is to provide for an accident victim medical care and rehabilitation services but mechanisms that are usually put in place does not usually involve such benefits. This usually discourages career progressions in the construction industry.

Compensations that exist for victims of construction accidents in Nigeria were identified in Employee compensation Act 2010, and Nigeria Social Insurance Trust Fund Document 1993. These documents, as analyzed in Adekile [12], include compensations in form of social security, monetary compensation, vocational rehabilitation and counseling, health care and related support, among others. In the Nigerian context, empirical evidence on the effect of accidents on construction workers is to a large extent inadequate. Moreover, there appears to be no sufficient data that can be used to measure the implementation of the employees' compensation Act in the construction firms. Also, there are little or no mechanisms available to ensure compliance to the Employee Compensation Act. The increase in accident rates has therefore attracted researchers' attention on ways to reduce construction accidents and ensure compliance to health and safety measures.

Although improving safety is an industry's need, there is also the need to examine compensation mechanisms put in place for accidents victims in the construction industry. Previous studies had shown that about 200 cases of accidents occur in workplaces in Nigeria daily with high fatality and mortality rates [13]. This is similar in other sectors. It is saddening that employers conceal most cases of construction accidents and secretly compensate victims with non-commensurable measures irrespective of the degree of injury suffered. Most victims are also dismissed after collecting tokens as compensation on behalf of employees. Most employers of labour usually avoid labour laws and edicts and this leaves dejected employees to no other options than to accept what is offered to them. Private sectors usually evade government policy on employees' compensation and usually win all the times.

2.1 Research Methodology

The research methodology adopted was quantitative approach with an in-depth literature analysis serving as the basis for identifying the factors that were assessed using a structured questionnaire. The use of structured questionnaire was adopted to enable easy assessment and analysis [14]. The respondents were selected by random sampling from top officials of 117 registered construction organizations in Lagos State, Nigeria. These comprised four groups as; quantity surveyors, architects, builders and engineers.

These groups were considered suitable since they are mostly involved directly in construction activities and are very familiar with workers social interaction and human resource management in the organizations. A total of 50 questionnaires were administered and a total of 44 which represents 84.5% were retrieved and found suitable for the analysis. The questionnaire comprises two segments. The section A of the questionnaire focused on personal data of the respondents such as age, gender, educational qualifications, professional qualifications and length of service, while section B focused on respondent's knowledge of compensation of accidents victims in their respective firms. The Section B of the questionnaire related to the research objective. The responses were assessed using five ratings ranging from most effective, very effective, moderately effective, least effective and ineffective, scaled at 5, 4, 3, 2 and 1, respectively. Various compensation methods were listed in tables for easy assessment by respondents.

The data retrieved were analyzed using frequency, percentage, mean score and reliability test, which was carried out to determine the reliability and internal consistency of the scales used. A Cronbach's alpha of 0.70 and above is good. From the results, all the five group of scales had Cronbach's alpha greater than 0.800, hence they were considered reliable and internally consistent.

2.2 Results and Discussions

2.3 Profile of Respondents

The profile of the respondents were analyzed based on age, gender, type of organization, years of working experience, age of organization, educational qualifications of respondents, professional qualifications, length of service. Analysis of the respondents' gender showed that most of the respondents, 38 (86.4%), were males, while 6 (13.6%) were females.

The highest proportion of the respondents group, 17 (38.6%), were engineers. Closely followed were quantity surveyors, 12 (27.3%). The least proportion of respondents, 3 (6.82%) were project managers. An evaluation of the highest academic qualifications of the respondents shows that more than half of the respondents, and 23 (52.3%) had bachelor of science/HND. About 19 (43.2%) were Masters Degree holders. In respect of the professional affiliations of the respondents, the result showed that a significant portion of the respondents, 28 (63.6%), were affiliated with Nigeria Institute of Quantity Surveying/NIQS, about 9 (20.5%) were affiliated with Council for the Regulation of Engineering in Nigeria (COREN). More than half of the respondents' organizations

Table 1. Profile of the respondents

Variable	Frequency	x	Fx	%
Gender of respondent				
Male	38			86.4
Female	6			13.6
Total	44			
Type of respondent				
Quantity surveyor	13			29.6
Architect	5			11.36
Engineer	17			38.6
Project manager	3			6.82
Others	6			13.6
Total	44			
Highest academic qualifications				
OND/NCE	1			2.3
HND/B.Sc	23			52.3
M.sc	19			43.2
PhD	1			2.3
Total	44			
Professional affiliations				
MNIQS	29			65.9
ARCON	1			2.3
COREN	9			20.5
HSE 123	4			9.1
NIA	1			2.3
Total	44			
Working experience				
1–5years	12	3	36	27.3
6–10years	17	8	136	38.6
11–15 years	8	13	104	18.2
16–20 years	2	18	36	4.5
above 20 years	5	23	115	11.4
Total	44			

MNIQS = member of Nigeria institute of quantity surveyors; ARCON = Architect registration council of Nigeria; NIA = Nigeria institute of Architects

(65.2%), have been in existence for more than ten years. The highest portion of the respondents, 17 (38.6%) had between 6 to 10 years working experience. Those with 1 to 5 years of work experience represented 12 (27.3%). The mean score for years of experience is 9.5 years. The overall results of the analysis adequately justify that the respondents are very suitable, reliable and experienced to provide reliable data for this study.

2.4 Evaluation of the Various Compensation Mechanisms Used by the Firms

The result in Table 1 shows the mean score, standard deviation, and Kruskal-Wallis test of the level of effectiveness of the mechanisms and methods adopted in compensating construction accident victims as rated by the four respondents' groups. The top ranked mechanisms of compensation was provision of health care and rehabilitation. This has a mean score of 4.02 which indicates that it has been reasonably adopted and very effective in compensating construction accidents victims. The provision of health care and rehabilitation for victims will help cure their injury and diseases and also restore the victim to his/ her former position before the accident. The finding agrees with provision of health care and related support as indicated in Adekile [12].

Adequate training of persons, health and safety education, welfare packages for victims, psychological needs, physical needs, food, and clothing, and considerate work schedules ranked second, third, fourth, fifth, sixth, and seventh with mean score of 3.86, 3.77, 3.74. 3.67, 3.67, and 3.63, respectively. These variables are substantially social measures and their high ranking suggests that the mechanisms and methods when adopted could be very effective in compensating victims of construction accidents. The significance of these mechanisms as social measures had been earlier justified in [6], where it was recommended that working without social security should be discouraged. The least five ranked mechanisms and methods adopted in compensating victims of construction accident were provision of monthly compensation payments to dependants for their life time, creation of collective liability shared among employers, establishment of a state managed compensation fund (SMCF), payment of debts, promotion at work, and bonuses after resuming to work with mean score 3.21, 3.09, 3.07, 3.05, 3.02, and 2.91, respectively. These were also interpreted as effective or moderately effective on the scale of assessment in the questionnaire and indicated that the methods and mechanisms were also moderately effective when adopted.

Kruskal-Wallis test was employed to determine whether the perceptions of the respondents across their professional designations were significantly different on the level of effectiveness of the examined mechanisms and methods of compensating victims of construction accidents at 0.05 level of significance. The result indicated that the views of the respondents were unanimous except on one of the 18 variables for compensating victims of construction accidents examined, which had a p-value less than 0.05. This method is bonuses after resuming back to work (p-value = 0.013). This implies that the perception of the respondent about bonuses after resuming back to work is significantly different.

Table 2. Mechanisms and methods adopted in compensating accident victims

Factors	M	SD	R	KW-Test**
Provision of health care and rehabilitation	4.02	0.91	1	0.114
Adequate training of persons	3.86	1.08	2	0.166
Health and safety education	3.77	1.09	3	0.244
Welfare packages for victims	3.74	0.82	4	0.279
Provision of psychological needs	3.67	0.92	5	0.135
Provision of physical needs	3.67	1.11	6	0.688
Moderate work schedules	3.63	0.98	7	0.437
Construction of better health facilities for better health care	3.49	1.26	8	0.469
Social needs e.g. belongingness, affection, love	3.37	0.95	9	0.563
Extension of payment of compensation to victims or dependents of deceased	3.35	1.15	10	0.261
Payment of compensation to the dependents of deceased	3.33	0.94	11	0.607
Lower cost of medical treatments	3.26	1.20	12	0.684
Provision for monthly compensation payments to dependants for their lifetime	3.21	1.30	13	0.250
Creation of collective liability shared among employers	3.09	0.92	14	0.335
Establishment of a state managed compensation fund	3.07	1.20	15	0.521
Payment of debts incurred for medical attention	3.05	1.38	16	0.167
Promotion not affected by period of treatment	3.02	1.19	17	0.122
Bonuses after resuming back to work	2.91	1.04	18	0.013*

KW-Test** = Kruskal Wallis H Test, M = Mean, SD = Standard Deviation, R = rank.

2.5 Rating of the Methods and Mechanisms of Compensation

Table 2 shows the frequency distribution and cross tabulation of the respondents' views in respect of critical issues relating to methods of compensation of accidents victims in the construction organizations. Overall, 14 (34.1%) of the respondents indicated that organizations sensitize employers and employees about compensation policies put in place while 26 (63.4%) said their organizations do not. This may be attributed to many organizations trying to avoid their responsibilities in an attempt to reducing expenses. The escalation in cost of injuries largely attributed to rising cost of medical treatment and insurance also discourages employers and this causes under-reporting of accidents Table 3.

About 33 (75.0%) of the respondents affirmed that organizations that are practicing total compensation for their employees seem more likely to succeed while 11 (25.0%) disagreed. Organizations practicing total compensation will have a higher success rate because total compensation will motivate workers and increase their efficiency. This

Table 3. Rating on the methods and mechanisms of compensation

Factor	Very poor		Poor		Fair		Good		Excellent		Mean	SD
	F	%	F	%	F	%	F	%	F	%		
How would you assess the compensation plan for accident victims in your establishment?	2	4.7	3	7.0	14	32.6	0	23.3	14	32.6	3.72	1.141
How would you assess the level of compliance of your firm to the Employee compensation Act of 2010?	0	0.0	6	14.0	13	30.2	5	34.9	9	20.9	3.63	.976
How is the relationship between the management and the workers?	0	0.0	5	11.4	16	36.4	12	27.3	11	25.0	3.66	.987
How would you rate the motivation system in this organization?	0	0.0	7	15.9	12	27.3	1	25.0	14	31.8	3.73	1.086
How is the compensation system in the construction industry?	2	4.5	10	22.7	19	43.2	9	20.5	4	9.1	3.07	.998
How would you assess the level of victims' turnover in your firm after compensation	1	2.3	10	23.3	12	27.9	5	34.9	5	11.6	3.30	1.036
How would you assess the level of implementation of the compensation Act in Nigeria?	5	11.4	11	25.0	20	45.5	7	15.9	1	2.3	2.73	.949

findings agree with those of earlier studies like [9, 10] with regards to labour productivity and project success.

Moreover, about 34 (79.1%) of the respondents indicated that workers' right to claim rightful compensations has never been encroached on before. This may be because some of the respondents have experienced no or little form of critical accident at work. More than half of the respondents, 32 (72.7%), agreed that equitable compensation systems result in high productivity and achievement of organizational goals while 12 (27.3%) disagreed. Most of the respondents, 42 (95.5%) indicated that they are not satisfied with the Nigerian construction industry's compensation system. This may be due to lack of transparency and accountability of public funds and lack of legal framework to ensure compliance to the employee compensation Act of 2010.

3 Conclusion

Construction accidents potentially affect human and properties both with adverse implications on the image and profitability index of a construction organization. The findings in this study revealed that the top ranked mechanisms and methods of compensation were provision of health care and rehabilitation, adequate training of persons, health and safety education, welfare packages for victims, psychological needs, physical needs, and considerate work schedules.

Respondents' opinion regarding rating of the mechanisms adopted were unanimous except in one (bonuses after resuming back to work, p-value = 0.013) of the mechanisms and methods of compensating victims of construction accidents where significant difference in their views were observed. The study also established a general level of dissatisfaction by the respondents on the Nigerian construction's compensation system but concluded that the level of implementation of the compensation Act 2010 is fair.

These findings support existing studies that revealed that organization that adopt efficient compensation system for their employees seem more likely to succeed and that equitable compensation systems result in high productivity and achievement of organizational objective. The robustness of these findings would largely improve by increasing the sample size and adopting mixed methodology involving interview.

3.1 Implications of the Findings

The study highlights the methods and mechanisms that can be adopted in compensating construction accidents victims in the construction industry for improving the productivity of the employees and the industry at large. This study also provides information relating to compensation of accidents victims that could enhance sustainable enforcement of appropriate compensation mechanisms by the construction organizations. This will provide implications for enhancing the productivity of the construction organizations.

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A Review of Effective Strategies for Retaining Female Professionals in the Construction Industry

Nondumiso Sangweni and Obinna Ozumba(✉)

School of Construction Economics and Management, Universityu of the Witwatersrand Johannesburg, Johannesburg, South Africa
0305617r@students.wits.ac.za, obinna.ozumba@wits.ac.za

Abstract. The Advancement of women is imperative for gender equality and sustainable development. Issues about women in construction exist globally and have been analysed from socioeconomic perspectives to women's inclusion in social capital. Most studies focus on challenges experienced by professional females in the construction industry. As a gap exists in the identification and proposal of solutions to identified challenges, especially the lack of emphasis on the effectiveness of retention strategies for female professionals. The current study investigates the existence or lack thereof, of effective strategies for the retention of female professionals in the construction industry. While the current paper is limited to literature review of reported interventions, findings indicate that current emergent patterns identify retention as an influencing factor in career development strategies of women in construction. The current paper substantiates the research gap and determines existing interventions, their adoption, and effectiveness in the retention of female professionals in the industry.

Keywords: Construction · Retention · Sustainability · Social impact

1 Introduction

The construction industry is the most vital integrals of any country's economy as far as infrastructure development is concerned. According to [1], the construction industry consists of a variety of activities that range from planning, design, procurement phase, and execution of infrastructure projects. According to [2] in South Africa, the contribution of the construction industry to the growth domestic product (GDP) figures has consistently exceeded 8% since 2007. Despite these contributions, the bottlenecks continue to persistent when it comes to infrastructure development [3]. In most countries globally, the construction industry has been male-dominated [4]. In developed and developing countries, the construction sector is described as 'an unwelcoming environment for women [5]. Othman & Jaafar [6] recognised the global marginalisation of women in the construction industry. In South Africa, the Construction Industry Development Board (CIDB) report of 2021 indicated that the construction industry employed roughly 1 222 000 individuals at the end of 2021 Quarter 2, with 87% of men and 13% of women,

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indicating a greater underrepresentation. The local construction industry has the highest percentage of male representation at 89%, compared to an average of 56% for other industries. [7, 8] also emphasize that post-1994 South Africa has recorded the most positive legislative and empowerment enabling period for women, yet there is still apparent exclude women, both professionally and at skills and crafts level.

2 Literature Review

The employment of female professionals is of significant interest and has been addressed by various scholars. Women professionals are an essential feature since they offer a largely untapped talent of human capital in the face of global demand for highly qualified persons. Women's abilities are frequently underutilized in the construction industry, [9]. The construction industry is a growing sector with a continually increasing demand for knowledgeable and competent professional workforce, which is still starved of female professionals [10].

Even though the construction industry is the largest employer of labour [11–13], other scholars have confirmed that most of its employees are male. Although the industry is a vital contributor to the economy of any country, it is still affected by negative perceptions [14]. According to [15], the male-centric culture in the construction sector continues to be accused of ignoring women's value by allowing the hostile atmosphere developed by sexist behavior and the use of sexist terminology. Furthermore, as reiterated by [16], the sexist male-dominant culture hinders women's progress within the construction industry.

Retention of employees at any level within an organization serves a vital function of HRM (Human Resource Management). Kossivi et al. [17] describes employee retention as a phenomenon of encouraging employees to continue working for an organisation for several years. The retention of employees exists to ensure the existence of a productive workforce that feeds the operational needs of the construction industry. There are notable obstacles that deter entry, development, and female retentivity in the construction sector [13]. According to [18], retention begins by having a clearly defined job description, orientation programs, followed by practical and capable recruitment drives and selections. There are numerous factors affecting women retention after they have conquered the deterrent factors that may hinder their entry into the construction sector; these factors affecting women's retention in construction fall under the work environment and work-life balance or private life demands [19].

From the foregoing, most studies merely suggest that current strategies for retaining female professionals in the construction industry are not effective, as evidenced by the trend of unexpected early departure of female professions from the industry. However, such indications are mostly unexplored in detail, in terms of the specific factors that determine the retention of women, and their nature and occurrence, and a measurement of the effectiveness of various strategies, as implemented by organizations. The current paper is therefore aimed at exploring the nature and occurrences of strategies adopted in the retention of professional female professionals in the construction industry to evaluate their effectiveness.

3 Methodology for the Study

The stated aim was achieved through a systematic review of extant literature. The methodology, findings, and discussion are presented hereunder. The study used a systematic literature review methodology to explore the retention of female professionals in the construction industry and establish the effectiveness of those retention strategies. A systematic review of literature is where all procedures are documented, and the research audit trail of databases and search terms are made explicit. Parahoo [20] suggests that a systematic review should detail the time frame within which the literature selection occurs, and the methods used to evaluate and synthesize the findings of the studies in question. Moustaghfir [21] emphasized the need for the approach to be "replicable, scientific and transparent," and provide an "audit trail of reviewers' decisions, procedures, and conclusions." The author further describes the stages of a systematic review, which are based on the methodology of [22]:

- Produce a review protocol for the review, with a consultation panel.
- Identify keywords and construct these into search strings.
- Select databases.
- Analyse identified papers (via their abstracts) and evaluate according to the agreed inclusion/exclusion criteria.
- Import selected papers into a reference management database (in this case, Procite was used). These papers are then subject to a process which termed "peer review", to set a quality assessment criterion: An explicit account of the theory, a succinct statement of objectives, a clear description of the context, adequately chosen sample, appropriate data analysis method clearly described, appropriate interpretation of data and findings relevant to theory.

Figure 1 illustrates the steps taken to conduct a systematic review. The steps were developed to answer the following research questions:

- What strategies are implemented in improving retention of female professionals in South Africa's construction industry and how effective are these strategies?
- What are the factors that would contribute retention of female professionals in the construction industry?

The first step involved the identification of relevant literature through Boolean searches of the following selected databases i.e. Web of Science, Emerald, ARCOM, JSTOR, Taylor & Francis, and Google Scholar). The search terms and the following keywords were used: "retention," "engineers," "career development," "feminism," "glass ceiling," "construction industry," "gender," "talent," "women." The search was performed to obtain the current information to establish a comprehensive view of retention of professional female professionals in the construction industry in the 21st century; the searches were restricted to studies between 2008 and 2019. The preliminary search resulted in 700 hits of related works that included empirical, theoretical, and conceptual studies, in articles, unpublished dissertations, books, conference papers, and official documents. However, after a comprehensive of reviewing the abstracts and removing

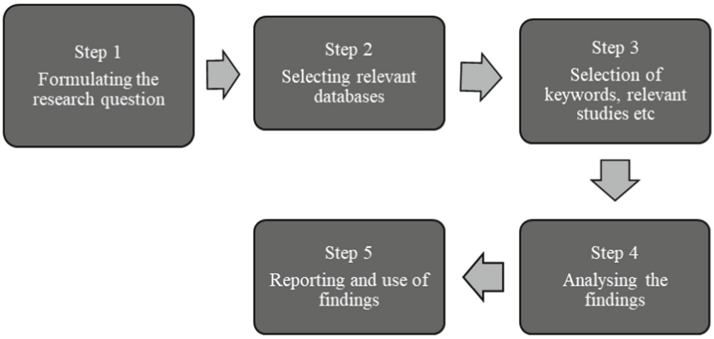

Fig. 1. Approach to systematic literature review.

duplicated papers and articles not aligned to the study, 60 papers were retained for further analysis. These papers were analysed using descriptive and thematic analysis. The analysis went through six stages through the inductive approach i.e. familiarization, coding, generating themes, reviewing themes, defining, and naming themes, writing up. A thematic map was formed in ensuring that distinctive themes were identified properly. The analysis software tool that was used was Linguistic Inquiry and Word Count program (LIWC).

4 Findings from Systematic Literature Review

4.1 Results from Descriptive Analysis

Research studies on the topic were steady during the first five years of the twenty-first century, with 30% of all works published from 2009 to 2013 and 40% published from 2014 to 2018 and a yearly average publication of 6 and 2. However, the last five-year period considered has been more prominent, doubling research output with a yearly average of 6. The year 2017 is highlighted as the year with most publications Fig. 2, Australia and United Kingdom being the majority contributors in this topic. In 2018, the publications dropped significantly by more than 50% compared to the highest peak in 2017. In 2018, South-East Asia emerged as one of the contributors, which has not been the case at the beginning of 2009.

4.2 Results from Thematic Analysis

Results from thematic analysis of literature review findings are presented below, highlighting key authors with prominent themes emerging from the period of 2009–2019. Identified factors that influence the retention of employees in organizations include: human capital factors, individual factors, and organizational factors. They are further broken down under discussion of emergent themes in Sect. 5.

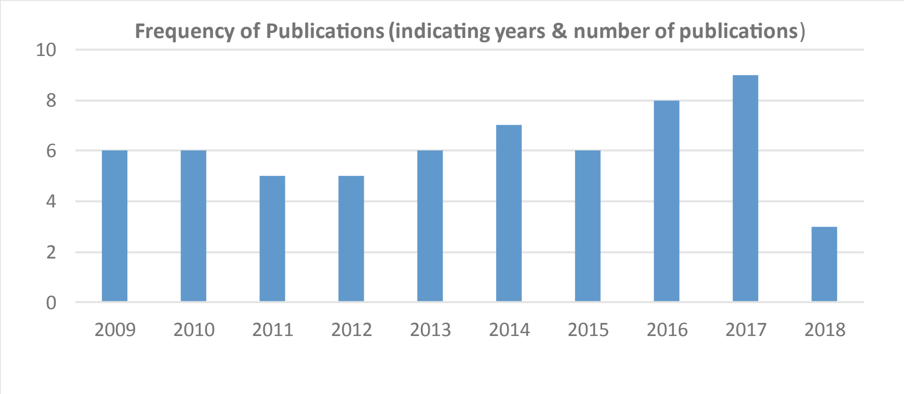

Fig. 2. Frequency of publications

5 Discussion of Emergent Themes with Key Authors

5.1 Professional Women's Career Development

Following the preceding analysis, Sect. 5 presents a discussion of the emergent themes from the perspectives of key authors identified in the systematic literature search in Fig. 3. Francis [23] investigated factors that influence professional women's career development and progression. In [23], the findings indicated that in individual factors like family variables, having children had a medium effect in hindering the career advancement of women in construction, especially when there is domestic assistance in the family. With personal variables, a vibrant personality had no vital correlation with women's career advancement, and it was, therefore, not considered a good predictor of success. The main findings by [23] were that the individual factors had the most significant influence on women's career progression and retention compared to interpersonal and organizational factors.

Moshupi [24] reviewed the career developmental experiences of women in senior positions within the civil engineering industry in South Africa. It was found that their experiences consisted of different factors that influenced their career choices, but their own will mainly drove the choice. Kaewsri and Tongthong [25] conducted an empirical review of the operational roles of professional women within the Thai construction industry. The lack of fieldwork knowledge was found to be the biggest hindrance to women's career advancement, which also affected women's performance in their duties. This was caused by women's refusal to perform site-based work on one hand and the lack of opportunities to perform site-based work on the other hand. In the study conducted by [26], findings revealed that the glass ceiling has a 27.4% influence on woman career development and retention among the female employees working in a private sector in Sri Lanka; further alluding that glass ceiling and women career development have a moderate negative relationship.

5.2 Career Barriers

English and Le Jeune [8] found that the construction industry culture ranked as the number one barrier that struggles to integrate women entering the construction industry. When referring to professionals, on-site stereotypes do exist. Men believe women are there to carry out administrative tasks, to take care of customers, and to answer the telephone: "On the phone, people assume you are in an office and ask whom they will see on-site" [27]. Aneke [28] concluded that hindrances that women entrepreneurs face in construction remain embedded in sociocultural factors that view women with a patriarchal lens. It becomes fruitless to talk about women retention when early attraction programs remain un-implemented and un-enforced by construction companies within the industry.

5.3 Mentorship and Sponsorship

Ganiron [29] analyzed the extent to which social capital served as a predictor of civil engineer success towards a career development program in the Philippines. The study employed survey questionnaires and unstructured interviews. Analysis of data was undertaken to obtain frequency and percentage count, weighted mean, correlation analysis, and multiple regression analysis. The study found that the most successful civil engineer is one that has acquired technical skills and employability through mentors, networks, and professional linkages. Further, high social capital plays a vital role in aspiring individuals to be successful civil engineers. The most objectively successful civil engineer appears to be one who possesses technical and other employable skills.

Helms et al. [30] conducted a study to explore the importance of mentoring and sponsorship in women's career development in the United States of America. They conducted data collection with the use of focus group discussions involving 16 prominent women leaders in the state of Tennessee. The study employed a qualitative analysis method involving hand-coding rather than a content analysis software program. Six key themes emerged from the study; the long-term aspect of mentoring, the formal and informal nature of mentoring, the need to mentor others once mentored, the non-linear relationship between mentoring and sponsorship and the need for internal training through mentors and sponsors to enhance the career development of women. The overall finding that emerged from the study was that mentoring brought about organisational benefits; it aided fostering commitment, retention of women in the workplace as well as improvements in productivity. This is despite the costs that are associated with mentorship in terms of time commitment.

5.4 Management

Nesbit and Seeger [31] conducted a study to review the actions of thirty Australian organisations within the finance and insurance, construction and engineering, and health and community sectors to create conducive work environments that support and enhance the advancement of women into management roles. The study employed both qualitative and quantitative methods. Quantitative data on the extent to which various actions that were implemented were obtained from compulsory organisational annual reports submitted to the Equal Opportunity for Women Agency. Qualitative data was collected through semi-structured telephonic interviews with respondents, including human resources managers.

The organisational activities that were reported by firms to support women include part-time work, wide range of ordinary working hours, daycare facilities, assistance for women returning from maternity leave, breastfeeding facilities, paid maternity leave, part-time managerial roles, review of salaries to decrease gender gap, identification and promotion of high potential women, and leadership training specifically for women. Despite these actions reported by organisations, the study found little improvement in women representation in managerial positions in the three investigated industry sectors. In the study, female managers found it hard to balance work and family roles and were forced to opt-out of managerial careers as a result. A lack of flexibility in managerial roles was found to be a contributing factor to the departure of females from managerial roles.

5.5 Supportive Environment

Kaewsri and Tongthong [25] conducted an empirical review of the operational roles of professional women within the Thai construction industry. Lack of fieldwork knowledge was the biggest hindrance to women's career advancement, which also affected women's performance in their duties; this was caused by women's refusal to perform site-based work on one hand and the lack of opportunities to perform site-based work on the other hand.

6 Conclusion

This study has examined published literature on the strategies that organizations adopt in the retention of professional female professionals in the construction industry. One of the key effective strategies that emerged was changing the male culture by promoting equitable and fair training opportunities for all the employees, thus encouraging women to stay longer within the industry. This can be achieved by creating explicit organizational policies for promotion and succession management. Another strategy that seemed to gain momentum is increasing gender diversity by looking at performance appraisal system that recognizes individuals' abilities and traits rather than rewarding behavioral uniformity only. One of the key factors that were identified in the literature that contribute to the retention of female professionals in the construction industry include the provision of role models, mentors, and as they are essential in a woman's professional development and retention. The other factor identified was networking opportunities that enables women to know about opportunities that exist within the organization. Through a systematic literature review of published papers between 2009 and 2018 and despite extra caution taken to ensure that the study methodology is in-depth, search results may vary if the electronic search is conducted on different days. Regardless, an effort was made to access relevant literature from a wide range of sources and covering a decade of research on the topic. Thus, the results provide a reasonable basis for further research.

From the systematic literature review, the results show that despite the significant economic contribution of the construction industry, there are persistent challenges, which include skills shortages. One major issue is the phenomenon of female professional females entering the construction industry and exiting, as opposed to following a career development path within the industry. The critical research outcome for this study can therefore be stated as:

> There is a need to critically understand the retention of female professionals in the construction industry, with a critical look at the relevant features, the design and operation of existing strategies, the strengths, weaknesses, opportunities, and threats, in order to determine relevant generic and contextual improvements, with adequate sensitivity to the experience of organisations and individuals.

To explore this area, pertinent questions will focus on the plans or strategies for the retention of female professionals and their effectiveness. There will be a need to explore the existing narratives and realities constructed by relevant players. There is a need for a sound theoretical framework to underpin the proposed study. Thus far from the study presented, the currently proposed framework is adapted from psychological theories, organizational theories, social theories, and economic theories from [23, 26, 29–32] and [16]. The above-mentioned theories will be used to define concepts and explain the retention of professional women in construction, in addition to others. Critical theories to be explored include human capital theories, non-economic, feminist or gender theories, traditional career models, changing family structures, and life course perspective of women's careers. Scope. There will also be a need for a sound conceptual framework for empirical studies. Proposed future studies should be based on the outcomes of the current paper, thus expanding the basis for an in-depth empirical study, which will provide further substantiation.

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Significant Cultural Intelligence Attributes for Performance Effectiveness in Cross-Organisational Project Teams

Florence Yaa Akyaa Ellis[1(✉)], Titus Ebenezer Kwofie[2,3], Clinton Aigbavboa[4], Didibhuku Thwala[5], and Samuel Amos-Abanyie[6]

[1] Department of Human Resource and Organisational Development, School of Business. Kwame, Nkrumah University of Science and Technology, Kumasi, Ghana
floellis@knust.edu.gh

[2] Cidb Centre of Excellence, Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa
tekwofie.cap@knust.edu.gh

[3] Department of Architecture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[4] Cidb Centre of Excellence, Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa
caigbavboa@uj.ac.za

[5] Department of Civil Engineering, College of Engineering, Science and Technology, University of South Africa (UNISA), Johannesburg, South Africa
thwaladw@unisa.ac.za

[6] Department of Architecture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
s.amos-abanyie.cap@knust.edu.gh

Abstract. The link between cross-organisational cultural intelligence (COCI) and performance effectiveness is deemed critical for dealing with culture differences in cross-organizational context, selecting employees with high COCI and optimizing effectiveness of boundary-spanning activities. However, the understanding of this linkage is lacking in existing literature. The aim of this study is to determine the significant cross-organisational cultural intelligence attributes on performance effectiveness in teams and organisations in project delivery. Data was collected from professionals in project teams and organisations involved in project delivery using a deductive questionnaire survey. Logistic regression and neural networks were used to investigate the impact of various forms of cross-organisational cultural intelligence attributes on performance effectiveness. The findings reveal that, varied forms of cognition, motivation, collaborative and behavioural adaptability dimensions of cross-organizational cultural intelligence attributes significantly impact on productivity and efficiency domains of performance effectiveness in cross-organizational teams and boundary-spanning activities. This suggests that the relationship between COCI and performance effectiveness is significant. This understanding can help cross-organizations engender high cultural intelligence to ameliorate cultural barriers, improve relationship and effectively manage complexity, interdependencies, managing roles and accountabilities so as to engender performance effectiveness. This can facilitate the development of key COCI

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among cross-cultural teams and organisations necessary for key task functions and boundary-spanning activities in project delivery in highly culturally diverse contexts.

Keywords: Cultural intelligence · Cross-organisational teams · Performance effectiveness · Productivity and efficiency

1 Introduction

Cross-boundary activities, globalization and international activities of project teams and project organizations have made the need for effective cross-cultural interaction and business links the more significant in project delivery. This need places premium on knowledge and competence about different cultures in project teams and organizations [1, 2]. Cross-cultural intelligence has been noted as organizational building blocks for teamwork, organizational effectiveness, performance and project success [1, 3]. The construction industry is said to be the most heavily culturally induced sector making teamwork and project organisations highly dependent on cross-cultural intelligence to ensure effectiveness and efficiency in task functions and interactions [2, 3]. The industry continues to rely on diverse teams and organisations to deliver projects and achieve goals through task performance [3]. As the industry continues to expand into global markets and becomes highly internationalized, project teams and organisations become cross-culturally diverse [1, 4].

Within such team and organizational dynamics, the performance and effectiveness of task functions of such culturally diverse teams and organizations' projects activities depend on their cross-cultural intelligence. Zhou et al. [1] alluded that addressing cultural differences in multi-teams and cross-organisations requires the selection of participants with high cross-organisational cultural intelligence. Emerging studies support that, high cross-cultural intelligence can significantly enhance performance, managerial effectiveness, team cohesion and success. Other studies also averred that, project teams' and organisations' awareness of cultural intelligence is vital for the ability to cope with multi-cultural situations, to perform in culturally diverse work teams, facilitate effective cross-cultural adjustment to manage cultural shock, decision making and influence project team dynamics [2, 3, 5].

With this significance, the urge for project organisations and teams to address cross-organisational cultural diversities through cultural intelligence to increase team performance, project success, efficiency and cohesion has becomes more critical. Currently, given the trends and dynamics of the industry, teams and organisations are confronted with people and participants with diverse cultural backgrounds to work together in diverse organizational settings [3]. This creates a situation where multi-teams and cross organisations with varied cultural backgrounds and diversity are required to work in harmony for project success [6]. Thus, it is significant for multi-teams and cross-cultural organisations to evaluate and gain an understanding of key COCI and the right balance between team effectiveness, performance, success and managerial effectiveness [1, 2, 6]. In the current state of the construction project delivery process, many projects delivered by multi-teams and project organisations are plagued with strained relationships, complex and uncertain external environments, boundary-spanning ineffectiveness, lack of success and managerial inefficiencies that are often resulting from low cross-organisational cultural intelligence and extreme culturally diversified project environment.

However, the potential for improvement could be substantial as some studies have demonstrated that enhanced cost and time success, team satisfaction, managerial and performance effectiveness can be achieved by understanding and improving the COCI of the team and organization [3, 4, 8]. Literature is replete with various forms of cross teams and organizational cultural intelligence criteria. However, it remains to be tested if these criteria are relevant to performance effectiveness. There is a seeming lack of understanding of the significant COCI that influence performance effectiveness in construction project delivery environment. Yeager and Nafukho [3] and Delgado Piña et al. [8] suggested that, the critical cross-organisational intelligence attributes that influence performance effectiveness, managerial effectiveness, project success and relationship management may differ. Given that studies exploring the significant cross-organisational cultural intelligence attributes on performance effectiveness is lacking, this study is positioned to fill this gap. The aim of this study is to explore the critical COCI attributes of multi-teams and cross-organizational teams on performance effectiveness. The understanding of the significant cultural intelligence attributes can be useful for multi-teams and cross organisations to apply themselves to these attributes so as to optimize performance effectiveness as modern project teams and organizations are facing complex and uncertain external environments due to cultural diversities.

2 Theoretical Background: Cross-Organizational and Team Cultural Intelligence

Cross-organizational and team cultural intelligence (COCI) is consistently conceptualized and operationalized as an ability of individuals in teams and organisations to interact effectively with persons from different teams, groups and organizational cultures [1, 5, 7]. The theoretical antecedents and foundations of cross-cultural intelligence are often based on the interactions, organizational systems and networks between an organization, groups, teams and its environment [9]. According to Lee and Sawang [10] cross-organisational team and group interactions, organizational systems and networks are premised on boundary-spanning activities. It is reckon that the success and effectiveness of boundary-spanning activities demands boundary spanners to develop corresponding abilities [9]. In this regard, Zhou et al. [1] identified team and organisational culture to have significant impact on boundary-spanning activities and performance effectiveness of the team and organisations in cross interactions and activities.

Lee and Sawang [10] defined group or organisational culture as the outline of collective values that define appropriate attitudes and behaviours and establish what is important for group or organizational members. Mishra et al. [6] alluded that, group or organisational culture significantly delineates the acceptable behaviour and the approach to addressing problems among participants in an organization, groups and teams. Schoen [5] and Sahadev et al. [11] recognized variabilities in teams and organisational cultures and thus identified COCI as being an important levelling factor for team and organisational effectiveness and performance. Given that team and organisational cultural differences often breed challenges to boundary-spanning activities and impact on performance, it should drive the need for the cross-organisational cultural attributes that can ameliorate these challenges. It is noted that, distinct cultures exhibited by teams, groups and organisations often induce varied behavioural patterns, activities, avoidance, orientation, performance, assertiveness, collectivism, power distance, masculinity and gender egalitarianism [5, 7, 12, 13].

From extant literature, the Hofstede Framework and GLOBE Study have been the two dominant focal domain conceptual approach in cultural reference models for teams, groups and organisations [5, 6]. COCI is often perceived as a personal ability expressed in the context of teams, groups and cross-organisational boundaries [1, 2, 10, 14]. Boundary spanning activates require intelligence to break cultural barriers and difference in teams, groups and cross-organisations [7, 12]. Williams [15] and Shcoen [5] noted that building sustainable relationships, effective management of influence and negotiation and managing complexities, interdependencies, roles, accountabilities and motivation must remain core skills and competencies of effective boundary spanners especially in culturally induced teams and organisations.

In the context of construction project delivery, sustaining relationships and managing complexities, interdependencies, roles, accountabilities and motivation have become the main tents of cross-organisational cultural intelligence in boundary spanning activities for teamwork, groups and organisations [5, 10, 13]. However, there has been markedly varied definitions and conceptualization of cultural intelligence. The noted variations primarily hinge on the number and type of factors that constitute cultural intelligence [16]. Cultural intelligence is often referred to as the ability of an individual to function effectively in culturally varied and diverse situations in teams, work groups and organization [16, 17]. Regularly cultural intelligence and cross-organisational cultural intelligence have been used consistently to refer to teams, groups and organisations [1, 5, 14, 17–19].

Earley and Ang [16] and Triandis [20] operationalized and measured cross-organizational cultural intelligence in the context of boundary spanning activities and delineated meta-cognitive, cognitive, motivational and behavioural dimensions as the domains of cultural intelligence. This has become the fulcrum of most emerging works on cultural intelligence. However, in recent times, cross-organisational cultural intelligence has been deemed distinct and has primarily focused and emphasized on organizational cultural differences especially in teams, groups and cross organization [18, 21]. From this perspective, COCI has been operationalized as a multi-faceted and multi-dimensional construct which include cognitive, motivational and behavioural elements [1, 5, 22]. Zhou et al. [1] validated a scale to measure cross-organisational cultural intelligence using a multi-dimensional concept to develop four domain of COCI. These were consistent with expert opinions and prior literature. These domains were cognition, motivation, collaborative communication and behavioural adaptability [1]. The four facets reflected the various aspects of COCI which have been theoretically expressed in extant literature.

2.1 Measurement Attributes of Cross-Organisational Cultural Intelligence

From the four facets of cross-organisational cultural intelligence delineated by Zhou et al. [1], the cognition dimension refers to cognitive cultural intelligence which relate to general knowledge of different cultures [11, 18, 23]. The cognitive domain causes cultural difference in teams, groups and organisations that are epitomized in the organizational practices variations [24]. The interactions among teams, groups and cross organisations employ the cognitive cultural intelligence to perceive the differences in visible organizational practices which often triggers subconscious aspects of employees and participants [1, 25]. This is measured by how the working style, operational mode, the organizational structure, knowledge of the working process, knowledge of their organizational culture and working atmosphere and cooperation of the organization is known and accepted by them [1, 6, 25, 26].

The motivation domain explains the willingness of an individual to interact with the members of other organizations [1, 21, 22]. Zhou et al. [1] alluded that, a highly motivated participants in teams, group and organisations, are able to interact effectively with co-workers to increase organizational performance in boundary-spanning activities. The motivation in the organisational cultural intelligence context measures how participants enjoy interacting with others, learn to coordinate the cultural differences between different organizations, participate in the cooperation with their organization and understand the style of other organizations actively [1, 6, 12, 23, 26, 27]. Collaborative communication dimension on the other hand focuses on the ability of an individual in a team or organization to effectively and appropriately share information and communicate with the members from other teams and organizations [1]. Zhou et al. [1] operationalized the collaborative communication dimension in COCI and found maintaining good cooperation with their organization, harmonious interpersonal relations with others, actively communicating with other participants and effectively handling exactly the conflicts caused by inter-organizational cultural differences and valid measurable criteria. Ohme and Zacher [28] proved that high COCI precipitates good communication with others in boundary-spanning activities that make employees develop harmonious relationship with other organizational members.

Behavioural adaptability dimension refers to the individual's ability to change behaviour in order to adapt to different organizational cultures and environment [1, 20]. In the notion of Zhou et al. [1] and Ohme and Zacher [28], behavioural adaptability brings stability and ability to adjust their thinking style and behaviour to the situations of different organizational cultures. Ohme and Zacher [28] found that behaviour adaptability among teams, groups and organisational work place promotes good attitude and mindset to work demands and ultimately promotes individual development and task performance especially in boundary-spanning activities. In this sense, Zhou et al. [1] accounted that, behaviour adaptability is often measured by ability to alter non-verbal behaviour, verbal behaviour, facial expressions as needed to adapt to other organizations, teams and workgroups.

2.2 Performance Effectiveness of Organizational Teams and Groups

Performance effectiveness of organizational teams or groups has dominantly been operationalized in two models that can be distinguished as an objective measure of the degree of real productivity [29, 30] or as a multi-dimensional assessment to embrace other criteria in addition to productivity [31, 32]. From the multi-dimensional domain, several models have emerged that embrace satisfaction or commitment in addition to productivity [33, 34]. In Cohen and Bailey [35] effectiveness was categorized into three main domains and delineated performance effectiveness as the multi-dimensional perspective of productivity and efficiency. The approach by Cohen and Bailey [35] presents a broad approach to performance effectiveness especially in teamwork and task functions in cross-organisations. This, in their perspective is important for and concerned with team values, attitude and activities that are crucial for boundary spanning actors and activities in cross-organisations [6, 8, 35].

Performance effectiveness of teams and organisation have consistently been objectively measured using a set of criteria defining productivity and efficiency [36–42]. Richard et al. [38], Bunderson and Sutcliffe [39] and Tata and Prasad [40] expressed team productivity as achieving goals, adopting innovation, quality outcome and adherence to schedules. In the measure of efficiency as performance effectiveness attribute, Cohen et al. [37], Bunderson and Sutcliffe [39], Gibson et al. [41] and Kwofie et al. [42] found team support, effective information sharing, mutual respect, monitoring and evaluation, defined responsibilities and roles, sound relationship, consensus and mutual trust and commitment to decision and goals as good measurable attributes of efficiency. Performance effectiveness in teams and organisations plays a fundamental role in the organizational success in a global, changeable and client-oriented economy and thus aligning COCI has become an emergent necessity.

Summary of the defining variables for COCI and performance effectiveness are summarized in Table 1.

3 Research Study and Methodology

The crux of the study focusses on gaining an understanding of the significant cross-organisational cultural intelligence attributes (COCI) that significantly influence performance effectiveness outcomes in teams and cross organisations in project delivery. Influenced by the dependent on multi-dimensional nature of cross-organisational cultural intelligence and performance effectiveness using measurable variables, a deductive research design using survey questionnaire was adopted. This is consistent with Zhou et al. [1], Delgado Piña et al. [8] and Bücker et al. [22], thus ensuring theoretical validity. The primary data for the study was collected through structured questionnaires administered on professionals forming project teams in construction project organizations in the Ghanaian construction industry. The questionnaire was developed from 18 items in the four dimensions of cognition (5-variables), motivation (5-variables), collaborative communication (5-variables) and behavioural adaptability (3-variables) that captured the cultural intelligence construct and 12 items of two factors of productivity and efficiency defining performance effectiveness.

The professionals were asked to provide response to the questionnaire on a five-point Likert scale defined as 1 = Not Very Significant, 2 = Not Significant, 3 = Averagely Significant, 4 = Significant and 5 = Very Significant. The rating was to be done by the respondents judging the influence of the COCI attributes on performance effectiveness.

Table 1. Variables for COCI and performance effectiveness

Variables	
Cross-Organizational Cultural Intelligence	
Cognition	
CG1: knowledge of working style of their organization CG2: knowledge of operation mode of their organization CG3: knowledge of the structure of their organization	CG4: knowledge of the working process of their organization CG5: knowledge of their organizational culture
Motivation	
MT1: accepting the working atmosphere and cooperating with them, MT2: interacting with other members, MT3: learning to coordinate the cultural differences,	MT4: participating in the cooperation with their organization, MT5: understanding the style of other organizations actively
collaborative communication	
CC1: maintain good cooperation with their organization, CC2: maintain harmonious interpersonal relations, CC3: keep communicating with others	CC4: good at sharing ideas and decisions with them actively, CC5: handling conflicts caused by inter-organizational cultural differences
behavioral adaptability	
BA1: change my non-verbal behavior to adapt to other organizations, BA2: adjusting facial expressions as needed	BA3: change my verbal behavior to adapt to other organizations
Performance Effectiveness	
Productivity	
PR1: achieving goals, PR2: adopting innovation,	PR3: quality outcome PR4: adherence to schedules
Efficiency	
EF1: team support, EF2: effective information sharing, EF3: mutual respect, EF4: consensus and mutual trust,	EF5: efficient monitoring and evaluation, EF6: defined responsibilities and roles, EF7: sound relationship, EF8: commitment to decision and goals

Source: [1, 27, 30, 36–42]

The data was analyzed by exploring which of the aspects of COCI have significant impact on performance effectiveness. Two aspect of performance effectiveness were measured as productivity and efficiency and were represented as two dichotomous (0/1) variables. Subsequently, logistic regression using stepwise approach and neural networks were used to analyze the data to reveal the significant COCI attributes that influence performance effectiveness in cross-organisational teams. The neural network was used to ascertain the robustness of the results obtained. Following a period of eight (8) weeks, 87 responses were gathered from 26 Class 1 construction organisations and 14 consultancy firms in Ghana in an online survey hosted on google forms. The google form link was sent to the managers and leaders of the construction organisations and consultancy firms to be shared with their teams. The participants were to draw on their experience in on-going project or recently completed projects that involved boundary-spanning activities with other teams, organizations, groups, sub-contractors and suppliers as this offers credence and credibility to results and findings in objective judgement and assessment.

Logistic regression model and Neural Network

In conducting the logistic regression model to explore the level of influence of multiple explanatory variables (X) to simultaneously predict membership of the dependent variable (Y), the approach adopted a binomial probability distribution. This was to predict membership of dependent variable in Category 1 with probability π and in Category 0 with probability (1-π). Thus,

$$E(Y) = (Y = 1) = \pi \tag{1}$$

Given that the probability π also depends on the values of the explanatory variables X, $\pi = \pi(X)$. Thus, from the dynamic nature of boundary spanning activities and cultural intelligence, if a curvilinear relationship between E(Y) and multiple X variables are assumed, then the logistic regression model generalizes to:

$$\log[[(\pi(X))/(1 - \pi(X))] = \alpha + \beta 1\ x1] + \beta 2\ x2 + \beta 3\ x3 \ldots + \beta kxk \tag{2}$$

This follows after McHugh [43]. A multi layered neural network was adopted where input nodes (variables) are connected with output node(s) (variable(s) using sets of hidden nodes to affirm the predictions, classifications and verifications from the logistic regression [43].

4 Results, Findings and Discussion

Background Profile

From the total of eighty seven (87) responses gathered following the eight (8) weeks survey, the cluster of respondents organizational roles were contractors (18), sub-contractors (4), suppliers (4), architectural consulting firms (4), Cost and Quantity consulting firms (5) and project management consulting firms (5). The mean organizational tenure was six (6) years. The mean years of experience within teams and organization was eight years. A synthesis of the characteristics of the background of respondents suggests that, they have adequate experience, an acceptable organizational tenure and draws on experience from the key organisations that deliver construction projects. This suggests that, the results and findings can be deemed to be valid and reliable thus offering credibility to the conclusions [37]. Cohen [35] and Cohen et al. [37] averred that for stability and credibility of results in regression and meta-regression, a minimum sample size of 25 is deemed adequate. Hence, a response of 87 used can be described as being adequate and likely to yield credible results and stable model.

Results of the logistic regression

Using the stepwise approach, the COCI variables denoted as independent variables were used to conduct a logistic regression to assess their influence on productivity (Model-A) and efficiency (Model-B) as dependent variables respectively. The results in Model-A retained eleven (11) explanatory variables whereas in Model-B eight (8) variables were accounted for. A preliminary assessment of multi-collinearity was conducted to assess if possible problems occur at much higher correlations which can affect the predictive accuracy of the assessment models. The Variance inflation factor (VIF) assessment of both models reveal a highest value of 1.904 for Model-A and 1.527 for Model-B. Cohen et al. [37] indicated that a VIF value of 4.00 and higher suggests issues of multi-collinearity whereas values less than 4.0 means multi-collinearity was not an issue for the dataset. From the model(s), all the VIF values were between 1.00 and 2.00. This indicates that issues of multi-collinearity were not present in the dataset and thus, the models are credible and have good predictive accuracy. The results of the models are presented in Table 2.

Model-A revealed CG1, CG4, CG5, MT1, MT3, MT5, CC1, CC2, CC5, BA1 and BA2 as significant COCI attributes predicting productivity. In the case of performance effectiveness in respect of efficiency as measured in Model-B, CG4, CG5, MT3, MT5, CC1, CC2, CC3, and BA2 were the significant COCI attributes predicting efficiency. By assessing the test of Model-A against a constant only model, a Chi Square of 39.963 with 11 degrees of freedom and a p-value of 0.001 was realized, meaning that the model was statistically significant. This suggests that, the set of eleven COCI attributes (variables) reliably influence the level of productivity in performance effectiveness in cross-organisational teamwork and task function in project delivery. In Model-B, an assessment against a constant only model reveal a Chi Square of 26.417 with 8 degrees of freedom and a p-value 0.001 meaning that the model was statistically significant. This indicates that, the set of eight COCI attributes (variables) in the model reliably influence the level of efficiency in cross-organisational task functions and activities in performance effectiveness. From Table 2, the coefficients of the variables in the models (A and B), their corresponding p-values, odds ratios and VIF values are presented.

The odds ratio of the dichotomous dependent variable which explains the probability of the membership in the performance effectiveness (i.e., productivity or efficiency) divided by the probability of the membership in the other group (i.e., not low productivity or inefficiency) was estimated. Likewise the odds ratio of the independent variables were conducted which explains how much the dependent variable's odds of membership in the target group would change with one unit change in the explanatory variable. According to McHugh [43] the odds ratio varies from zero to positive infinity. Thus an explanatory variable with an odds ratio greater than one suggests an increase in probability of the dependent variable in the target group with increase in the explanatory variable. By this, having positive values of the natural log of the odds ratio or the β coefficients suggests that, with an increase in the value of the corresponding independent variable, there is a

Table 2. Logistic regression models for predicting performance effectiveness.

Model-A: dependent variable – performance effectiveness (productivity)					
Explanatory variables	Log odds (B)	Standard error	p-Value	Odds ratio (exp. B)	VIF
Constant	−53.351	19.082	0.001	0	–
CG1	1.508	0.610	0.003	1.006	1.032
CG4	3.132	1.927	0.001	11.261	1.355
CG5	5.091	2.542	0.000	96.309	1.122
MT1	1.707	0.738	0.000	3.947	1.307
MT3	4.362	2.441	0.002	32.062	1.284
MT5	2.459	1.703	0.001	8.608	1.710
CC1	1.916	0.807	0.000	7.744	1.336
CC2	1.663	0.768	0.000	2.393	1.019
CC5	1.782	0.905	0.004	4.196	1.513
BA1	2.027	1.439	0.003	8.001	1.427
BA3	1.680	0.496	0.000	0.792	1.004
Model-B: dependent variable - performance effectiveness (efficiency)					
Explanatory variables	Log odds (B)	Standard error	p-Value	Odds ratio (exp. B)	
Constant	−48.005	12.891	0.002	0	–
CG4	1.988	0.915	0.004	5.210	1.407
CG5	−3.074	1.072	0.001	0.895	1.229
MT3	1.931	0.606	0.000	4.632	1.391
MT5	2.933	1.434	0.000	23.437	1.108
CC1	7.106	2.504	0.003	120.098	1.324
CC2	2.031	1.257	0.000	10.981	1.099
CC3	4.564	1.736	0.001	72.862	1.482
BA3	2.004	1.410	0.000	9.633	1.083

high chance of an increase in the dependent variable in the target group while a negative log odds would have the reverse effect [43].

Referring to Model-A, *knowledge of their organizational culture* as an independent variable generated an odds ratio of 96.309. This is an indication that the odds of the task functions and boundary-spanning activities having acceptable productivity would be 96.309 times greater when the rating for *knowledge of their organizational culture* increases by one unit. The log odds of knowledge of their organizational culture is 5.091 and a p-value of 0.000. This means that, *knowledge of their organizational culture* as a COCI attribute has a positive effect in influencing the chance of good productivity and the effect is significant. Additionally, the results suggest strong evidence were deduced for other ten (10) COCI attribute variables in Model-A which were all significant. The evidence from this suggests that various attributes of COCI in the form of *knowledge of working style of their organization,: knowledge of the working process of their organization, knowledge of their organizational culture*-cognition*, accepting the working atmosphere and cooperating with them, learning to coordinate the cultural differences, understanding the style of other organizations actively*- motivation, *maintain good cooperation with their organization, maintain harmonious interpersonal relations, handling conflicts caused by inter-organizational cultural differences*- collaborative communication and *change my non-verbal behaviour to adapt to other organizations* and *change my verbal behaviour to adapt to other organizations*- behavioural adaptability significantly influence the chances of improving productivity in cross-organisational teams in project delivery.

In the case of Model-B, the logistic regression results for performance effectiveness in respect of efficiency, eight (8) COCI attributes emerged to have significant impact on efficiency. All these variables were also found in Model-A except CC3. It is worth to note that, one of variables in Model-B had negative log odds thus higher values of this variable would results in the situation of reduced efficiency in teamwork and cross- organisational boundary-spanning activities. All the explanatory variables in Model-B were found to be significant with positive values of their log odds except one. This suggests that the other seven positive variables would positively influence the likelihood of efficiency within teamwork and boundary-spanning activities in cross-organisations in project delivery. Additionally, a Nagelkerke's R^2 value of 0.663 with Hosmer and Lemeshow Test Chi-Square 14.721 and 10 degrees of freedom for Model-A and a Nagelkerke's R^2 value of 0.710 with Hosmer and Lemeshow Test Chi-Square 9.805 and 8 degrees of freedom for Model-B (see Table 3) is an indication of a strong predictive accuracy for the models.

Table 3. Logistic regression model quality test.

	Model-A	Model-B
Nagelkerke's R^2	0.663	0.710
Hosmer and Lemeshow test		
Chi-square	14.721	9.805
Degrees of freedom	10	8
p-Value	0.146	0.203

The associated p-values generated for the Hosmer and Lemeshow goodness-of-fit test statistic from Table 3 for Models A and B were 0.146 and 0.273 respectively. This can be described as not statistically significant, thus suggesting there are no obvious difference between observed and predicted values. This is an indication that the estimates of the two models fit the data at an acceptable level [43]. It can further be said that, these results affirm that, the proportions of cases for the models were appropriately classified, hence, there are no statistical violation that undermines the results. From Table 4, the details of the classification of the models are presented. Model-A registered 83.18% as the overall predictive accuracy rate whereas that of Model-B was 86.25%.

These accuracy rate of prediction can be deemed as high [43] and thus suggest these COCI attributes in the logistic regression models undeniably significantly contribute to productivity and efficiency (performance effectiveness) in task functions and boundary-spanning activities in project delivery.

Table 4. Logistic regression models classification tables.

Model A: dependent variable - acceptable productivity outcome			
Observed	Predicted		
	Acceptable p roductivity	Poor productivity	Percentage correct (%)
Accepted Productivity	22	5	81.48
Poor productivity	4	24	85.71
Overall percentage			83.18
Model B: dependent variable - Efficiency Outcome			
Observed	Predicted		
	Efficiency	Inefficiency	Percentage correct (%)
Efficiency	27	3	90.00
Inefficiency	4	10	71.42
Overall percentage			86.25

Results of the neural network analysis.

The neural network analysis utilized all the eighteen (18) variables contained defining cross-organisational cultural intelligence to predict acceptable productivity and good efficiency in performance effectiveness in task functions and boundary-spanning activities. This approach offers an independent verification of the most significant factors using a different method [43]. From this, about eighty percent of the data was selected randomly and applied to train the network and the rest were applied in testing the predicted results. In all, about twenty eight sets of such random samples were generated from the data set and used to determine the influence of these eighteen explanatory factors in predicting the performance effectiveness (productivity and efficiency) outcomes in a neural network. By using the multi-layer perception of neural network, importance or weights of each of these variables were assigned so as to obtain optimum possible predictions. The weights or importance ratings emanating from twenty 28 experiments were obtained as well as their average values used to define the relative importance of the explanatory variables influencing performance effectiveness outcomes.

From this, the frequency at which each attribute appears within the top 3 ranking among the total 18 COCI attributes based on the importance rating in each of the 28 experiments were also obtained. Based on these two criteria the relative importance of the 18 attributes in influencing productivity and efficiency performance effectiveness is determined. The results are summarized in Table 5. From Table 5, it can be appreciated that, following the three evaluation criteria, the four top significant COCI attributes that influence acceptable productivity were *knowledge of their organizational culture, learning to coordinate the cultural differences, understanding the style of other organizations actively* and *maintain harmonious interpersonal relations.* In the case of efficiency performance effectiveness, the top four attributes were *learning to coordinate the cultural differences, understanding the style of other organizations actively, maintain harmonious interpersonal relations* and *knowledge of their organizational culture.* The rankings of these top four attributes for productivity and efficiency were similar across neural network method and logistic regression model. Neural network-based criteria ranked *knowledge of their organizational culture* as the top factor in productivity. In the logistic regression model, same factor was deemed significant with highest odds-ratio values. Same can be said for the top ranked variables in efficiency. The neural network results affirm consistency and suggest that the logistic results are valid, reliable, acceptable and credible.

Table 5. Top ranked factors impacting Productivity and Efficiency performance effectiveness

Top Factors	Ranking of attributes for acceptable productivity in respect to:			Ranking of attributes for efficiency in respect to:		
	Average Importance (NN)	Frequency with Top 4 Ranking (NN)	Odds Ratio (LRM)	Average Importance (NN)	Frequency with Top 4 Ranking (NN)	Odds Ratio (LRM)
CG5	1	1	1	4	4	4
MT3	2	2	3	1	2	3
MT5	3	4	2	2	1	1
CC2	4	3	4	3	3	2

5 Discussion of Findings

The findings have underscored the significance of cross-organisational cultural intelligence factors to performance effectiveness in respect of productivity and efficiency. In respect of productivity, the results revealed eleven attributes from cognition, motivation, collaborative communication and behavioural adaptability to have significant influence. In the case of efficiency in performance effectiveness, the findings revealed eight attributes to have significant impact.

Contribution of Cognition to performance effectiveness

In the case of cognition, the results highlighted three factors to significantly impact on productivity and two factors on efficiency. These were knowledge of working style of their organization, knowledge of the working process of their organization and knowledge of their organizational culture to influence productivity whereas knowledge of the working process of their organization and knowledge of their organizational culture significantly influenced efficiency. The perspectives surrounding cognition dimension of COCI and performance effectiveness (productivity and efficiency) in cross organizational teams and groups especially in boundary spanning activities have often focused on individual attributes in the meta-cognition cultural intelligence domain which embraces cultural cognition and judgment of measures in the psychological domain [1, 24]. However, the position of Ang et al. [18] is that cognitive cultural intelligence focuses on general knowledge of different cultures and thus showing such competencies can engender effectiveness, efficiency and productivity. From this, it can be said that the emergence of these cognitive cultural intelligence is an indication that the position of Earley and Peterson [17] is valid especially in cross-organisational teamwork in boundary-spanning activities.

From the influence of the cognitive cultural intelligence dimension on productivity and efficiency, it can be affirmed that, developing employees and team participants to have knowledge and understanding of COCI can motivate the handling of organizational culture differences effectively and interact well with people from different organizational cultures. It is accounted that, organizational culture difference is an important challenge which often stifles coordination and inter-organisational cooperation in boundary-spanning activities which are key tenets for performance effectiveness [10, 21]. Against this, Zhou et al. [1] and Gerhart [24] averred that cognition of COCI has become an important skill for employees and participants in boundary-spanning activities across organisations. This knowledge can be deemed as a precursor for building sustainable relationships and managing complexity, interdependencies, managing roles and accountabilities in cross organizational boundary-spanning activities in culturally diverse teams and organisations to engender productivity and efficiency [11, 15].

Contribution of motivation on performance effectiveness

Motivation dimensions in COCI are necessary for boundary-spanning activities and it embraces the mental capabilities that reside within the "head" of the person. However, previous studies on cultural intelligence in the motivation domain have primarily focused on a cross-national context, which is not appropriate for direct application in the cross-organizational cultural context [13]. Organizational culture is what people accept after they enter a new organization. Individuals need to learn consciously their organizational cultures. Organizational culture differences are reflected mostly in practices, while national cultural differences are seen in values [13, 25]. Ott and Michailova [25] alluded that the motivations dimensions of organizational cultural intelligence is what allows people be accepted after they enter a new organization to effectively work, interact and perform. The findings reflect that higher motivational COCI dimensions can foster good interactions, acceptance of working atmosphere and cooperation with others across teams and organisations that are key recipes for performance and cross-functional task activities. Hence, cross-organisational teams and groups in project delivery can motivate performance effectiveness in respect of productivity and efficiency through cultural intelligence by focusing on learning to coordinate the cultural differences and understanding the style of other organizations actively. These are deemed as key tenets of motivations for cultural intelligence in boundary-spanning activities in cross-organisations.

This development in boundary-spanning activities in the motivations dimensions can prompt employees' performance in the cross-organizational context that are necessary for productivity and efficiency in performance effectiveness. It can also be necessary for bridging cultural differences that may hamper effectiveness of inter-organizational coordination and cooperation [21, 27].

Impact of collaborative communication on performance effectiveness

From the collaborative communication dimension, Delgado Piña et al. [8] and Lee and Sawang [10] proved that, culturally diverse teams tend to have group anxieties that becomes a challenge to sharing information in boundary spanning activities which subsequently affects team performance. However, the relevance of collaborative communication and information sharing in cross-organisational teams have well been documented. The emergence of collaborative communication to make significant impact on team performance effectiveness re-affirm such significance. [15], Getha-Taylor [19] proposed the development of collaborative communication competence and strategies as a critical boundary-spanning abilities for culturally diverse teams and organisations. This can be very relevant in operating external linkages and collaboration to improve performance and cope with competition [10]. In this regard, it can be affirmed that, cultural issues relating to sharing ideas and decisions, maintaining harmonious interpersonal relations, keeping communication with others and handling conflicts in inter-organizations must remain a top priority in cross-organisational task functions and activities largely due to its antecedents to boundary-spanning activities. From this perspective, it is anticipated that collaborative communication capabilities should be considered from the dimension of diverse contexts and different organizational cultures so as to optimize performance effectiveness among organisations and teams [10, 19].

Impact of behavioural adaptability on performance effectiveness

Ohme and Zacher [28] noted that, behvaioural adaptability in teams, organisations and workplace enables team participants, leaders and employees efficiently cope and meet work demands and ultimately promotes individual development and task performance. Prior to this study, the findings from literature remained vague as to what dimensions of behavioural adaptability is needed in cross-cultural organizational teams and boundary spanning activities that can engender performance. Lee and Sawang [10] averred that, teams in boundary-spanning activities often experience group attachment anxiety that impede behavioural orientations. Zhou et al. [1] on the other hand proved that, strategic behavioural adaptability in cross-organisational teamwork and activities are necessary for building sustainable relationships and managing complexity, interdependencies and managing roles that are precursors for enhanced performance. With the emergence of behavioural adaptability having significant impact on performance effectiveness suggests that, cross-organisational teams in project delivery can change their verbal and non-verbal behaviour to adapt to other organizations. These changes can help teams and organizational participants to adapt behaviourally to create the necessary conditions and motivations that are necessary for performance effectiveness in respect of productivity and efficiency.

Though the complexity of organizations and subjectivity of boundaries are well acknowledged, developing adaptive behaviours in cross-cultural intelligence among individual employees and teams can be deemed as crucial in building and maintaining team functions and harmony that induce performance in activities.

Conclusions and implications of findings

Though cultural intelligence has been deemed very crucial in cross-organisational task functions and managerial effectiveness, an understanding of its linkage to performance effectiveness has been lacking. This linkage is significant for team-based work style, the team-based organization, project-based organization and the multi-team systems that have become a synonymous feature of cross-cultural organisations. Given the growing interest in the need to understand cross-cultural intelligence of teams and employees in cross-organisatons especially in boundary-spanning activities and the impact on performance effectiveness, this study has been developed to bridge this knowledge gap. This study makes contributions by identifying the significant COCI attributes that impact on performance effectiveness in respect of productivity and efficiency using logistic regression.

One of the important responsibilities for project teams, groups and participants is to cross team boundaries on behalf of their teams and organizations, perform and manage task and activities to ameliorate the effects of cultural differences. From the findings, a valid conclusion is that, cognitive, motivation, collaborative communication and behavioural adaptability attributes of organizational cultural intelligence significantly impact on productivity and efficiency domain of performance effectiveness. The findings further revealed knowledge of their organizational culture, learning to coordinate the cultural differences, understanding the style of other organizations actively and maintaining harmonious interpersonal relations as the four topmost cross-organisational cultural factors that significantly influence productivity in performance effectiveness. In the case of efficiency dimension of performance effectiveness, the top four attributes were learning to coordinate the cultural differences, understanding the style of other organizations actively, maintaining harmonious interpersonal relations and knowledge of their organizational culture. This inquiry opens up an area where cross-organisational cultural intelligence attributes can be applied to teamwork and boundary-spanning-activities across organisations and teams to identify and optimize it benefits to external activities, cross-boundary collaborations and performance effectiveness.

The insight from the study offers implications in the area of managing cross-organisational cultural difference especially in the area of teamwork and task functions in boundary-spanning activities. First, the current findings have important implications for managing cross-organisational cultural differences. It is well acknowledged that, organization cultural attributes has an impact on boundary-spanning activities and performance. Hence, the insight from the study can thus motivate the development of values, work ethics, behaviours and cultural orientations, from the cognition, motivation, collaborative communication and behavioural domains that are important for cross-organizational teams and employees. These are necessary to curtail the effects of cultural differences that can be a hindrance to teamwork, building relationships, managing complexity, interdependencies and managing roles.

Another implication of the findings is in the area of breaking cultural barriers and building bridges among organizations by dealing with organizational cultural differences. The fact is that, collaborative communication and adaptive behaviours are deemed as precursors for overcoming organizational cultural differences in cross-organisational teams and groups. The effectiveness of communication, coordination and behaviours is influenced by set of key criteria, which are determined by organizational culture. Hence, the results should help project teams in cross-organisations to align their communication strategies and information sharing behavours to curtail the effects of organizational cultural differences so as to generate the needed team effectiveness and harmony inherent from communication task functions. These can be deemed as being crucial especially in boundary-spanning activities and task functions. This perspective is premised on the theoretical foundation that, individuals and teams that are good at communicating with others in boundary-spanning activities and cross-organisatons are persons with high cross-organisational cultural intelligence. Cross-organisational teams must consciously develop and improve their communication ability and adaptability to the culture of different organizations to engender performance effectiveness.

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The Impact of Corporate Culture on Value Management Adoption in the Construction Industry

Comfort Olubukola Iyiola and Modupe Cecilia Mewomo(✉)

Department of Construction Manaagement and Quantity Surveying, Steve Biko Campus, Durban University of Technology, Durban, South Africa
22176415@dut4life.ac.za, modupeM@dut.ac.za

Abstract. Value management (VM) is considered a multidisciplinary process that seeks to achieve the best value in a construction project to meet clients' needs and enhance the sustainability of construction projects in the built environment. In addition, it has been referred to as a team-oriented, structured, and analytical process that targets the systematic analysis of function. However, despite numerous studies on VM and its importance, the concept of VM has not been fully embraced in the construction industry. Its application is still confronted with multiple barriers and challenges. This study, therefore, aims to bridge the gap by understanding the impact of corporate culture on VM adoption by examining the relationships between corporate culture and VM integration through an extant literature review. This is one of the first papers to measure corporate culture's importance in the VM context.

Keywords: Value management · Culture value · Corporate culture · Adoption · Construction industry

1 Introduction

The main goal of a construction project is to meet clients' satisfaction in terms of cost, time, and quality [1]. However, the present-day construction industry is experiencing dramatic changes from what it was some decades ago. Issues attributed to increased project complexity, inefficiency in the construction process, cost and time overrun, delay in delivery, poor project planning, and project abandonment have been significant concerns in the construction industry [2]. To curb some of these issues, many studies have advocated the integration of value management (VM) practices to successfully deliver construction projects [3–6]. Notably, many studies have proven its benefits when successfully implemented in construction firms as an effective tool in achieving clients' satisfaction, reducing project abandonment, and reduced construction costs [7].

However, some studies describe a pattern of failure in VM adoption. Its idea has not been widely implemented worldwide, particularly in developing countries [8]. Some of the major factors attributed to VM integration are attributed to readiness to adopt,

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organisational barriers, awareness, lack of implementation by decision-makers, collaboration, skill and training, management support, corporate strategy, and teamwork among different project team members that are impacted by the culture of the firms [9].

Among all the possible antecedents of VM adoption, this paper is predominantly intrigued by corporate culture (CC), which is referred to as the values and beliefs shared by an organisation [10]. CC plays a vital role in the adoption of VM because appropriate CC will influence the integration and behaviour of team members regarding information dissemination, partnership, collaboration, trust, decision-making, and risk-taking, among others [11]. These CC-related features are also significant for the successful implementation and adoption of VM as these will help improve workflow and guide the decision-making process. It will also overcome ambiguity barriers and promote an organized work structure that will help team members work together with purpose. Organisations may not achieve their stated goals if they lack the backing of a suitable corporate culture [12]. According to [11], Japanese firms' European subsidiaries have occasionally failed to provide good courier service due to internal workplace conflict.

Given the relevance of corporate culture for VM, the impact of corporate culture on VM incorporation must be investigated. This study aims to examine corporate culture using the Competing Value Framework (CVF) model, which is regarded as a highly reliable and widely used framework for measuring the culture in an organization. Several studies have acknowledged the use of CVF for analyzing corporate culture on innovation [13] and [14], knowledge management [14], job satisfaction [15], among others. However, there is no research focusing on the impact of corporate culture on VM integration. Research in this area needs to analyse how corporate culture may facilitate organisations' value chain processes. This study intends to establish the impact of CC on VM adoption in the construction industry.

2 Research Method

This study was conducted as a systematic literature review. This technique is critical in any particular research since it highlights existing research and identifies research gaps in previous papers. According to [16], a systematic literature review involves assessing, analyzing, and summarizing all existing studies about a specified research topic to identify knowledge gaps and recommend areas for additional research. A systematic literature review is typically conducted utilizing large databases with an extensive number of articles and comprehensive search techniques that permit the use of complex and sophisticated expressions. Qualitative content analysis was used to obtain the primary data. Based on this method, a two-stage process was used to acquire, analyse and present the findings from the articles. In the first stage, articles published in journals and academic conferences were collected in major databases such as Emerald, Scopus, Science Direct, Google Scholar, and Web of Science. A total number of 112 articles were retrieved. The literature sample includes English-speaking journals and proceedings from academic conferences on value management practices in the construction industry, covering periods from 2008 to 2020. The second stage involved testing the eligibility of the papers based on inclusion, exclusion, and quality criteria, and some papers were filtered out based on incomplete abstracts or conclusions, literature reviews, language, duplications, and papers that did not apply to the research. A literature search was conducted to compile the literature based on a pair of keywords such as "VM," "adoption," "organisational culture," "corporate culture," and "construction industry" to be jointly found in the title keywords or abstract. Forty-two (42) scholarly articles about VM and CC were identified (hereafter referred to as the 'final' number of articles).

3 The Moderating Role of Corporate Culture

The concept of corporate culture (CC) has received considerable attention in organisational theory. CC has been defined as the social or normative glue that holds an organisation together [17]. According to [18], CC is a long-term collection of shared attitudes, beliefs, and meanings that influence the thoughts and behaviour of members of the organisation. Cameron and Quinn [19] suggested that implementing change developments while maintaining the CC is difficult, even if the organisation offers basic capabilities, methodologies, and change strategies. According to [20], the successful adoption of change programs in a firm is determined mainly by CC, including the values and ideas underpinning the culture. Since CC can explain more about internal characteristics such as managerial attributes, human resource management, and organisational behaviour, CC becomes an essential subject in sustainable goals [20]. According to [21], CC comprises a firm's rules of conduct, organisational standards, processes, and management systems. Galpin et al. [22] further claimed that organisations must stress their mission, values, norms, and strategy to accomplish excellent CCve the sustainable development aim, [23] stated that sustainable efforts should be gradually integrated with CC, necessitating bringing cultural changes to an organisation. Arditi et al. [17] investigated the influence of organisational culture on construction projects delay and observed a substantial link between corporate culture and the extent of project delay. Albayrak and Albayrak [24] also examined the effect of organisational culture on the construction sector's adoption in Turkish and found a significant impact. Prior research has extensively investigated an association between CC and adoption [14]. For example, Change-resistant behaviour, information sharing among workers, and non-acceptance of external innovation are all CC-related characteristics influencing a firm's ability to innovate, according to [13]. As a result, [25] emphasized the role of management in encouraging employees to promote innovative behaviours to build a CC that fosters innovation. Several other researchers have also concentrated on the impact of CC on innovation [13] and [14], knowledge management [26], and job satisfaction [15]. The reviewed literature shows that professionals and researchers acknowledged that CC substantially impacts the long-term adoption of construction projects, change programs, and even the organisation. However, research on the effects of CC on VM integration and adoption in the construction industry is limited.

4 Measuring Corporate Culture - the Competing Value Framework (CVF)

In order to understand the impact of CC in an organisation, several theoretical models have been proposed to measure organisational culture [24]. The literature review shows that the Competing Value Framework (CVF) is well known in research and practice and has been widely employed in management studies. Cameron and Quinn [19] divided the CVF framework into the group, rational, hierarchical, and developmental cultures. The group culture value involves trust, participation, commitment, involvement, and teamwork [11]. Cameron and Quinn [19] asserted that "group culture" is modeled after a family-type pattern. According to [11], group culture is the value of long-term advantages embraced by employees in a firm. Employees in a firm give more attention to tasks that create long-term value when they have a strong group culture [27]. This is because organisations adopting such a culture encourage flexibility and individual openness [15]. This study affirmed that construction project stakeholders who embrace group culture are interested in establishing teamwork, information sharing, cooperation, and partnership within the value chain. However, [24] concluded that communication is crucial for adopting this culture in the value chain. The absence of communication will lead to confusion, thereby altering the informal relationship. Development culture involves innovativeness, creativity, risk-taking, and adaptable nature [1] and [19]. The organisation that adopts this culture focuses on entrepreneurship development, motivation, and a sound reward system [28]. This dimension of culture emphasises incentives to achieve a firm's well-defined goals, such as outstanding adoption and competitive advantages. Atuahene and Baiden [29] asserted that leaders adopting such cultures are risk-takers, and the followers or employees are committed to taking a risk in the value chain.

Rational culture involves a competitive culture that involves addressing rivalry and reasonable achievement toward corporate goals and objectives [17]. In rational culture, the organisation's leaders adopting this culture are result-oriented, mainly concerned with how the task or project will be completed [19]. Arditi et al. [17] mentioned that rational culture focuses on getting the job done, bringing goal-oriented competition. Adhesives in the organisation are mainly the desire to win a competition. On the other hand, the organisation's employees or members have clear instructions regarding their roles and are rewarded based on their adoption [30]. The hierarchical culture dimension is focused on ensuring a hierarchy and strict control of activities [19]. The hierarchy culture led by an organisation has a formalized structure, formal rules, and policies. There are standard procedures that define how work should be performed. Cao et al. [11] mentioned that shared values of top-down control and coordination are maintained. Strategies and activities are limited, decision-making frameworks are standardized, and outcomes are presented to superiors for authorization in a company that has a robust hierarchical culture [31]. In a value chain system, hierarchical culture has two meanings. Firstly, personnel at companies with a robust hierarchical structure are dominated by a "functional silos" approach [11]. Implementation is hampered because the division of operations prevents a company from taking a holistic approach to sharing responsibilities with external value chain partners. Secondly, personnel in hierarchical organisations are accustomed to following rules and regulations [32]. As a result, they are reluctant to respond to change.

5 Cultural Alignment and VM Integration

Arditi et al. [17] discovered that CC with a high degree of group, development, rational cultures, and low hierarchical culture is ideal for implementing numerous management strategies. This assertion overlap with VM practices. Successful VM has a specific culture profile, according to [33], which includes more institutional collectivism, future orientation, a compassionate orientation, and a reduced level of aggressiveness. CC can help VM adoption by creating an environment where companies can learn and collaborate with value chain partners, especially in developing countries where VM practices have not been fully adopted [3]. As a result, it is envisaged that CC will substantially impact VM integration as a crucial component of a firm's operational practice. According to the literature, effective VM integration involves both the ability and the intention to adopt [5]. Organisations that fully implement VM can create and handle connections with clients and project personnel and facilitate teamwork, client satisfaction, and cross-functional cooperation, allowing them to integrate their value chains [34]. Firms willing to implement trust and interpersonal influence are more likely to proactively implement internally and externally, allowing them to better engender cooperation during the VM process [5]. As a result, CC is linked to relationship abilities and willingness to integrate, influencing VM adoption.

Group culture emphasises interpersonal relationships, communication, cooperation, and collaboration with internal and external team members during and after a VM process [11]. There are clear communication and transparency, and every team member is comfortable voicing their opinions and ideas, which is a significant prerequisite for positive VM adoption. Cooperation and collaboration values are essential for VM because VM requires the working together of team members/ stakeholders involved to solve problems [25] jointly. Employees that lack a cooperative spirit will find it challenging to collaborate closely with their colleagues during a VM process. In competitive situations, group culture will enable team members to work together to win [11]. Organisations will be motivated to cooperate to improve shared understanding, minimize conflict, enhance trust relationships, and commit to relationships with their clients to enhance the successful integration of VM [35]. According to [36], collaborative practices such as brainstorming are beneficial to establishing a shared language, which is a popular approach utilized during the VM workshop process. This sort of shared language is critical for information and knowledge sharing [37] and communication across functions within project stakeholders. The client's involvement and participation in group culture will be enhanced [1], which is an essential prerequisite for successful VM integration. In addition, [38] found that group culture is positively related to trust. Trust is a crucial component of the successful implementation of the VM process [39]. Therefore, it can be deduced that group culture would positively influence VM adoption.

The importance of a long-term goal shared by all personnel in an organisation is emphasized by a development culture. Workers give more importance to initiatives that have the potential establish lengthy worth when a firm has a substantial development culture [15]. Thus, VM, as a crucial practice for generating long-term value for organisations [40], is more likely to be realized in organisations that prioritize development culture. In this case, an organisation is motivated to gather data on present conditions, future requirements, and technological innovations or skills that could help them steer their VM-related programs. To obtain such market and technological data, a firm must integrate its internal activities with external stakeholders and clients through VM integration [8]. Also, a development culture that encourages enterprises to take risks and accept short-term losses can integrate VM practices. According to existing research, VM integration necessitates a significant collective commitment from value chain partners, both tangible and intangible [41]. Therefore, organisations concentrating on short-term rather than long-term goals cannot afford the short-term losses caused by risky integration practices. Firms with a strong development culture and a focus on long-term goals, on the other hand, will be more ready to take risks and endure short-term losses because they will expect to reap long-term rewards from doing so. As a result, VM facilitates product innovation, which is crucial for a company's long-term success. Hence, these findings suggest that VM integration will be more prevalent in a construction firm with a development culture.

Control and top-down decision-making are critical aspects of hierarchical culture. These characteristics may hinder employees' willingness to take chances and adapt to change, reducing the scope of VM practices and thwarting their effectiveness. The hierarchical culture places a high value on getting the task done, defining protocols and routines, standardized decision-making mechanisms, and superiors reporting decisions for authorization [29]. The integration and adoption could be hampered in this situation because the division of functions could prevent an organisation from taking a broader view of responsibilities shared with external value chain partners. Also, employees in firms with a hierarchical culture are used to following rules and regulations [28]. Functional and organisational boundaries may need to be broken to combine multiple functions and project stakeholders into cohesive entities. Furthermore, if organisations want to combine their operations, they may need to modify their relationships with clients. Also, organisations may need to shift from transactional ties to strategic partnerships to accomplish VM [42]. As a result, VM implementation may be hampered by a hierarchical culture that prioritizes stability. Furthermore, such a culture will provide little or no encouragement for employees to participate in dealing with the new problems and contingencies that VM entails, limiting VM deployment and negatively impacting its adoption.

Rational culture refers to the shared beliefs and incentive systems adopted to fulfill the objectives of a firm [11]. In rational culture, values are emphasized as result-driven, rational-oriented, and highly competitive. This culture is influenced by outcomes, and it works tirelessly to infiltrate the market and gain its most market share attainable. This dimension of culture emphasizes rewards for accomplishing a business's well-defined objectives, such as extensive utilization and competitive advantages [42]. Organisations with a solid rational culture will motivate their staff to devote time, resources, and effort to VM to deliver construction projects successfully and meet their defined objectives. As a result, the four culture dimensions are predicted to influence VM integration and adoption. Furthermore, the four culture dimensions may affect VM integration as a whole. When both group and development cultures are emphasized, for example, the group attitude of teamwork may help to speed up the VM development culture-driven process. By emphasizing the importance of VM for the firm's future success, development culture can boost the effect of group culture on VM adoption. As a result, the four dimensions of CC can have a combined impact on VM adoption. In summary, the group, development, rational and hierarchical culture can influence VM adoption individually and jointly. In relating the rational culture dimension to VM, this study asserts that a construction project stakeholder adopting such a culture is interested in satisfying the client regardless of the principles and opinions of other stakeholders [11].

6 Conclusion

In corporate firms, corporate culture can be considered an essential factor affecting the adoption and integration of VM, most especially in developing countries. This paper presented a systematic review of various renowned literature concerning CC's role on the adoption of VM in the construction industry. The result found that CC strongly impacts the adoption and implementation of VM practices. The study also revealed that the lack of cultural integration between members of an organisation might lead to failure in the successful implementation of VM practices. Therefore, it is ascertained that enhancing value culture would result in VM adoption enhancement. Organisational stakeholders must understand the values and customs emphasised in their organisations to facilitate the effective implementation of VM practices at the initial stage of construction projects. Organisations with a quality focus should support the values and beliefs of group and development cultures. Greater organisational involvement, decreased project costs, waste reduction, employees' engagement, empowerment, job satisfaction, early project delivery, and increased productivity will help improve work-life quality. Furthermore, appropriate CC and knowledge of VM will enhance organisational effectiveness. Moreover, the findings of this study will help clients, construction professionals, and other construction stakeholders better comprehend the influence of CC on the adoption of VM practices, especially in developing countries. This knowledge of the influence of CC will assist in developing and making VM implementation easier. Therefore, the effectiveness of CC in enhancing VM implementation can be recognized as a needed research scope.

7 Limitations of the Study

In this research, a systematic literature review is used which might have a few limitations such as may not represent the studies of VM in totality, only selected journals and conference articles were considered for the study while other sources of information were not considered in this study.

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Sustainability and the Law: A Legal Framework for Digital Technologies in an Inclusive Construction Industry

Louis Koen(✉) and Letlhokwa George Mpedi

University of Johannesburg, APK Kingsway Campus, Cnr Kingsway and University Rd, Auckland Park, Johannesburg, South Africa
{ljkoen,lgmpedi}@uj.ac.za

Abstract. This paper considers the need for a clear legal and policy framework to guide a more sustainable construction industry and the use of digital technologies. It commences with an analysis of the meaning of sustainable development and briefly reflects on the three components of sustainable construction industry. The paper argues that while much has been written on the environmental aspect there has been more limited engagement with the social component of sustainable development. It critically analyses decent work deficits in the construction industry and the role of law and technology in addressing these deficits. In so doing it follows a doctrinal and legal research methodology. The paper argues that while the benefits of certain digital technologies for safer construction industry are undeniable, there is not much certainty on the extent to which the construction industry is legally obligated to adopt such technologies. Ultimately, it considers that codes on corporate social responsibility could play a valuable role where they operate alongside clear legal frameworks to guide the construction industry in the adoption of such technological tools. These technological tools are then to be used as part of a broader commitment to promoting a sustainable construction industry in which there is decent work for all. It concludes with recommendations for legal reform to guide a more sustainable construction industry.

Keywords: Sustainable development · Decent work · Occupational health and safety · Social insurance · Social protection

1 Introduction

The need for all industries to act sustainably has been attracting growing international attention. The construction industry has also not been immune from these calls for a more sustainable approach that encourages the use of resources sustainably while promoting social well-being [1]. This includes a meaningful contribution by the construction industry to promoting decent work, gender equality and sustainable production. To this end, construction companies should positively address decent work deficits. According to the International Labour Organisation (ILO), the decent work deficit is expressed in the

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absence of sufficient employment opportunities, inadequate social protection, the denial of rights at work and shortcomings in social dialogue [2].

The rise of digital technologies can positively and negatively contribute to sustainable development. Systems such as proximity warning systems can play an essential role in promoting safer working environments within the construction industry. Occupational safety and health (OSH) are critical components of decent work and are particularly important in the construction industry [3]. The ILO has noted that one construction worker succumbs to workplace injuries every 5-min [1]. However, technology is also increasingly being used as a tool for the casualisation of the labour market resulting in increased decent work deficits and a rise in informality. Therefore, a clear legal and policy framework is needed to guide the construction industry in the sustainable incorporation of digital technologies.

This contribution critically analyses the value of existing labour and social security laws as well as specific codes in the construction industry in guiding a sustainable construction industry. It then considers the role of digital technologies specifically and recommends more precise guidelines to promote digital technologies in the construction industry that contribute positively to a more inclusive and sustainable construction industry free of decent work deficits.

2 Overview of Sustainable Development

The Brundtland Commission's 1987 report established sustainable development's most widely used definition [4]. According to this definition, sustainable development entails "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition is broad and goes far beyond the narrow understanding of the concept previously adopted by the World Conservation Strategy. The World Conservation Strategy's definition of sustainable development was primarily focused on environmental protection, and as a result, sustainable development was defined as the need to preserve the earth's natural resources [5].

As a result, the Brundtland report and its understanding of sustainable development significantly expanded on the concept's meaning. The Brundtland report was primarily concerned with people's wants and needs. Its human-centred approach sought to ensure global justice for future generations by redistributing resources and promoting economic growth in developing countries, allowing all people to meet their basic needs. Du Pisani argues that:

> "The report expressed the belief that social equity, economic growth and environmental maintenance are simultaneously possible, thus highlighting the three fundamental components of sustainable development, the environment, the economy, and society, which later became known as the triple bottom line. The report discussed the need to apply integrated, sustainable solutions to a broad range of problems related to population, agriculture and food security, biodiversity, energy choices, industry, and more." [6]

The South African government has also endorsed this broader concept of sustainable development. The National Environmental Management Act, Act no. 107 of 1998

(NEMA) defines sustainable development as "the integration of social, economic and environmental factors into planning, implementation and decision-making so as to ensure that development serves present and future generations." [7] While this definition is contained within legislation governing environmental matters, it does not confine sustainable development to environmental considerations but calls for an integrated approach.

The Department of Public Works has also adopted a Green Building Policy in which it recognises the importance of sustainable development in the construction sector [8]. This policy document also adopts a broad understanding of sustainable development and notes that: "Sustainable building and construction is a sub-set of sustainable development – namely about meeting the needs and aspirations of people (especially the poor) in a manner that does [not] impede future generations from being able to meet their own needs and aspirations." [8] It recognises three components of sustainable development in the construction industry namely: environmental sustainability, social sustainability and economic sustainability [8]. While the policy recognises that the built environment has an important role to play in achieving sustainable development, it regrettably focuses almost exclusively on the environmental component of sustainable development. The policy is largely focused on green buildings and does not take a broader policy position on the integration of the social component into sustainability in the building sector.

Various soft law instruments, i.e. quasi-legal instruments such as recommendations which are not legally binding, also guide our understanding of the broad concept of sustainable development. The United Nations General Assembly's adoption of the Millennium Declaration in 2000 demonstrated a commitment by world leaders to take steps to ensure the realisation of sustainable development for all [9]. The Millennium Declaration provided some of the earliest guidelines on what an integrated approach to sustainable development looks like. It called on states to take a broad range of actions aimed at preserving the environment and eradicating poverty, including promoting decent work and gender equality [9]. The Millennium Declaration also recognised that equitable access to new technologies should be promoted.

The Millennium Development goals have since been followed up by the UN Sustainable Development Goals contained in the 2030 Agenda for Sustainable Development. The 2030 Agenda for Sustainable Development, which all UN Member States adopted in 2015, provides a shared blueprint for peace and prosperity for people and the planet now and in the future. The 17 Sustainable Development Goals (SDGs) are at the heart of it, and they are an urgent call to action by all countries - developed and developing - in a global partnership [10]. They recognise that eradicating poverty and other deprivations must be accompanied by strategies that improve health and education, reduce inequality, and stimulate economic growth – all while combating climate change and working to protect our oceans and forests [10].

The African Unions' Labour and Social Affairs Committee (LSAC) adopted the Ouagadougou Plan of Action on Employment Promotion and Poverty Alleviation in 2004, recognising the inextricably linked relationship between labour, social protection, and human development. The Ouagadougou plan provides more detailed guidelines to African states on the integration of the social element of sustainable development and recognises that social protection and occupational safety, health and hygiene form an important component of sustainable development [11]. States are called upon to implement measures aimed at the extension of social protection to those in the informal economy.

These soft law instruments all provide valuable guidance in understanding the content of sustainable development. However, they do not generally create binding legal obligations save for the extent to which they are domesticated in states' law or where it reflects customary international law. Notwithstanding their non-binding nature, sustainable development goals have also widely been incorporated into industry codes of conduct and voluntary codes on corporate social responsibility [12].

The section that follows this contribution will consider decent work deficits in the construction sector and the role of law in addressing these deficits. The Director-General of the ILO has noted that 'decent work is not just a goal- it is a driver of sustainable development' [13]. This statement considers the broader contribution of decent work to the attainment of various other sustainable development goals, including eradicating poverty, zero hunger, and gender equality [14]. Therefore, this contribution considers eliminating decent work deficits in the construction industry to be a core component of the sustainable construction industry.

3 Methodology

This paper follows two legal research methodologies, it follows a doctrinal research methodology in critically analysing the contemporary legal and policy framework promoting sustainable development in the construction industry. In so doing the paper draws on a variety of sources including case law, legislation and various academic articles. The paper then also follows a law-reform methodology to suggest legal and policy options to address existing shortfalls in the law within the area of sustainable development.

4 Decent Work Deficits in the Construction Industry

There has been growing concern over decent work deficits in the construction industry. Bong et al. argues that the construction industry has been plagued with a growing negative perception of the quality of work in the industry. According to Bong et al. this poor reputation arises from the countless accidents on construction sites and the perception that construction firms fail to effectively enforce safety procedures on construction sites [15]. Haupt and Harinarian also argue that the South African construction industry has not been immune from these perceptions. There are widespread media reports of serious workplace accidents on construction sites [16].

In their research, Haupt and Harinarian focused specifically on casual workers in the construction sector. These casual workers often work for various sub-contractors on construction sites and report that they are not generally provided with personal protective equipment (PPE) by the 'employer'. These workers report that where such PPE is provided the 'employer' usually deducts the cost of this equipment from their wages. The effect thereof is that many of these workers work on construction sites without the appropriate PPE [16].

4.1 Protection in Terms of Labour and Social Security Legislation

The prevalence of casual labour in the construction industry also creates additional problems as far as decent work deficits are concerned. In particular, the significant casualisation of the industry deprives these workers of protection in terms of important statutory workplace social insurance schemes. The Unemployment Insurance Act, Act no. 63 of 2001, which establishes the Unemployment Insurance Fund (UIF), only extends protection to employees [17]. In terms of the Act, an employee is ‘any natural person who receives any remuneration or to whom any remuneration accrues in respect of services rendered by that person but excludes and independent contractor’.

Casual labourers in the construction industry would often be classified as independent contractors and consequently do not enjoy protection in terms of the UI Act. This is because the determination of who is an independent contractor still draws substantially on the common law tests distinguishing between a contract for works and a contract of service [18]. Factors such as the fact that the casual labourer is appointed to complete a specific project would usually favour finding that the worker is an independent contractor. Nevertheless, the line may become blurred if the worker is subject to the overall control of the ‘employer’.

Within labour law, there has been significant efforts made to combat disguised employment. The legislature has introduced Section 200A of the Labour Relations Act, Act no. 66 of 1995 (LRA) and Section 83A of the Basic Conditions of Employment Act, Act no. 75 of 1997 (BCEA) to combat disguised employment. These sections introduce a range of factors to be considered and where one or more of these criteria are met the worker is presumed to be an employee until the contrary is proven. This shift in the burden significantly assists workers who may be in a weaker bargaining position.

The COIDA establishes the Compensation Fund which is aimed at providing employees with compensation for occupational injuries and diseases [19]. The COIDA also confines protection to persons who are defined as ‘employees’. It contains a comprehensive definition of an employee and defines it as ‘a person who has entered into or works under a contract of service or of apprenticeship or learnership, with an employer, whether the contract is express or implied, oral or in writing, and whether the remuneration is calculated by time or by work done, or is in cash or in kind, and includes - (a) a casual employee employed for the purpose of the employer’s business; (b) a director or member of a body corporate who has entered into a contract of service or of apprenticeship or learnership with the body corporate, in so far as he acts within the scope of his employment in terms of such contract; (c) a person provided by a labour broker against payment to a client for the rendering of a service or the performance of work, and for which service or work such person is paid by the labour broker; (d) in the case of a deceased employee, his dependants, and in the case of an employee who is a person under disability, a curator acting on behalf of that employee…’ [19].

The definition specifically includes casual employees, which seemingly refers to workers such as day labourers. This specific inclusion of these workers is to be welcomed particularly in an industry, such as the construction industry, where workplace injuries are fairly common. These day labourers should accordingly also be covered should they suffer workplace injuries. The Compensation Fund will then provide the ‘employee’ with compensation should the 'employee' suffer a workplace injury resulting in their disablement or death [19].

Nevertheless, where a worker is classified as an independent contractor such a worker would also be excluded from protection in terms of the COIDA. In *Compensation Commissioner v Van Vuuren* the court explained that even though the Act defines an 'employee' relatively broadly, it still limits its scope to an employment relationship. Where a worker enters into an agreement for works (*locatio conductio operis*) such person will not be entitled to claim for any occupational injuries or diseases for want of an employment relationship [20]. Only those workers who have entered into a clear employment relationship through a contract of service would be entitled to protection. Therefore, the widespread use of independent contractors in the construction industry could still see many persons excluded from the vital protection afforded by the COIDA.

4.2 Legal Interventions for a Safer Construction Industry

The Occupational Health and Safety Act, Act no. 85 of 1993 (OHASA) also principally applies between employers and employees [21]. However, the Act also creates obligations regarding persons who are not 'employees' as defined in the Act. Section 9(1) of the Act provides that '[e]very employer shall conduct his undertaking in such a manner as to ensure, as far as is reasonably practicable, that persons other than those in his employment who may be directly affected by his activities are not thereby exposed to hazards to their health or safety.' This creates certain obligations for the main construction contractor to ensure that appropriate measures to mitigate the risk of injury in the construction industry are implemented, including injury to sub-contractors on site.

The obligations in terms of the OHASA within the construction industry are expanded upon in terms of the Construction Regulations, 2014 [22]. These regulations set out the obligations of each stakeholder in greater detail and impose a range of obligations on the principal contractor. In terms of the regulations, the principal contractor is expected to ensure that every sub-contractor to be appointed is aware of the health and safety plan and that these sub-contractors have made sufficient provisions for health and safety measures during the construction process. The principal contractor is also obligated to ensure that every sub-contractor is registered with the Compensation Fund or with a licensed compensation insurer as contemplated in COIDA [22].

The client is in turn obligated to ensure that the principal contractor has an appropriate occupational health and safety plan in place. The regulations are ultimately aimed at ensuring a safe construction environment regardless of the contractual nature of the relationship between the parties. It accordingly recognises that all stakeholders have a role to play in securing a safe working environment and places varying degrees of responsibility on the different stakeholders based on their overall level of control over the site and the construction works. For example, while the principal obligator is obligated to check that sub-contractors are registered with the Compensation Fund, the responsibility to register and pay the contributions remains with the sub-contractor in question [20].

Despite the important role that these regulations play in promoting safer construction environments compliance issues remain. A study commissioned by the Construction Industry Development Board (CIDB) found that the Construction Regulations have only contributed to a relatively minor uptick in improved health and safety plans among subcontractors [23]. The report notes that there is a need for greater awareness among industry participants that good occupational health and safety practices are not merely reflective of responsible corporate governance but also present binding legal obligations [23]. The work of the CIDB in seeking to promote a safer construction industry is commendable as is its awareness-raising campaigns. The section that follows this contribution will consider the role of corporate social responsibility codes in promoting a safer construction environment. It will consider the effectiveness of such codes and the interaction between such codes and the legal responsibilities created in terms of the Construction Regulations.

The OHASA also does not directly address the extent to which contractors would be under a legal obligation to adopt technologies that promote a safer construction industry. This is not entirely unusual as the Act is meant to afford employers a degree of discretion to consider which methods of promoting occupational safety and health would be most appropriate in a particular workplace. Nevertheless, the employer is expected to take all measures that are reasonably practicable to prevent injuries in the workplace. In *MacDonald v General Motors South Africa (Pty) Ltd* the court had to determine whether an employer had a duty to secure a platform by providing railings. The court held that "here again the test as to whether the protective devices contended for by the plaintiff ought to have been supplied must be the view that a reasonable person would take." [24].

This means that employers may have a legal duty to adopt certain technologies as part of its overall safety measures in the workplace. However, this duty would only apply if the risk in question is foreseeable in the ordinary course of business and the technological tool suggested would address these concerns. Although there has been very limited guidelines from the courts, it seems likely that a court would also weigh the cost of the technological tool suggested against the likelihood of the risk occurring. Certain risks in the construction industry occur relatively frequently. For example, Jo et al. notes that globally collision accidents are one of the major causes of fatalities on construction sites [25]. In their paper they consider the substantial contribution that new technologies such as HASARD, a proximity warning system, has made to alleviating these risks. They note that HASARD is based on a magnetic sensor, where the receiver measures the strength of the magnetic field generated by the transmitter and then warns workers and machine operators alike when persons are within close proximity [25]. This has contributed to a substantial reduction in workplace fatalities where such systems are being implemented.

The benefits of these new technologies for a safer work environment are accordingly indisputable. However, the different digital technologies also differ substantially in cost which could make the adoption of some more reasonable than the adoption of other technological aids. These costs coupled with the absence of clear legal guidelines also mean that a greater industry understanding of the benefits of these technologies may be required to encourage their adoption even in the absence of an explicit legal obligation. To this end, corporate social responsibility policies may play an important role alongside binding legal obligations.

5 Codes of Corporate Social Responsibility

There has been substantial growth in codes of corporate social responsibility being adopted by large multinational corporations (MNCs) [26]. Proponents of such codes have long argued that these codes offer MNCs the ability to influence the behaviour of various other entities in the global supply chain. It is argued that a large customer can influence its suppliers to adopt more sustainable business practices, including the effective recognition of core labour standards, through its economic power [27]. Within the construction industry, the CIDB has noted that the principal contractor can have a significant influence on the health and safety practices of the sub-contractors [23]. This need for influencing extended role players is particularly important within the construction industry considering the widespread use of independent contractors. In this respect the CIDB has noted that the construction industry represents an anomaly in that although it is a large sector, it is dominated by many small, medium and micro enterprises (SMMEs) who sub-contract with larger enterprises. According to the CIDB, a disproportionate percentage of workplace-related challenges about a lack of social insurance and proper workplace safety measures occur within these SMMEs [23].

The Construction Regulations also recognises the power of the principal contractor to influence the behaviour of other contractors on site. However, the regulations are limited to occupational health and safety and the need to check that all sub-contractors are registered with the Compensation Fund [22]. While these obligations should contribute positively to the attainment of decent work within the construction industry, it is still somewhat limited. The use of codes of corporate social responsibility could potentially be used by principal contractors and clients to expand on minimum standards of behaviour expected of all contractors and stakeholders involved in the project.

However, while such codes have great potential to influence a change in business behaviour, it has been suggested that these codes are often merely used as a form of virtue signalling [28]. Scholars argue that where these codes are used in this way the larger entities have little desire to actively enforce the code and merely seek to benefit from the good publicity of having such codes in place [29]. Therefore, these scholars argue that regulation is required rather than voluntary codes of corporate social responsibility.

This contribution acknowledges these concerns surrounding the use of codes of corporate social responsibility and does not advocate for self-regulation. However, there is no reason to consider these options to be mutually exclusive as it is entirely possible to create extended producer responsibility as a matter of law while corporate codes provide additional guidance to suppliers. For example, technology changes rapidly and law may not always be updated as quickly as needed to regulate such emerging technologies. Corporate codes could provide more general guidelines and could usually be updated more readily than laws. The codes could also offer the added benefit of consolidating an entire range of sustainability considerations into a single document that is easily accessible to principal contractors and the many SMMEs in the construction industry.

6 Conclusion

This contribution has considered decent work and its critical contribution to more sustainable construction industry. The critical analysis of the contemporary labour and social protection regulatory framework in the construction industry reveals that existing legislation does not always adequately address decent work deficits in the industry. However, certain legislative interventions are promising and could promote broader compliance with occupational health and safety measures which could, in turn, contribute positively towards addressing decent work deficits. The recognition of the important role of principal contractors to promote a safer work environment for all contractors is particularly important.

Nevertheless, it is also clear that these obligations are still quite limited. The regulations could be expanded to include checks that sub-contractors are compliant with other important legislation such as the UI Act as well. This would not pose a substantial additional burden as such confirmation could be obtained at the same time as the COIDA registration checks. The paucity of guidelines for the adoption of digital technologies for a sustainable and inclusive construction industry should also be addressed. This contribution also showcased that where legal obligations exist, there is still somewhat limited knowledge of these obligations by construction contractors. To this end, this contribution suggests the use of a consolidated corporate code of conduct to go along with education campaigns such as those by the CIDB.

This consolidated document could then also promote an integrated approach to sustainable development. While this contribution has principally focused on the social component of sustainable development, the industry must consider all components thereof when implementing new solutions. A corporate code could bring together the primary legal obligations across all spheres of sustainable development while also providing the industry with more general guidelines. These more general guidelines could be particularly valuable to the adoption of digital technologies where there is a paucity of such guidelines within the legal framework. Such codes could also stress the importance of digital tools more broadly in promoting a safer and more sustainable construction industry.

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Establishing the Need for Utilising Market Intelligence by Local Construction Firms in Developing Countries

Joseph Asante[1(✉)], Edward Badu[2], Ernest Kissi[2], Adjei Kumi[2], and Ivy Maame Adwoa Abu[2]

[1] Department of Buiding Technology, Sunyani Technical University, Sunyanu, Ghana
joeasante73@gmail.com

[2] Department of Construction Technology and Management, Kwame University of Science and Technology, Kumasi, Ghana

Abstract. The use of competitive information (also known as market intelligence) as a basis for strategic decisions by businesses is well documented. Even though market intelligence (MI) is a well-studied topic in other industries such as services, retail, and manufacturing, little is known about how construction firms can strategically use market intelligence to enhance their competitiveness. This conceptual paper examines market intelligence theories developed and implemented in other industries to provide a theoretical framework. The purpose is to propose strategic areas in which local construction firms may utilise MI as a basis for strategic decisions to improve their competitiveness in the face of increased competition. Based on the project marketing phases, four possible areas have been identified where MI can be used to improve the competitiveness of local construction firms. As a conceptual paper, the current paper does not provide new data, but it does provide a direction for future research on the utilisation of market intelligence in the context of the construction industry by indigenous construction contractors in developing countries.

Keywords: Competitiveness · Construction industry · Developing countries · Local construction firms · Market intelligence

1 Introduction

The increasing participation of foreign construction firms in the developing countries' markets has heightened competition in the construction industries in these countries [62]. For wholly-owned indigenous construction contractors (henceforth, local construction firms) to enhance their competitive position and survive the current and future, the local construction firms (LCFs) must aggressively pursue alternative marketing strategies [68]. It is a fact that the performance of any firm is largely influenced by its business environment [16]. The events in the external environment can determine the success or continued survival of any organisation [47]. Yet, businesses have little control over external factors [44]. High-performing firms scan their external environment more regularly

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and widely better than their low-performing counterparts [10]. Finding out more about the business environment cannot be taken for granted. In construction, the business environment refers to all the external factors that influence the construction process [4]. It comprises government policies, technology, products, customer, institutional stakeholders, competitors' strategies, economic, demographics, political, and even metrological climate [7, 2]. Choo [21] posited that the survival and growth of any firm depend on its ability to anticipate changes in the business environment. A deeper understanding of the dynamics of external factors is a prerequisite to identifying potential opportunities and threats [65]. This suggests that the interface between the firms and their external environment provides opportunities for and threats to the Construction firms. This also shows that businesses must adopt a management tool that can assist them to become more aware of the events in their business environment [16]. Scanning the business operating environment for relevant market information can help businesses to avoid surprises, identify threats and opportunities, gain competitive advantage, and improve long-term and short-term planning [36].

2 Literature

2.1 Nature of Construction Business Environment in the Developing Countries

The linkage between the construction industry and the economic growth of developing countries has long been highlighted [5, 57, 59]. In Ghana, the contribution of the construction industry to GDP growth has been improving over the years [57]. Notably, even in 2013, when Ghana recorded its lowest GDP in recent years, the construction industry recorded 8.4% while other sectors recorded an average of 5.4% [38]. As the economies of developing countries like Ghana expand, so does the demand for construction and, by extension, demand for the services of Construction firms due to the strong link the construction industry has with other sectors such as transportation, manufacturing, commerce, utilities, finance, and firm's services (Song and Liu, 2006). The expansion of the developing countries' economies presents business opportunities for LCFs.

The challenges facing LCFs are not significantly different from those in other developing countries [68, 46]. Despite the remarkable growth of the construction industry in developing countries over the years, the funding invested in infrastructure development does not benefit LCFs as much as it ought to be [32, 74]. Pheng and Hou [59] stated that the presence of foreign contractors in the developing countries' markets is one significant factor posing an existential threat to LCFs. Foreign Construction firms perform between 80% and 90% of the construction work in Ghana [8, 9, 76], depriving LCFs of the opportunity to develop and grow. Payment delays in Ghana's construction industry are widespread [6, 46, 71], and the LCFs are the most affected in the developing countries [58]. Whereas there is a contractual obligation on the clients to pay the Construction firms promptly for the work done, the LCFs are largely reluctant to seek legal remedy for the fear of losing clients [71]. Macroeconomic factors such as unexpectedly high inflation [2, 23, 24], an unstable exchange rate [55], and high borrowing costs [31, 46] harm Ghanaian firm profitability [39].

Although client feedback provides insight into whether firms are doing well or not in the course of delivering a service (Celuch et al., 2015), Construction firms generally tend to evaluate client satisfaction at the completion phase of the project, where a large percentage of the project funds have already been expended [70]. This means that little or no attention is paid to long-term customer relationships [7]. The current strategy for evaluating client satisfaction appears to be outdated in the current business environment, where two-thirds of dissatisfied customers fail to report their dissatisfaction to the company [19]. Given that fierce competition and a lack of customer satisfaction deprive Construction firms of work opportunities, and even if they do find work, macroeconomic fluctuations and payment delays deprive them of the desired profitability. As indicated by [52], higher levels of monitoring of the business operating environment can assist businesses to learn how to effectively manage competition, understand customer needs, and target profitable markets. This is why leveraging MI is critical for LCFs as it provides the opportunity to spot early business opportunities ahead of competitors [29, 37], identity competitive threats [36, 29]; understand competitors [67]; and develop long-term relationships with customers [3, 51].

2.2 Concept of Market Intelligence

The term "market intelligence" has been around since it was coined by Professor William T. Kelley in the year 1961 [42]. The concept of using intelligence in strategies, on the other hand, dates back over 5,000 years [60]. Yet there is still no universally accepted definition. Chitwood [20] suggested that for any piece of information to be considered intelligence, it must be relevant to the problems the decision-makers are seeking answers to. Erickson and Rothberg [30] stated that knowledge, information, and/or data subjected to analysis and applied to decision-making can be considered intelligence. MI can be either a process or a product [15]. MI as a product is the valuable information used as the basis for decision-making. As a process, it is a set of activities used to transform information or data to support decision-makers [17]. The consensus about MI is that it helps managers make better strategic and tactical decisions [17, 45].

2.2.1 The Purpose of Undertaking Market Intelligence Activities

It is abundantly clear that the external environment influences the success or failure of firms [47]. Despite this reality, managers have little control over what prevails in the external environment [44]. In light of that, a firm that can identify changes in the external environment ahead of competitors obtains a competitive advantage (Higgs, 2006). As such, MI has become one of the key drivers of both strategy and success in firms [45]. This is because effective decision-making is a critical antecedent to the attainment of business goals within a given time and budget [66]. According to McGonagle and Vella (2002), MI enables a firm to understand the forces that influence the external business environment and develop appropriate strategies to compete successfully. According to Samat et al. [63], MI is a critical management tool that enables businesses to make informed and beneficial strategic decisions. Decision-making takes place daily, everywhere, and at any time in the life of a firm [75], and contractors are no exception, as they must make countless decisions such as market entry, pricing, funding source, purchasing, customer satisfaction, and so forth. Moctar and Arditi [53] describe how MI helps businesses to make decisions they face each day in their various areas of responsibility. Yap et al. [77]

describe how MI facilitates effective decision-making that leads to actions. MI also helps to improve and optimise firms' decision-making (du Toit, 2003). MI helps to develop a firm's strategies that address threats to gain a competitive edge, thereby enhancing its sustainability [17, 73, 34]. Actionable information about the external business environment has become an essential resource for strategic decision-making [22]. Strategic decision-making based on intelligence assists firms to build a position of sustainable competitive advantage from a well-informed position [41]. Consequently, the first task in decision-making is to gather sufficient actionable information related to the problem at hand [75]. Firms that utilise MI effectively improve their competitive advantage and overall performance [35].

2.2.2 Why Local Construction Firms Must Care About Market Intelligence?

Currently, most developing countries are expanding their infrastructure bases to support their economic growth, and that presents business opportunities for LCFs. Nonetheless, developing countries' construction market is characterised by intense competition, bribery and corruption, pervasive payment delays, unstable macroeconomic indicators, dissatisfied construction clients, and a high incidence of firm failure. Therefore, MI utilisation is increasingly relevant for LCFs [28]. This is because proactive actions instead of reacting to the changes in the business environment are key to firms' success [36]. From the foregoing, the question that arises is: *how can MI be utilised strategically in the context of construction to improve the competitiveness of LCFs?*

2.2.3 Framework for Utilising Market Intelligence by Local Construction Firms

The project marketing life-cycle model suggested by Turner et al. (2019) provides an appropriate model for MI utilisation by LCFs. The objective of project marketing by construction firms is to secure more business opportunities (Turner et al., 2019). They suggested a four-phase (i.e., pre-project, bid invitation, project delivery, and post-project) project marketing life cycle. The authors explained that the contractor's marketing starts in the very early pre-project phase and continues into the post-project phase. This method of marketing strategy improves a firm's competitive advantage by developing a business model that matches the client's needs at each phase of the project (Turner et al., 2019).

Pre-project Phase Business opportunities arising from the business environment may go unnoticed if the company is not actively involved in market scanning [36]. A firm that is the first to identify and act on new observed trends (demand for construction) can obtain first-mover benefits (Higgs, 2006). A construction firm that capitalizes on competitive information [36], arising from weak signals (triggers of demand for the services of Construction firms), can gain a competitive edge. Construction firms that can identify business opportunities before their competitors may gain first-mover benefits of loyalty, market share, possibly high margins, and strong brand recognition [36]. A construction firm (CF) creates the necessary conditions for a favourable negotiation outcome by making the first contact with a prospective client and doing so aggressively and well [25]. That first-mover advantage can be a source of potential entry barriers for competitors [43, 72]. This means that Construction firms that can detect competitive information from weak signals in the business environment and act upon it timeously gain a first-mover advantage.

Bid Invitation Phase In construction, competitive bidding is the major means through which construction firms compete with one another to obtain work in the market. Competitive bidding in construction means that Construction firms must make strategic decisions [56]. So, gathering intelligence about competitors is important for any CF that wants to achieve sustained competitive advantages [50]. Diamant [26] stated that it is important to know against whom you are bidding. This is important because bidding demands considerable resources in its preparation and is, therefore, an expensive exercise. Through MI, a CF would be able to identify the key and average competitors, and this would help in the pricing or influence bid/no-bid decisions. The suppliers of special concrete or equipment, the agency, or the architect/engineer who provided the drawings can provide information about potential competitors [56, 53, 27]. Intelligence about potential competitors and the business environment would allow a CF to base pricing decisions on facts rather than gut feelings, reflective thinking, and instinct [53].

Project Delivery Phase Similarly, threats arising from the business environment may go unnoticed if the company is not actively involved in market scanning [36]. Monitoring the external business environment helps in the detection of threats to the firm's current and future interests [64]. MI provides an early warning sign [12]. An early warning sign is an expression, indication, or proof of the existence of some future occurrence [54]. The early warning provides firms with the necessary information for strategic direction [48]. Payment delays [61], price instability [11], and supply chain disruption [1], are major contributory factors to the financial distress of Construction firms. Regular intelligence gathering about a client's current financial status, factors affecting the client's ability to meet its financial obligations, macro-economic risks, materials, and labourer supply disruption, enable firms to take proactive countermeasures [12] to forestall or reduce the adverse impact on the construction firms' finances.

Post-project Phase Firms that are keen on improving their service listen continuously to their customers. Firms that engage their customers deliver a better service that exceeds customers' expectations (Berry and [14]. In the construction industry, time, cost, and quality have been largely acknowledged as desirable if clients' expectations are to be met [40]. But the process of constructing a project consists of both product and service components [49]. So, there are many situations when clients can still be dissatisfied even though the product (time, cost, and quality criteria) has been accomplished [70]. Gathering intelligence in the course of service delivery (construction process) can be manifested in the following, as indicated by [13], 1995),

- encourages the incorporation of customer needs into decision-making.
- it reveals customers' service priorities.
- it identifies priority areas for improvement.
- it allows the tracking of company service performance over time.
- it discloses the impact of service quality initiatives and investments.
- it offers performance-based data to correct poor service.

2.3 Conclusion

Both opportunities for and threats to LCFs arise from the operating environment. A firm that capitalises on the opportunities and succeeds in minimising the impact of threats gains competitiveness. As a result, better knowledge of business environments can be a key determinant of LCFs' competitiveness. This is because firm competitiveness depends not only on the firm's actions but also on the impacts of other external forces. These forces include customers, competitors, suppliers, and government, social, political, legal, technological, political, and demographic. Competition is an inevitable force in today's construction business environment. For this reason, LCFs that systematically gather intelligence about key competitors would be able to make an effective bid/no-bid decision based on an informed position instead of intuition and experience. While competition is unavoidable in the construction industry, intelligence gathering about prospective projects will enable LCFs to approach clients before a project is announced. Payment delays remain a major challenge to LCFs' cash inflow, yet they are largely unwilling to seek legal remedies for delayed payment. Gathering intelligence about the financial "health" of the client during the construction phase will allow the LCFs to strategise to minimise the adverse impact of late payments on their finances. Client retention or referral is a major source of securing jobs devoid of the usual competition with other competitors. Accordingly, the LCFs that go beyond the dictates of a contract to gather intelligence about what clients' values most create opportunities for future engagement and referrals. MI can be a useful strategic tool for LCFs in developing countries. The current issues confronting LCFs show the need for more research into how MI might be strategically utilised in the Ghanaian construction industry to boost LCF competitiveness.

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Investigating the Effects of River Channel Meander on Bridge Hydraulics

Chidozie Charles Nnaji[1,2(✉)], Godwin Akeke[3], and Christopher Afangideh[4]

[1] Department of Civil Engineering, University of Nigeria, Nsukka, Nigeria
chidozie.nnaji@unn.edu

[2] Faculty of Engineering and Built Environment, University of Johannesburg, Johannesburg, South Africa

[3] Department of Civil Engineering, University of Cross River, Calabar, Nigeria

[4] Department of Civil Engineering, Akwa Ibom State University, Mpat Enin, Akwa Ibom State, Nigeria

Abstract. Meanders in a river channel can result in significant changes in river hydraulics, and in time, the river could transform into an entirely different river from what it was originally. River Mayogwa in Jalingo, Taraba State is one of such rivers that have undergone remarkable change of course over the years. This paper was aimed at investigating the effect of a sinuous meander at the upstream reach of the bridge on flow characteristics at the inlet and outlet of the bridge. A ground survey of the river channel and flood plain was first undertaken. Digital elevation model (DEM) of the area was then created in Geographic Information System (GIS) using the survey data as input. The 50-year and 100-year discharges at the bridge point were determined using the Hydrological Engineering Corps Hydraulic Modelling System (HEC-HMS). The digital elevation model and the river discharge at the bridge were used as input in the Hydrological Engineering Corps River Analysis System (HEC-RAS) to simulate flow along the present river channel. Afterwards, the river was trained to straighten out the meander, and the flow hydraulics through this new (alternative) course was simulated again in HEC-RAS to study the effect of the new river course on the river hydraulics. The 50-year and 100-year discharges were obtained as 82.02 m^3/s and 177.6 m^3/s. Results showed that siltation on the downstream face due to the meander resulted in flow area reduction of 72.7% and 65% for the 50 years flood and 100-year flood respectively. The bridge was able to pass the 50-year flood without overtopping, but was overtopped by the 100-year flood, passing only 61% of the discharge. The alternative course will allow 94.5% of the 100-year flood to pass under the with a corresponding water surface elevation attenuation of 1.41 m downstream and 0.96 m upstream of the bridge. The river meander at the bridge section has severely impaired the flow of water through the bridge. The results obtained indicate that the bridge would be overtopped in the vent of the 100-year flood.

Keywords: Bridge · River · Hydraulics · Geographical information system · Flow · HEC-RAS

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1 Introduction

Rivers provide a dedicated channel for all hydrological response units within a catchment or watershed. Stable river channels are indispensable to proper drainage and flood mitigation. However, in many parts of the world, rivers have been known to change course repeatedly due to geogenic and anthropogenic factors. In fact, Nath et al. [1] noted that river change of course is a common geomorphological process. Distortion of natural drainage network due to anthropogenic activities such as agricultural activities and mining can sometimes necessitate a change of river course. Flowing water has erosive power and will naturally flow downslope in the path of least resistance, eroding obstructions in the process. Maurya and Yadav [2] observed that River Ramganga in India has been making an overall south-western shift due to erosion and shifting characteristics of the river. Bhargava [3] classified the social and environmental impact of three centuries of Ganges' change of course as a natural disaster. Panda and Bandyopadhyay [4] reported that River Bhagirathi has been changing course for a long time leading to formation of bars, meanders, ox-bow lakes and cut-offs.

Usually, when a river abandons its original course for whatever reason, it leaves behind a wasteland and thoughtlessly cuts its way through a farmland or forest reserve. In some cases, it might cut through an entire community thereby threatening their entire livelihood and existence. Changes (bank shifting, river widening and settlement displacement) in the morphology of River Jamuna in Bangladesh is responsible for the erosion and deposition of 3356 ha and 5342 ha of sediment respectively from 1972 to 2013, leading to displacement of the local population, loss of arable land and lack of water, sanitation and hygiene [5].

The Installation of a hydraulic structure such as a bridge or culvert has been known to cause major hydraulic and morphological changes in river channels if proper measures are not taken. Biswas and Banerjee [6] noted that the constriction of the width of River Chel due to the construction of a bridge across the river has caused extensive alterations in the normal hydrology of the river with a higher probability of bank erosion and flooding. Zhang et al. [7] reported significant effect of bridge pier geometry on the hydrodynamics of the Yellow River in China.

River Mayogwa is a major river in Taraba State, Nigeria that drains Yorro and Jalingo local government areas of the State. A bridge was built over this river to provide access into Jalingo from the southern part of the country. However, a major change of course has occurred at the upstream side of the bridge as a result of the following major reasons:

1. Deposit of sediments along the river course.
2. Slow down of flow due to constriction caused by the bridgeway which further encouraged deposit of sediments.
3. The change of course is further encouraged and aggravated by agricultural activities in the river flood plain. These agricultural practices facilitate detachment of soil particles and soil loss which goes on perpetually.
4. The silty and loose nature of the soil renders the river channels susceptible to attack by water current. Because of their weak nature, they easily give way and a new course is easily charted by flowing water when it encounters an obstruction. Most of the natural water channels in Taraba State manifest these characteristics, changing course

indiscriminately and causing environmental/ecological degradation. This change of course has given rise to a severe meander at the bridge section.

The aim of this study is to ascertain the effects of this meander induced by a change of course on the channel hydraulics at the bridge point (Fig. 1).

Fig. 1. Change of water course near the bridge (red arrows)

2 Methodology

To achieve the stipulated objective, an extensive ground survey was undertaken along the river channel, its banks and flood plains. Based on this survey, a digital elevation model of the desirable ground features was produced in Quantum GIS. This was used to generate geometry input data in HEC-RAS Mapper for hydrologic modeling. Also using the bridge point as an outlet, the catchment area was delineated in HEC-HMS (Hydrologic Engineering Centre's Hydraulic Modelling System) (Fig. 2). Then the 50-year and 100-year discharges were determined using the Soil Conservation Services Curve Number method (SCS-CN) [8], for both the 50-year and 100-year return periods based on the rainfall pattern of Taraba State (Table 1). For the 50-year storm, the hydrograph had an early peak on the first day at 21:00 h. The peak discharge for the 100-year storms occurred on the 3rd day at 17:30 h. The entire system response lasted for about 3 and half days for both the 50-year and the 100-year storms. The maximum discharge at the basin outlet is 68.4 m^3/s and 148.0 m^3/s for 50-year and 100-year storms respectively. Multiplying by a factor of 1.2 to account for the 20% expected increase in precipitation due to climate change [9], the expected flood becomes 82.08 m^3/s and 177.6 m^3/s for 50-year and 100-year storms respectively. These discharge values were used as flow data input into HEC-RAS for the analyses.

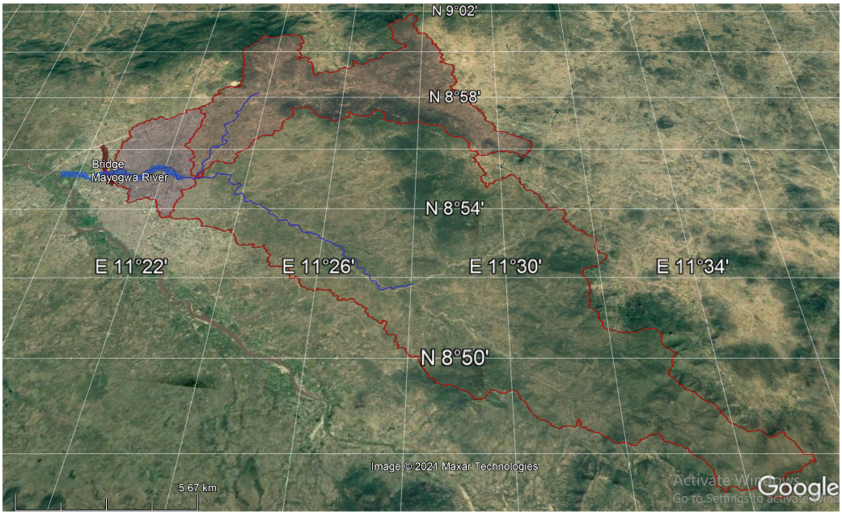

Fig. 2. Catchment at of Mayogwa River at the bridge overlain on Google Earth map (277 km^2)

Table 1. Rainfall statistics of Taraba State

Location/station	Geographical coordinates		Rainfall (mm)			
	Northing	Easting	35 years max	Year of max daily record	35 years daily average	35 years annual average
Sardauna	11.2500	6.7129	155.54	2008	11.32	4119.8
Kurmi	10.6250	7.3374	184.74	2013	6.01	2186.8
Donga	10.0000	7.6496	215.28	2011	4.53	1664.7
Wukari	10.0000	7.9618	194.5	1982	4.23	1557.5
Ibi	9.6875	7.9618	262.75	2007	4.2	1554.7
Ussa	10.0000	7.0251	137.03	1983	4.3	1547.5
Gassol	10.3125	8.2741	190.45	2014	4.11	1510.4
Takum	10.0000	7.3374	187.1	1993	4	1459.0
Bali	10.9375	8.2741	166.3	2011	3.88	1418.5
Yorro-Zing	11.5625	8.8985	156.7	2003	3.7	1344.4
Gashaka	11.2500	7.6496	192.5	1990	2.99	1097.5
Karim Lamido	10.9375	9.2107	187.85	1996	2.9	1067.6
Ardo Kola-Jalingo	11.2500	8.8985	167.191	2002	2.76	1008.2
Lau	11.5625	9.2107	171.162	2003	2.3	855.1

Two scenarios were considered in the hydraulic analysis viz:

(i) The hydraulic performance of the present river course was assessed for the two return periods chosen (50 and 100 years).
(ii) The river was trained to by-pass one limb of the sinuous meander as shown in Fig. 3. The total length of the by-pass is 0.875 km. This is expected to make flow faster by shortening the reach and reducing the shear stress generated by the bend. This option is also expected to reduce the wearing impact of the meander on the bridge abutment by ensuring that the channel crosses the bridge at a fairly regular angle.

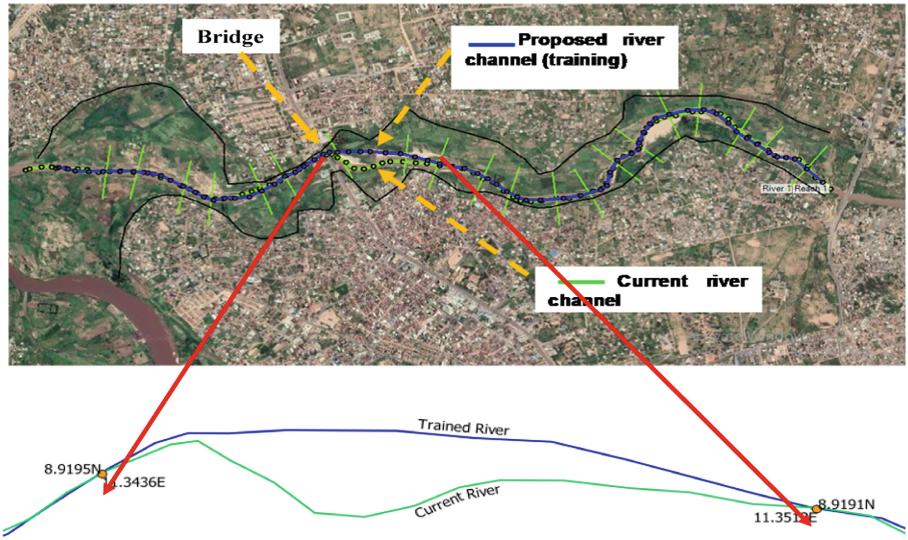

Fig. 3. New river route determined

3 Results and Discussion

River Mayogwa is currently experiencing high level of sediment deposit which often cause the river to change it course, resulting in meanders along the river channel. This high rate of sediment discharge is most likely because of the high velocity runoff moving downslope of the eastern highlands of the catchment, coupled with agricultural activities in the flood plain. As the runoff slows down towards the western part where the slope is gentle, the sediments are deposited along the riverbed. Massive deposition of sediments along the flow path of the river, coupled with the loose silty nature of the soils has caused the river to change course at various points along its course. The sedimentation and possible change of course by the river however is now causing riverbank erosion, encroachment into farmlands over flooding within its banks. Table 2 presents

Table 2. Effect of river training on channel/bridge hydraulics

Hydraulic parameters	50-year		100-year	
	Present course	Trained	Present course	Trained
Total discharge	82.02	82.02	177.6	177.6
Discharge passing through bridge	82.02	82.02	109.43	168.17
Water surface elevation at bridge (US)	199.37	199.17	201.21	200.25
Water surface elevation at bridge (DS)	198.88	198.67	200.41	199

the hydraulic parameters at the bridge face (upstream and downstream) for the 50-year and 100-year floods.

Siltation on the downstream face resulted in flow area reduction from 93.32 m^2 upstream to 25.49 m^2 downstream, which corresponds to a 72.7% reduction in flow area for the 50 years flood. Despite the reduction in the flow area, the bridge was still able to pass the 50-year flood without overtopping. The new course proposed for the river at the bridge approach did not have any significant effect on water surface elevation upstream and downstream of the bridge face. However, the hydraulic condition for the 100-year flood presented an entirely different and concerning scenario. For the 100-year flood, there was a flow area reduction from 139.01 m^2 upstream to 48.4 m^2 downstream, corresponding to 65% reduction in flow area. This reduction in flow area caused a reduction of 79.84% and 82% in the channel conveyance at the downstream section for the 50-year flood and 100-year flood respectively. The present river course causes a drastic reduction in the flow velocity at the bridge, so that the bridge passes only 61% of the discharge while the remainder flows over the roadway. However, the proposed course will increase flow velocity and allow 94.5% of the 100-year flood to pass under the bridge. This also corresponds to a water surface elevation attenuation of 1.41 m downstream and 0.96 m upstream (Table 3).

Table 3. Water surface elevation attenuation

Attenuation	50-year	100-year
Water surface attenuation US (m)	0.2	0.96
Water surface attenuation DS (m)	0.21	1.41
Increase in bridge discharge (m^3/s)	0	58.74

Results show that while the bridge is adequate for the 50-year flood, its conveyance has been severely degraded by the meander which will make it impossible to pass the 100-year flood. The proposed river course to reduce the sinuosity at the upstream bridge face of the channel will cause significant attenuation of the water surface elevation but will allow 5.5% of the discharge to flow over the roadway. Since the river has two other significant meanders a short distance away from the bridge (upstream and downstream), further training is required to increase the bridge conveyance and capacity to allow the passage of the 100-year flood. Further attenuation can be achieved by de-silting the river reach in the vicinity of the bridge. The gradual deposition of sediment the downstream side of the bridge has caused a flow area reduction of 72.7%. Hence, the downstream cross section constitutes a limiting factor in the performance of the bridge (Fig. 4).

Fig. 4. Showing flow deflection, siltation and undermining of bridge abutment

4 Conclusion

The change of course of Mayogwa River at the bridge point has severely altered the geo-morphology of the river channel as well as the hydraulics of flow. Because of this change of course and consequent reduction in flow velocity, there has been a gradual accumulation of sediments in the reach in the immediate vicinity of the bridge. The conveyance of the bridge has also been drastically reduced by the change of course such that the bridge cannot pass the 100-year flood. River training was very useful in increasing the carrying capacity of the bridge by increasing the flow velocity.

5 Recommendation

Based on the foregoing, it is recommended that the river meanders in the river reach close to the bridge be fairly straightened out to facilitate water flow. Besides, the river channel upstream and downstream of the bridge should be de-silted to increase the river channel conveyance. Further research should investigate the effect of de-silting of bridge hydraulics.

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A Review on Digital Quality Control Practices on Building Construction Projects

Margaret Damilola Oyewole and Modupe Cecilia Mewomo(✉)

Durban University of Technology, Durban, South Africa
ModupeM@dut.ac.za

Abstract. In an attempt to replace the existing quality control tools and techniques that are time-consuming and ineffective, researchers have been fruitfully spurred to develop and use state-of-the-art technological tools for quality control of construction projects. The application of technology to quality control on construction projects has been proved to help in the timely identification of an error in a short time, reduce rework and hence improve quality and project performance. Therefore, this study aims to review the available digital tools being used for quality control on building construction projects and their applications to ensure their adoption. The benefits and limitations of these tools were also highlighted in the study and this was achieved through a systematic review of past and current works of literature on digital quality control technologies. The study result thereby revealed the various technologies applied to construction projects for effective quality control as well as their benefits and limitations. The study also observed that most of these technologies are yet to be fully adopted especially in developing countries. The study thereby suggests the application of digital tools in combatting quality issues faced by construction industries.

Keywords: Quality control · Construction project · Digital technology

1 Introduction

Existing quality control (QC) techniques and methods on construction sites are time-wasting and ineffective since they provide information only at a specific period and location about the work in place, thereby limiting the capability of quality managers to detect and manage non-conformances. These QC methods and techniques include on-site supervision and monitoring, use of checklists, and manual method of collection and management of quality data.

On the whole, QC is an important aspect of quality management that ensures that human resources, materials, methods, and machinery all function at the expected standards and that the construction meets the required standard and specifications, including the client's requirement [1]. Overall, QC applies to construction projects throughout the life cycle, from the inception to the maintenance stage. Its practices include inspection/test, conformance verification, feedback, alongside non-conformance reporting and documentation to ensure that all the required standards and specifications are adequately

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met. According to Achkar [2], a well-planned quality assurance can result in quality failures as long as the QC practices are not adequately implemented. Therefore, effective QC management on a construction project requires an accurate, overall and regular evaluation of the construction status, detection of variations and material quality-related non-conformances of the work in place [3].

According to Romero et al. [4], automating QC and quality assurance procedures can enable the architecture, engineering and construction (AEC) sector to save time, improve quality, lower costs, and improve operations, allowing them to thrive in a highly competitive environment. Likewise, Salvi and Kerkar [1] opined that the AEC industry's critical problems in developing construction works could be solved by employing effective and continuous QC throughout the construction process and testing outputs and structures with modern tools and machines. In the real sense, digital QC is referred to as the application of modern systems and automated equipment to control and manage construction projects. They are used for monitoring and supervision, detecting and correcting errors or defects, material testing, and accurate and timely record of quality data.

Research into the application and implementation of technological devices in construction works has begun to effectively control and inspect construction projects, spurred by intense accentuation. Nonetheless, there are sparse reviews that consider the subject matter holistically. To this end, this study seeks to explore the application of digital technologies for construction QC management of building projects alongside their benefits.

2 Literature Review

Advanced digitization has tremendously trend in this present era of the fourth industrial revolution, and the AEC industry is not immune. Meanwhile, construction management is somewhat challenging due to the sector's complexity, uniqueness, and involvement of a broad group of specialists, which necessitates a fast, accurate, and efficient quality control technique. The application of digital technology to work control, according to Synek [5], considerably boosts the productivity of construction site control tasks. By and large, digital technologies are typically referred to as modern information and communication technologies and tools used in enhancing project performance throughout the construction life cycle [6]. In real-world applications, these digital technologies have been explored by the research community for construction QC through diverse case studies.

3 Methodology

A systematic review of extant and past literature was conducted in the study to access the digital technologies applied to QC on construction projects. The review was carried out by searching Scopus and Goggle scholar using these keywords; "*technology and quality inspection*," "*digital technology and construction*," "*drones and construction sites*," and "*digitization and construction*". Over 8000 records were found. The documents were screened by reading the abstracts to select those that are relevant to the research topic. Also, the inclusion of the articles was based on the practical implementation of digital quality control technology in construction industries. That is, the paper reviewed were those with case studies concerning digital QC and those published in English. Total case studies included for review resulted in 24 articles as presented in Fig. 1.

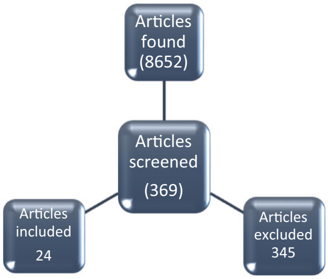


Fig. 1. Chart showing the systematic literature review process

3.1 Selected Applications of Building Information Modelling (BIM) on QC Practices of Construction Projects

For decreasing quality faults on building projects, Achkar [2] designed an integrated building information modeling (BIM) quality management system that encompasses the notion of QC, quality assurance, and communication methods. On a building project in the Netherlands, the model was validated. The BIM integrated quality management model helped to provide the foundation for the essential information and knowledge management, according to the findings. Due to time restrictions, the key goal of decreasing quality faults on site was not evaluated. Lou et al. [7] explored an applied BIM integrated with augmented reality (AR) technology for QC in urban complex projects. According to the study, using BIM technology leads to automatic quality inspection of data and documents, fast inspection and completion, comparative quality data evaluation, and superior QC. Similarly, Chen and Luo [8] developed a construction quality model based on BIM. The model was used in the foundation works of the Wuhan International Exhibition Center in China. The proposed methodology was found to ensure timely inspection and verification of construction tasks. The BIM model was solely used for design, not for temporary buildings. In the meantime, Wang et al. [9] built a construction QC program using BIM and LiDAR. The system's five components comprise QC, LiDAR-based real-time tracking, point cloud coordinate translation, BIM-based real-time verification, and data processing. The proposed system improved real-time QC by efficiently detecting flaws.

The application of a mobile BIM and lean interaction paradigm was demonstrated by Koseoglu and Nurtan-Gunes [10] using a mega airport in Turkey as a case study. The design process, on-site information system, QC and assurance record, material and resource management, and project performance all benefited from the mobile BIM. Furthermore, the solution tackled the challenges of traditional QC and quality assurance methods, such as excessive paperwork and time. In the domain of 3/4 Dimension application, Jin et al. [11] demonstrated the use of 4D BIM model for risk detection during the design phase of a construction project. The authors revealed that using a 3D model alone was insufficient for determining a design's safety performance since it lacked appropriate information to assess safety hazards and carry out on-site safety planning. Thus, they further developed the 3D model to construct a 4D-BIM model which was implemented by conducting the risk assessment of a 3-story concrete building project in China. Both designers and constructors were able to discover dangers and other faults in the design in terms of safety and constructability using the 4D BIM model. Furthermore, it assisted the contractors in identifying activities with high hazards in the project, allowing them to implement the appropriate safety precautions at an early stage. The researchers suggest that the proposed approach be used in the design-build project delivery process to allow designers and contractors to collaborate.

3.2 Selected Applications of Internet of Things (IoT) on QC Practices of Construction Projects

For assessing the strength of concrete structures, Lim et al. [12] proposed using internet of things technology (IoT) with the integration of temperature sensors and a data collection system. The proposed technology was utilized to record concrete temperature during curing and the investigation found that the proposed system collected and sent data efficiently. Furthermore, the temperature data gathered can be utilized to create concrete maturity indexes, which can help determine the concrete samples' strength. Chen et al. [13] employed IoT to design a digital quality monitoring system for construction gravel piles which was used in the Tianfu construction site in Chengdu. There were 163 gravel pile machines in use, with 144,476 pile point data which aid users to obtain quality report data of the piling process, observe the construction process, acquire and share relevant information that was simple, timely, and accurate; supervising work efficiently, enhanced data storage, and evaluation of quality data feedback through the system. John Shemin et al. [14] proposed using IoT to monitor concrete's early age strength. The system's ability to forecast early age strength was tested on five distinct concrete mixtures. When compared to the actual experimental compressive strength of the cast cubes, the experimental results demonstrated that the compressive strength predicted by the suggested system was accurate. They concluded that the system will be effective in concrete quality control, formwork stripping time, and concrete post-tensioning since the early age of concrete strength is critical in determining prestressing tendons' time and pretension losses. The system's drawbacks, however, are cost, complexity, and power consumption. The research of Reddy et al. [15] used sensors to demonstrate how IoT may be used to check concrete strength. The device correctly records the temperature, maturity, and compressive strength of the concrete, as well as provides real-time concrete moisture monitoring and automatic curing.

3.3 Selected Applications of Digital Sensors on QC Practices of Construction Projects

For reinforcement bar inspection, Yuan et al. [16] proposed utilising an RGB-D sensor. The developed system helped to detect non-conformances and post-process the inspection of the reinforced concrete structure in an economical, non-defective and safely manner. Furthermore, the authors stated that the LiDAR needs to warm up for sixty minutes to obtain an accurate output while their study recommended the inclusion of rebar diameter inspection for future use. Yao et al. [17] demonstrated the application of sensing technology for quality control and warning system for sleeve grouting of prefabricated buildings that comprise prefabricated uniformed layers using a prefabricated project in China as a case study. The system's results indicated the grouting compactness quality and assisted in achieving instant monitoring of quality change; performing an automatic fault analysis for resolving quality concerns, and sending signals and specific suggestions to construction participants via mobile application. Moreover, Im et al. [18] developed a durability monitoring system using sensors and a wide-band antenna. The system assisted in the real-time detection of chloride ion concentration and concrete temperature.

3.4 Selected Applications of Radio Frequency Identification (RFID) on QC Practices of Construction Projects

Iliescu and Ciocan [19] illustrated how current technologies such as radio frequency identification (RFID) can be used to control the operation of site trucks and equipment during the earthmoving and material testing processes for base building. A total of ten trucks were used in the inquiry, while the traditional method used written time sheets for record and observations, site visits for work supervision and verification of the required quality. The conventional approach took 72 months and had a 67% working efficiency, but the modern approach took 68 months and 80% working efficiency, hence, increasing work performance. Kim et al. [20] developed RFID and ZigBee to monitor construction materials using an indoor experiment and Yonsei–Samsung library construction site in Korea as case studies. The result revealed that the technology is suitable for transferring material information on construction sites. Furthermore, the readability of the RFID tag was found to be dependent on the type of material and location, with the reading rate of metallic construction material being poor. The study eventually recommended the use of a special RFID tag for metallic materials.

In a material testing laboratory in Taiwan, Wang [21] proposed using RFID to inspect the quality of concrete components. The findings of the experiment showed that concrete specimen progress and quality inspection in the testing laboratory could be tracked precisely and in real-time. More so, for RFID tags to be read, RFID tags and readers must be close to each other.

3.5 Further Applications of Digital Technologies on QC Practices of Construction Projects

Promisingly, numerous tools have been applied to bolster and advance the practice of QC in construction projects. For instance, Kim et al. [22] proposed the use of *mobile computing technology* for on-site management, using the construction of a hospital facility in Korea as a case study. The results showed that the suggested mobile system allowed for successful site monitoring via online task direction in terms of time and location site work tasks management, real-time data exchange, and effective communication among construction participants. Furthermore, the proposed mobile system reduced rework and increased the quality of the construction project. The authors suggested integrating the construction schedule and resource planning with BIM for effective information management. Vasquez-Armas et al. [23] employed a *mobile digital technology* for residential building inspection and observation management. The system aided in reducing inspection times and subcontractors' response times. In the context of drones and unmanned aircraft system/vehicles (UAVs), Ashour et al. [24] used a drone to inspect construction sites and detect non-conformances in the United Arab Emirates. The suggested technology enabled the control station to remotely inspect and monitor the construction site. Similarly, Freimuth and König [25] tested the application of integrated UAVs with 4D BIM for construction inspection planning and execution. The system assisted in achieving automatic inspection with minimal operator effort.

Meanwhile, Kim et al. [26] proposed using a *personal digital assistant* (PDA) connected to a wireless web system to collect defect data and arrange repair operations on building construction sites. The proposed technology was used in ten residential projects in South Korea to test its performance, with an average of roughly 700 home units. As a result of the system, contractors and quality managers were able to easily supervise work, monitor defect statuses and maintenance outcomes across all locations as the project progressed, and keep track of data for future projects. Functions such as quality inspection and material testing (concrete) on site, as well as a module that automatically analyzes the exact reasons for problems, were suggested by respondents. On the other hand, Gordon and Akinci [3] investigated the application of *laser detection and ranging system* (LADAR) with embedded sensing technologies for quality control and inspection processes of five construction sites. Data collecting range and speed were high with these technologies while they determined that one of the footings' concrete had been replaced using embedded temperature sensors in concrete. In addition, the inspection was carried out easily and in real-time. They further recommended that such factors as technology interference, weather, terrain extremes, and silent failures should be worked upon to increase the technological performance and should be considered whenever the system is to be used.

By embedding electrical components in the concrete, Chang and Hung [27] established the usage of *radio frequency integrated circuit* (RFIC) and sensor technologies to monitor the internal temperature and humidity of concrete automatically and in real time. Nonetheless, several limits exist, such as the need to shield the system from concrete contact which might compromise signal transmission, service life, and power consumption. In addition, Arora and Ogra [28] conducted research on mobile Geographical Information System (GIS) for construction quality managers and surveyors in an attempt to alleviate the problem of quality documentation and management in building projects. Quality data was collected, stored, and analyzed in real time.

4 Results and Discussion

Through the several case studies of digital control technology applications, ten technologies were identified from the review as presented in Table 1. BIM is the most implemented digital quality control technology followed by the IoT, and RFID, among others. These technologies were based on articles reviewed. From the review, it was observed that the use of BIM for quality control and implementation on construction sites enhanced collaboration among project participants through an effective communication system provided by the platform. Also, the quality inspection was made easy and fast; collection and storing of quality data in real-time and timely detection of non-conformance which make corrective actions to be implemented without delay [10]. BIM was also integrated with other technologies such as Augmented reality [7]; LiDAR [9] to increase the performance.

Table 1. Digital quality control technologies

References	Digital technology employed	Major function(s)
Achkar [2], Lou et al. [7], Chen and Luo [8], Wang et al. [9], Jin et al. [11], Koseoglu and Nurtan-Gunes [10]	Building information modelling	a) Used to detect discrepancies and clashes in the design thereby preventing costly and time-consuming mistakes b) Used to cross-check design following the specified standards and specifications
Lim et al. [12], Chen et al. [13], Reddy et al. [15], John Shemin et al. [14]	Internet of things (IoT)	Used to monitor and track construction materials, tools and machines to ensure compliance
Iliescu and Ciocan [19], Kim et al. [20], Wang [21]	Radio frequency identification (RFID)	a) Provides easy access to supervising and controlling hard to reach construction projects b) Detection of non-conformance remotely and in real-time
Yuan et al. [16], Yao et al. [17], Im et al. [18]	Sensors and/or actuators	Used for real-time detection of non-conformances and errors in construction materials
Ashour et al. [24], Freimuth and König [25]	Drones/unmanned aircraft system/vehicles (UAS/UAV)	a) Provides easy access to supervising and controlling hard to reach construction projects b) Detection of non-conformances remotely and in real-time
Kim et al. [22], Vasquez-Armas et al. [23]	Mobile computing technology	a) Information management and monitoring of construction works provides complete and consistent quality data information
Kim et al. [26]	Personal digital assistant (PDA)	a) Used for the collection and documentation of defect data and the management of corrective works on building construction sites b) Help to enhance efficient supervision of construction sites as the work progresses

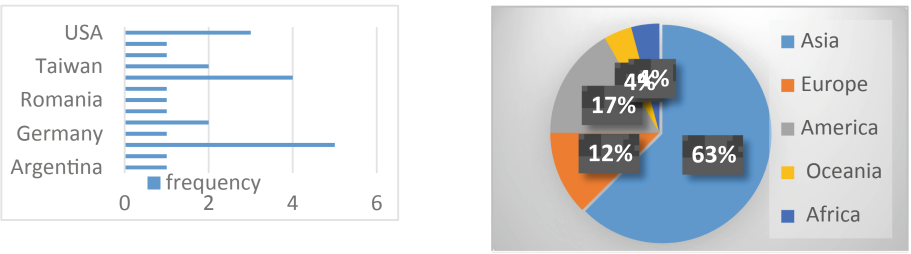
(*continued*)

Table 1. (*continued*)

References	Digital technology employed	Major function(s)
Gordon and Akinci [3]	LADAR with sensor	Used to scan construction materials to ensure that they meet the specified standard
Chang and Hung [27]	Radio frequency integrated circuit (RFIC)	Used to monitor the internal temperature and humidity of concrete automatically and in real-time
Arora and Ogra [28]	Geographical information system (GIS)	Used for collecting, storing and analyzing quality information

Quality inspection is known as one of the key practices of quality control to ensure that work requirements are met. Drones which are known as UAVs have been employed by researchers for the survey and inspection of works because of their ability to survey and inspect construction sites accurately and at a high speed. Findings from Ashour et al. [24] and Freimuth and König [25] confirm that the use of UAVs can help to achieve automatic inspection and detect nonconformances. Furthermore, Technologies such as sensors, RFIC and IoT has also been used for material testing and control on construction sites and laboratory. Gordon and Akinci [3] used sensors integrated with LADAR to monitor the strength of concrete and to collect data in real-time. Quality data collection, analysis and storage were achieved in real-time and efficiently by the use of mobile technology, AR and PDA.

However, it was observed from the review that the application of these technologies tools in controlling quality has not received much attention in construction industries. From Fig. 2a, nine (9) countries were identified (Argentina, Australia, China, Germany, India, Netherlands, Romania, South Africa, South Korea, Taiwan, Turkey, United Arab, USA) based on the country where the case studies reviewed were implemented. Also, across the five continents as shown in Fig. 2b, Asia and America were found leading with 63% and 17% respectively while Africa and Oceania were found lowest at 4% each.



a b

Fig. 2. a) Geographical implementation of digital QC technologies based on case studies reviewed. b) Geographical implementation of digital QC technologies based on case studies reviewed

5 Conclusion

The systematic review revealed that various technologies exist for enhancing quality control management practices on building construction projects. These technologies have been applied to quality control practices such as supervision and monitoring, detection of defects, material inspection and test, collection and recording of quality data, acceptance criteria etc. on construction projects in a timely and efficient manner. The application of digital technology for quality control can help construction managers and quality control engineers to supervise the quality of construction works in real time, accurately and efficiently. Therefore, construction companies can utilize these identified technologies for their adoption in improving quality management and control. However, the literature provides limited information on the emerging technologies as the technologies identified are those within the articles reviewed and this was because of time constraints.

We hereby recommend the application of digital quality control as a technique to combat quality issues faced by construction industries. In addition, more work should be done on improving the performance of these technologies in terms of power consumption, silent failures, complexity and other limitations as stated in the review.

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Key Drivers of Building Information Modelling Adoption for Post Construction Management: A Review of Existing Literature

James Olaonipekun Toyin[1], Abdulkabir Opeyemi Bello[2], Modupe Cecilia Mewomo[1(✉)], Olubukola Comfort Iyiola[1], and Kingsley Sunday Ihedigbo[2]

[1] Department of Construction Management and Quantity Surveying, Durban University of Technology, Durban, South Africa
{22175967,22176415}@dut4life.ac.za, Modupem@dut.ac.za

[2] Department of Building, School of Environmental Technology, The Federal University of Technology, Minna, Nigeria
{abdulkabir.pg207392,ihedigbo.pg208262}@st.futminna.edu.ng

Abstract. The adoption of innovative technology in the construction industry is constantly faced with various challenges globally. The industry now sees embracing Building Information Model (BIM) as a revolutionary promising innovative technology capable of improving accuracy, efficiency, and reliability. Moreover, the construction industry has been known for its critical resistance to change, and technological change, even though it is beneficial. Such change requires various drivers to motivate its adoption and implementation in the construction industry. The adoption of innovative technologies such as BIM has been established by researchers' findings, whereby it was documented to have a significant impact on the operation and maintenance of building facilities. BIM is an efficient tool for the operation and management (O&M) of building facilities. There is a need to take full advantage of these benefits as soon as possible.

Nevertheless, BIM has been appreciably implemented in the design and construction stage, while its post-construction (PC) adoption is still at an infant stage. There is a need to investigate the key drivers of BIM for PC O&M. The methodology approach adopted is an extensive review of published literature for PC. Thirteen (13) key drivers were identified and grouped into three clusters: "Management Related Drivers; Sustainability and Efficiency Related Drivers; Economics Related Drivers." Wherein 4, 6, and 3 were numbers of variables in the cluster grouping. The findings of this study will increase the chances of adopting BIM for PC and add to the existing body of knowledge in the realisation of BIM in developed and developing countries.

Keywords: Adoption · BIM · Integration · Management · Operation and maintenance

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1 Introduction

The increased acceptance of Building Information Modelling (BIM) by the client and built environment stakeholders indicates a significant advancement from the traditional design, build, and maintenance method of construction projects to the current trend of BIM use for the building lifecycle [1]. BIM usually enables experts to generate reliable building data and accurate information about the project at any given time [1, 2]. BIM does not have a single, universally acknowledged definition, as different experts and bodies construct their meanings based on their perspectives and operational needs [3]. The American Institute of Architects defined BIM as using cutting-edge digital technology to create a predictable representation of all physical and functional characteristics of a facility and its associated project [4]. BIM uses advanced digital technology to create a predictable model of all material and valuable features of a facility and its associated project. From planning to design, construction, and post-construction (PC), BIM technology is meant to be used throughout the project life cycle [5]. Azhar [6], Van Tam et al. [7] define BIM as a digital tool for managing project information during the design, construction, and PC phases. Eric Teicholz [8] noted that more than 80% of the overall cost incurred on a project during its life cycle is spent during the PC period. Similarly, Lu et al. [9] agreed with Council [10] wherein stated that "The operation and maintenance (O&M) phase is significant from the life-cycle perspective, which covers over 85% of the total costs in ownership and 30–50 years of the total period". Lately, Lee et al. [11] study revealed that an asset's life cycle costs might be 5–7 times more than its initial invested capital. In agreement with the assumption of Olanrewaju et al. [5] PC stage is a critical stage of any construction project. Therefore, the adoption of BIM at this PC stage is vital, as it has been proven to greatly improve and enhance the O&M process [19]. As a result of this, building information modelling has attracted the attention of many researchers and practitioners due to its ability to retain critical data information linked to various elements of buildings, which is crucial for building maintenance and asset control over the entire construction life cycle [12]. It has been reported by numerous authors that BIM has some important benefits that can be achieved with its integration for the post-construction O&M phase of building facilities. Hence, this study aims to investigate the key drivers that promote the adoption and implementation of BIM in the building O&M phase. The documentation of this driver will possibly improve its awareness and adoption for the PC stage.

2 Methodology

The literature review is one of the most critical processes in conducting good scientific research [1, 13]. Therefore, this study adopts an extensive review of published literature on BIM for PC management of the building. These were carried out to determine the possible drivers of BIM for building operation and maintenance (O&M). The study adopts data collection by reviewing related literature sourced from online databases of "Web of Sciences, Elsevier (Scopus), Google Scholar, Research Gate" with no year limitation. The search keywords "Drivers of BIM for PC management"; "BIM drivers for O&M", were used to locate relevant academic articles in the study context, as done in similar studies [1, 14]. These search queries were reiterated in the selected databases. The retrieved articles included journal articles, conference proceedings, books (chapters), thesis. This was done to locate likely papers in the context of the study. The exclusion criteria were limited to publication in languages other than English and field not related to construction. Initially, ten papers were located; after that, an additional 15 were located from the references of the initially located papers. This was done to get more related papers. The limited publications on the subject matter area may be due to a low concentration on "BIM drivers for post-construction". The final population of n = 25 was finally considered in this study. After retrieving the selected articles extensively reviewed and analysed, the result and the drives were addressed. The final phase involves discussion, conclusion, recommendation, and suggestion for further studies, based on the findings from the reviewed literature.

3 Research Findings and Discussion

3.1 Post Construction Phase: Facility Operation and Maintenance

The PC phase consists of management and maintenance of building facilities, aimed at improving the lifespan of the building. Comparatively, "this area attracts less research, and general awareness is low (even in developed countries); however, some advanced applications in the industry are apparent" [15, 16]. Lifecycle management, emergency management, and facilities management could all extensively benefit from BIM adoption [17]. The PC phase of the building project lifecycle was noticed to have been neglected to a considerable degree, resulting in severe infrastructure deterioration globally. Majorly in developing countries. This problem can be eased using BIM conforming software for managing the building. Integrating O&M decisions into facility design, where the role of each area has been determined, O&M has been planned and scheduled. The functioning of the components inherent in the facilities can carry the predicted population without defects [18]. Furthermore, as stated by Patacas et al. [19], "the future of effective and efficient facility management is dependent on how quickly the industry adopts BIM for the management of buildings". Mainly for the high-rise buildings that are evolving globally. These are known to pose significant challenges to the facility managers, owing to the complicated components and numerous elements inherent in such structures. BIM is changing the way the construction industry builds and maintains assets all over the globe, because it helps organisations identify and address issues before they occur, maximise results, and eliminate process waste, particularly rework [18]. Therefore, there is a need to identify and document findings in the area of drivers of BIM for post-construction O&M.

3.2 Overview of Published Articles on Drivers of BIM for Post-construction (PC)

Decades Ago, publication around BIM for PC has again slit attention. Studies in this context reveal that if the data generated within the BIM environment is accurately and well maintained, BIM has a definite possibility to generate cost reduction in the building O&M phase [20, 21]. However, crucial high-quality information is expected to be promptly ready and available as soon as possible throughout the building phase. Nevertheless, either there is too much information to keep or insufficient information to assure optimal performance. Moreover, the quality of data generated is often poor, and since it is kept in a collection of forms, it is difficult to locate. To address these issues, a proper information flow that is integrated, accessible, and transparent to all stakeholders is required [22]. The advent of BIM and its proper implementation promises to tackle this problem by considerably enhancing the inherent quality of BIM and offering mechanisms and processes for communicating and sharing information across project team members [22]. On this note, some drivers needed to be in place to assist and encourage BIM use for the PC phase of building facility management. The drivers for adopting innovation are simply the enablers for implementing a new process or product [23]. The enablers are the facilitators; it allows the removal of the barriers hindering the implementation of innovative adoption. Thereby, making it easier, just as the drivers assist in speeding up the adoption process. Most of the time, overcoming a challenge or barrier motivates adopting new technology. Solving problems like a shortage of BIM experts/trained individuals, for example, entails giving BIM training.

3.3 Drivers of BIM for Post-construction (PC)

Various related studies have identified or specified the factors influencing BIM implementation in PC. Olanrewaju et al. [18], in their study, identified three possible drivers for BIM implementation for PC building O&M. Eastman et al. [13] found that sustainability assessment, facility ease of management, increased efficiency, and coordination, are among the motivations driving clients and government to embrace BIM solutions. The ease of BIM use to promote successful cooperation amongst design disciplines, according to Chegu Badrinath et al. [24], is the primary motivation behind its growth, with mandates and policies aimed at increasing the Architecture, Engineer, and Construction (AEC) sector productivity around the world. The fact that BIM helps the client and the whole supply chain – with downstream advantages to customers who utilise built assets and society as a whole – is a key motivator of its growing adoption by clients and industry [25]. BIM permits information to be saved over time as the project advances and then handed on to the facility manager, who has been listed on the project since its inception and can help ensure effective and efficient facility management throughout its shelf life [26]. Kiani et al. [27] research revealed the following as drivers encouraging the implementation of BIM for PC in Iran: Availability of BIM experts and Government legislation action. These drivers indicated that more available BIM experts in Iran are willing to take up the task in the PC phase. The government is willing and ready to subsidise the price of the software and enact laws backing the implementation of BIM for the PC phase in the country. It was documented in the RIBA outline plan by Sinclair [28] that some drivers motivate the implementation of BIM for PC O&M of building facilities. The drivers are Collaboration among professionals, Cost reliability and management, Increased efficiency, and coordination. Therefore, client and built professional need to take advantage of these positive awaiting advantages BIM has over traditional means of O&M. Hergunsel [26] research find out the following as drivers of BIM for PC management: Facility ease of management, space management, and defect tracking, Sustainability assessment and Energy management, and maintenance schedule. The author's findings are majorly based on managerial driving factors. These factors are crucial in the PC phase. Eadie et al. [29] study emphasises government contribution to BIM implementation for PC as one of the key drivers that will escalate BIM implementation in the UK. Enforcing law/order and subsiding the software/tools allows ease of purchase and availability. This will boost the interest of developers in adopting BIM. In the three case studies examined, Azhar [6] findings indicated that increased efficiency and coordination, Space management and defect tracking, and cost reliability and management are the primary drivers of BIM for PC building projects. Babatunde et al. [30] findings noted: “Increased efficiency and coordination, availability of BIM experts, and Government support through legislation”, as the main drivers in their study. The study of Becerik-Gerber et al. [31] identified Ten (10) potential areas in that BIM can function successfully in the PC phase of building operation and maintenance. The author suggested that the following could be seen as BIM drivers for the O&M phase of building: BIM enables space management, emergency management, controlling and monitoring energy, and ease of locating building component. Toyin and Mewomo’s [1] study on the impact of successful BIM technology implementation at the PC stage reveals that increased efficiency and coordination, enabling significant data storage, and collaboration among the maintenance team are key drivers of BIM at these phases.

Poor information management and documentation are standard in the construction sector, negatively influencing the project’s lifecycle. The study by Saka and Chan [14] conducted in Africa reported that “the industry is notoriously slow to adopt modern digital technologies such as BIM, which has stunted industry growth and modernity”. Recently, Cavka et al. [32] opined that BIM is regarded as a promising solution for creating, organising, and managing these linked databases containing critical information for a facility to aid in carrying out O&M. Furthermore, discovered three significant drivers of BIM adoption for PC. Facility management record model; improved efficiency and coordination; improved quality and sustainability. Lin and Hsu [33] integrated BIM to support problem visualisation and management during the PC phase, using an application programming interface (API). This documented the capability of BIM to visualise problems and work progress at PC. The various identified drivers motivating and accelerating BIM adoption as an innovative construction technology in the O&M phase of buildings as identified by various scholars are collated and shown in Table 1.

Table 1 summarises the drivers of BIM extracted from the literature reviewed and systematically categorises them into groups. The adopted systematic grouping was adapted from Olanrewaju et al. [15, 34]. The authors previously used the principal component analysis approach to group the variables. Based on the knowledge of their grouping, this study systematically grouped the variables into three related clusters: (1) Management Related Drivers (MRD); (2) Sustainability and Efficiency Related Drivers (SERD); and (3) Economics Related Drivers (ERD).

Management Related Drivers (MRD). Management-related drivers refer to the administrative attributes that built professionals, contractors, and built professional bodies portray towards BIM adoption. Four drivers fall within this category: “Availability of BIM experts; Ease of facility Management; Awareness of the BIM among the built professionals; Cooperation and liability of professional bodies to its integration”. These drivers could be seen as the result of the hard work of BIM experts, the cooperation of built professionals, and government intervention in countries that have fully integrated BIM

Table 1. Drivers of BIM adoption in the O&M phase

S/N	Driver grouping code	Drivers toward BIM adoption	References
1.	MRD1	Availability of BIM experts	[23, 27, 30]
2.	MRD2	Ease of facility management	[7, 13, 22, 26, 35]
3.	ERD1	BIM software affordability	[29]
4.	SERD1	Ease of maintenance scheduling	[9, 23, 26, 36]
5.	SERD2	Increased efficiency and coordination	[1, 6, 13, 30]
6.	SERD3	Clients' interest in the use of BIM in their projects	[11, 18, 23, 29, 36–38]
7.	MRD3	Awareness of the BIM among the built professionals	[18, 23, 39]
8.	SERD4	Sustainability assessment and energy management	[9, 13, 26, 31, 40]
9.	MRD5	Cooperation and liability of professional bodies to its integration	[18, 22, 31, 35]
10.	ERD2	Cost reliability and management	[6, 18, 23, 28–30, 35]
11.	ERD3	Government legislation action	[23, 27, 29, 30, 41]
12.	SERD5	Space management and defect tracking	[6, 26, 31]
13.	SERD6	Enable large data storage and collaboration among professionals	[1, 7, 9, 18, 22, 27, 28, 35, 42]

into their construction industry. If these drivers' variables are in place, there are high chances of implementing BIM for PC [23, 30].

Sustainability and Efficiency Related Drivers (SERD). The drivers grouped under SERD as identified among the variables are six: "Ease of maintenance scheduling; Increased efficiency and coordination; Clients' interest in the use of BIM in their projects; Sustainability assessment and Energy management; Space management and defect tracking; Enable large data storage and Collaboration among professionals". These drivers directly attract the proposed developers, clients, government, and professionals. They identified the main expected capacity of BIM use if adopted for PC. Through the usage of BIM, clients may receive the best return on their investment in the project [37], with the guidance of BIM through the phases of projects with more focus on the O&M phase of the existing building. Furthermore, by eliminating rework and early identification of possible problems and enhancing the management and exchange of information created by the model, BIM improves efficiency and cooperation [43]. The use of BIM could also assist in improving the process of protecting the environment, making the notion of going green and achieving environmental goals end up to be a reality [34]. Governments worldwide have taken considerable steps to legislate green standards to make building projects more environmentally friendly and sustainable, in countries like the UK, Israel, and Nigeria [34, 43]. Similarly, BIM has been considered a critical tool for promoting sustainable construction and maintenance methods [34]. Olapade and Ekemode [42] noted that when there is an availability of avenue for facility managers in developing countries to collaborate with International Facilities Management Association (IFMA) sister Chapters in developed countries, it will drive the integration of BIM for PC since they are well experienced in the PC BIM integration. Toyin and Mewomo [1] noted that built professionals are ready to collaborate via the BIM platform in the building construction stage. If this energy is channeled to the PC phase, it will go a long way in hasting the integration of BIM for the PC phase.

Economics Related Drivers (ERD). The drivers related to economics among the identified variables were three: BIM Software affordability; Cost reliability and management; Government legislation action. Various research results have revealed that the ability to get optimum value for capital spent could be achieved by adopting BIM for PC. This could be agreed upon based on BIM's positive impact over conventional means of coordinating maintenance work. Government subsidising and enforcing its use could also assist professionals and clients in being able to afford and adopt the technology [27, 29]. For any new technology to be integrated into the built environment, its initial cost may directly influence the fast adoption. Hence, subsidising it by government or professional bodies is crucial.

4 Conclusion, Recommendation, and Suggestions for Further Studies

This study provided the possible key drivers of BIM adoption for PC activities carried out by maintenance managers. Thirteen key drivers were identified from the reviewed published literature on the subject matter. The study further grouped the identified key drivers' variables into three clusters: Management Related Drivers (MRD); Sustainability and Efficiency Related Drivers (SERD); Economics Related Drivers (ERD). The study noted MRD is synonymous with the administrative attributes posed by built professionals, contractors, building professional bodies toward the reliability of BIM for PC. Wherein four key drivers fall within these clusters. The reliability of these drivers resulted from BIM experts' input, cooperation of built professionals, and government intervention in countries toward full integration of BIM into their construction industry. SERD is the driver that directly attracts the clients, governments, developers, built professionals to adopt BIM for PC. The variable in this cluster comprises five key BIM drivers. These BIM key drivers speak about what is derivable with BIM adoption for PC activities. At the same time, ERD comprises three variables related to cost. It was noted that the initial cost of any new technology in the built environment might directly influence the fast adoption. Therefore, government or professional bodies subsidising it is crucial. According to the reviewed literature, it would attract clients, developers, and maintenance managers to quickly take up its integration.

This study recommends that government or various built professional bodies should try to subsidise BIM full or partial package, organise more BIM training on its practical integration for PC. This will increase the chances of having more developers and clients keying into the BIM system and increase the number of BIM experts.

The following could be suggested for further studies:

- Scholars may investigate the challenges hindering BIM realisation for the post-construction O&M phase through case studies and first-hand information from BIM experts in developed and developing countries.
- May investigate developing a road map model for integrating BIM for existing building O&M.

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Building Information Modelling for Information Management in the Construction Industry: A Systematic Review

Opeoluwa Akinradewo(✉), Clinton Aigbavboa, and Ayodeji Oke

Faculty of Engineering and the Built Environment, cidb Centre for Excellence and Sustainable Human Settlement and Construction Research Centre, University of Johannesburg, Johannesburg, South Africa
opeakinradewo@gmail.com

Abstract. Information is derived from the interpretation and understanding of information contextually. Information has been adjudged to be very important in any contemporary society. In the construction industry, information is significant as it is the 'things' shared among project stakeholders from inception to completion to achieve the client's objective. Tracking, security, retrieval and control of information in the construction industry has become tasking as there is an increase in the production of documents and its distribution channel. Due to this reason, there is a challenge of information fragmentation, non-accessibility, possible loss, and non-traceability. To solve these problems, there is a need to manage information for day-to-day usage in the industry through the adoption of information technology tools. This is because information technology is gaining more grounds globally. To address how information technology can be adopted for information management, this study carried out a systematic review on how a BIM-based information management system can be adopted in the construction industry. This was achieved by accessing published articles on this topic area from globally-rated academic research databases named SCOPUS and Web of Science. Downloaded articles were carefully refined to ensure they are related to the subject area and there was no duplication before extensive content analysis was employed to analyse them. Findings revealed that information can be adequately managed using BIM by applying intelligent management principles which include planning the information management process, organizing the information into the different categories, as well as the development of control over information and information access and usage.

Keywords: Building information modelling · Construction industry · Construction information · Information management · Project documentation

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1 Introduction

The construction industry employs a wide range of professionals with a wide range of preferences, expertise, and experiences. Built environment professionals, suppliers, retailers, insurance and lending companies, legislative bodies, regulatory bodies, technical experts, and end-users make up the core team [1]. These members of design teams collaborate during the project life cycle [2]. Since the construction industry is known for its variety of operations, projects go through all the life cycles to ensure successful control of the schedule, cost, and quality [3]. The use of information at any stage of the construction process is critical to achieving good management. According to Drucker [4] "*Information is data endowed with relevance and purpose*". In the context of the construction industry, information comes in form of a '*document*' which is exchanged, transferred, and stored. These documents are important in the construction industry because they are exchanged by participants to express the client's concept, often known as project information. Construction documents, according to Chan and Leung [5], are the focal point of the information phase of construction project management and information management is extremely important in modern construction firms. Zhu and Issa [6] emphasized the importance of clear and timely project documentation for the development phase. Failure to do so could lead to sloppy and time-consuming decision-making during the project implementation phase. Due to the proper documentation, project partners would be able to share information in a clear and timely manner. Fisher [7], opined that in the construction industry, coordination and information processing takes up between 75 and 90% of a project manager's time.

According to Hjelt and Björk [8], information management in the construction industry has grown over time. It began in the 1960s with the introduction of photocopying machines, which lowered the expenses of material replication and prompted the establishment of dedicated photocopying businesses. This was followed in the 1980s by the introduction of personal computers with CAD-systems for creating drawings but sharing of documents was achieved only by couriered copies or mails, or by diskettes so that the recipient could view the information in its digital format. Faxing took centre stage shortly after, and information transfer through the internet became simpler, though massive sketches could not be shared and received in digital form. With the advent of point-to-point modem dial-up and a bilateral line combined with a local area network, computer networking took over. About 1995, the Internet became widely used around the world, and the construction industry followed suit due to the opportunities it offered. In the construction industry, this resulted in project documentation using a record management framework. With the advent of automated document processing through the Internet, device enhancements have mostly centred on Internet technologies, based on the new dimension employed [8, 9]. Recently, digitalisation is being applied to the design process with the start of the fourth industrial revolution (4IR). In achieving this, Building Information Modelling (BIM) is taking centre stage. BIM is seen as an ideal tool for creating effective and innovative strategies for the architecture and construction industries (AEC) by offering additional information layers capable of interacting in real-time and collaborating during the design stage [10]. This research, therefore, set out to review how a BIM-based information management system is adopted in the construction industry.

The research also discussed the benefits BIM-based information management system will bring to the construction industry.

2 Methodology

To achieve the set objective of the study, a systematic review of articles approach was employed. This involved accessing both Web of Science (WoS) and SCOPUS databases due to their popularity and efficiency [11]. A thorough search of publications was carried out using the following keywords: "Building Information Modelling" AND "Information Management" OR "construction engineering" OR "building sector" OR "building engineering" OR "construction sector" OR "building industry" OR "construction management" OR "construction industry". Title, abstract, and keywords of published articles were searched using the keyword strings and a total of 26 files were retrieved. However, only 16 were suitable for analysis having sieved the result to remove duplicates and unrelated articles. The 16 documents comprise of journal articles and conference papers. Content analysis was adopted to evaluate the articles and extract contents used to provide answers to the set research questions.

3 Information Management in the Construction Industry

Information is obtained through the retrieval and analysis of data [12]. Radović-Marković and Vučeković [13] described information as transformed data that some users find useful due to its inherent value. The use of information in daily English has been determined to be critical in every contemporary society [14]. This is because information technology is gaining traction worldwide. Capurro and Hjrarland [14] added that information, along with labour, resources, and raw material supply, can be considered a necessary condition for economic growth in a society. Machlup and Mansfield [15] viewed information as a human process characterized by the transmission and reception of messages by individuals in preparation for future acts. To bolster this, Capurro [16] described information as "an anthropological category referring to the phenomena of human messages, whose vertical and horizontal forms correspond to both the Greek definition of message (*angelia*) and philosophical discourse (*logos*)". From these presentations, it can be concluded that information acts as a vehicle for communication between people in order to ensure that the recipient takes action.

The scope [17] and relevance [18] of information management practices in the construction industry have been illustrated in a variety of reports. After extensive analysis, studies have shown that construction firms are largely unhappy with their IT investments from the perspective of managers tracking return on investment [19]. In attempting to propose new technology and systems for information management, researchers discovered that information storage and sharing within the construction industry already occurs manually, with individuals or organizations manually reformatting and transmitting documents [20], usually on a paper basis [21]. This results in time and cost overrun, inefficiencies due to rework, additional unnecessary time spent finding valuable information due to uncoordinated, and/or inadequate exchange of information [22]. The decentralized nature of the construction industry often results in incompatibilities of software application used by the different professionals (clients, planners, contractors, and suppliers) [21, 23]. Dawood et al. [20] addressed the difficulties inherent in developing a structure that accommodates the diverse perspectives and desires of the many technical disciplines engaged in the building process by suggesting the adoption of BIM as it is ideally suited to address these requirements in the construction industry. Sacks et al. [24] established synergies between BIM and lean construction concepts and demonstrated that information can be handled leanly. However, little research has been conducted directly on quantifying information flows across BIM to assess its effect on the information sharing and coordination problem.

4 Overview of Building Information Modelling (BIM)

BIM can mean a variety of things to different people and in a variety of ways. BIM is a broad term that refers to a "modelling technology and related collection of processes for creating, communicating, and analysing building models" [25]. BIM extends 3D modelling principles by adding non-graphical object information into the model. Numerous studies defined BIM in terms of the benefits it provides, including parametric modelling [26], detailed building analysis [27], 4D programming, in which the construction schedule is integrated into the building model [28], 5D modelling, in which cost information is also integrated into the building model [29], and more broadly *n*D modelling [30]. BIM is characterized for the purposes of this research as a detailed collection of information (including documents) about the design, development, and operation of a building that is anchored to an emergent geometric (2D/3D) model of the building.

The basic distinction between a BIM model and a CAD model is the object orientation and the symbolic detail associated with the geometry. A 3D shape can be labelled with the symbol "panel" allowing other information structures and human users to use the geometric information more easily as a building object [31]. To optimize material management, BIM technology offers a new approach to forecast, monitor, and track product quality and quantity. Currently, existing construction management tools can be combined with BIM 360 to expand BIM capabilities in the construction area during the project planning process [32]. BIM can be utilized optimally throughout the project construction process by incorporating 4IR's critical elements, such as the Internet of Things (IoT), cyber-physical systems (CPS), Internet of Services (IoS), Big information, artificial intelligence (AI), and smart manufacturing applications [33]. Using the BIM platform, these tools strengthen BIM's capabilities by monitoring on-site inventory handling, on-site waste sorting, job process management, and workplace supervision. BIM integrates the planning process and aids in the creation of a visual representation of each component of the infrastructure. 61% of companies are expected to use BIM for most of their programs in the next five years [34, 35]. This wind of progress means that BIM has the ability to bridge the technical gap between manual and computer-aided design (CAD) systems.

5 Building Information Modelling (BIM) and Construction Information Management

According to Lee et al. [36], BIM can be adopted as a database which incorporates both structural and non-structural information used in the construction industry. The authors expressed the opinion that BIM facilitates the aggregation of information in the construction industry, which allows easier coordination and standardization, as well as the accumulation and control of materials and management of information. In regard to these advantages, it also serves as an automated project manager, which cuts down on drawing and estimating times, the time taken for schedule creation, organizing, and other areas of construction [37, 38]. BIM can organise all the data that is available on construction sites into a system that groups and classifies it according to specific purposes and connects it to the project model so that construction details can be accessed in relation to their components [36]. Figure 1 depicts a construction database built on BIM principles.

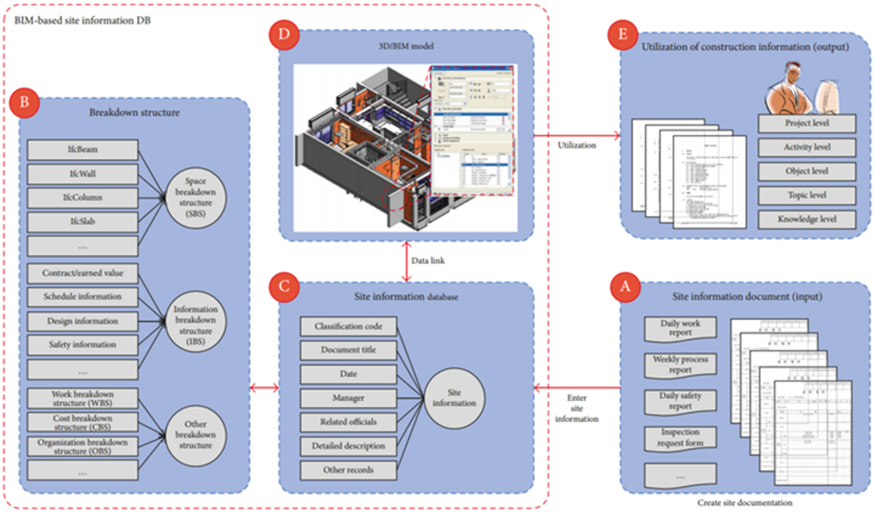

Fig. 1. BIM-based information management system [36]

The BIM-based database system shows that documents produced on the construction sites seen in Part A are both prepared and organized using the categorization system designed to categorize information as seen in Part B. The organized documents are then saved in the BIM-based database system shown in Part C. In Part D, the stored construction information is linked to the BIM model, and the BIM model is then used by construction managers and other stakeholders in Part E. Based on the depicted BIM-based information management system, the benefits to be derived are highlighted as follow.

5.1 Simultaneous Access to Information

According to Maher [39], BIM enables simultaneous access to project databases or repositories by project teams and stakeholders. This phenomenon does not always result in faster design and meeting times; rather, it enables early identification of design conflicts and failures so stakeholders can collaborate and exchange ideas easily [40, 41]. Additionally, concurrent access enables the respective disciplines to simultaneously construct, upgrade, sort, engineer, and input their design opinions and details. As a result, BIM consumers benefit from BIM because it enables timely convergence, information exchange, and the creation of comprehensive information about design elements that is transferrable across the project's life [42].

5.2 Effective and Quality Communication

Numerous research activities have been directed toward establishing the critical role of contact in building processes [43, 44]. Nonetheless, the shortcomings of both manual and computer-aided design applications have been shown. They have been related to increasing the vulnerability of construction systems to design mistakes and clashes, as well as other types of information flow inconsistency [45]. Although manual and CAD applications lack the necessary mechanisms for robust information and communication, BIM transmits information through photo-realistic graphics, or their convertible formats. Additionally, a plethora of information from various business surveys [11, 43] suggests that when project information and coordination are streamlined, project partners are more able to incorporate and cooperate efficiently. As a result, BIM offers long-term platforms for interactive teaching, simulation, information sharing, and value integration. As a result, the risks associated with mistakes, contradictions, and subjectivity are reduced [46].

5.3 Project Documentation

Apart from the contradictions, discrepancies, and mistakes that fractured systems inevitably introduce, Olatunji and Sher [37] have identified additional significant disincentives to the needs of clients when project information is fragmented electronically or manually. While Sommerville and Craig [47] demonstrated how electronic content management systems (EDMS) can result in cost savings, interoperability in traditional CAD has been a significant constraint [42, 48]. BIM enables the comprehensive incorporation of project documents from conceptualization to detailed planning, sourcing, installation, and facility management through coordination and constructive communication [49]. Contractors can also receive pre-quantified drawings in electronic formats while also modifying fabrication and installation models and storing them for use of the project's life cycle model. This approach increases efficiency, coordination, and creativity in construction product development processes, but no cost savings have been identified [40, 42].

6 Lessons Learnt

From the review carried out in this research, it is evident that information management in the construction industry is still at infancy phase as little attention has been given to it. Information is mostly shared and saved in hardcopy format while few are in softcopy. However, the information in softcopy format is not adequately shared due to the fragmented nature of the industry. There is limited room for collaboration among the professionals involved in the construction industry as individual professional have their information in various formats. BIM is a software that extends 3D modelling principles by adding non-graphical object information into the 3D model. This software can be programmed to incorporate all the information shared by all the professionals on a construction project and make the information accessible to all. The BIM-based information system will promote accurate documentation of construction information and promote quality and effective communication among construction industry professionals. It will make simultaneous access to information by construction professionals possible.

7 Conclusion

This research set out to review how BIM-based information management system can be incorporated into the construction industry and the benefits to be derived from it. The research adopted a systematic literature review approach with published journals and conference articles on BIM and information management used. The review focused on the components of a typical information system, the use of BIM in the construction industry and the benefits of BIM-based information system. The design and adoption of a BIM-based information management in the construction industry will go a long way in improving the usage of information. It will also provide up-to-date information for professionals on each construction project. With the construction industry globally accused of being late to adopt technological innovations, it is not strange to find out that only few professionals are putting BIM into use for information management. It is recommended that construction professionals be signed up for continuous professional development courses where they will be trained on how BIM can be used for information management. Also, the developers of BIM software can organise trainings to keep the professionals abreast of the different features their products have and how it can be put to maximum use by professionals. This study was limited to secondary data which was retrieved from prominent research databases. Further studies can be carried by collecting primary information from construction professionals to seek their opinion on the incorporation of BIM-based information system into the activities of the industry.

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Ascertaining the Benefit Indexes of Life Cycle Assessment in the South African Construction Industry: A Hybrid Fuzzy Analysis Approach

Titus Ebenezer Kwofie[1,2](✉), Clinton Aigbavboa[1], Samuel Amos-Abanyie[2], Didibhuku Thwala[3], and Lusca K. Ngwepe[1]

[1] Faculty of Engineering and the Built Environment, cidb Centre of Excellence, University of Johannesburg, Johannesburg, South Africa
tekwofie.cap@knust.edu.gh, caigbavboa@uj.ac.za

[2] Department of Architecture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
s.amos-abanyie.cap@knust.edu.gh

[3] Department of Civil Engineering, College of Engineering, Science and Technology, University of South Africa (UNISA), Pretoria, South Africa
thwaladw@unisa.ac.za

Abstract. Given the lack of consensus on the clear benefits of Life Cycle Assessment (LCA), the purpose of this study was to gain understanding of the significance and weightings among the key benefits of LCA adoption and develop a benefit index towards a more sustainable construction development in the South African construction industry. The study gathered data through the use of survey questionnaire on 126 sustainability stakeholders in South Africa using a 9-point scale pairwise comparison. A total of 105 responses were received out of the 126 distributed questionnaires. The data gathered was analyzed using hybrid fuzzy ANP technique with the DEMATEL method to determine the significance and weightings of the four benefit index from extant literature review. The results highlighted policy and legislation as the most significant and effective benefit of LCA followed by environmental performance benefits, marketing benefits and strategic planning and management benefits. In the case of the weighting of these benefits, policy and legislation was noted to be the highest, contributing about 40% to the benefit index. Environmental performance was the second highest contributing about 34% to the benefit index. However, strategic planning and management benefits accounted for about 14% of the benefit index and was ranked third whereas, marketing benefits weighted about 12% of the total benefit index and was ranked 4th. The contribution of the study is in the area of highlighting the benefits of LCA adoption towards increased sustainable building process and industry in an integrated index form. The study revealed the significance and weightings of the benefits of LCA adoption in the SACI. The understanding of these benefits should motivate an agenda and strategies by construction stakeholders, policymakers and researchers to increase LCA adoption so as to optimize these benefits to the SACI.

Keywords: Life cycle assessment · Project performance · Sustainable construction development · Construction industry · LCA benefits

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1 Introduction

Given the increased awareness of the environmental impacts of buildings and infrastructure delivery, the understanding of the role and benefits of Life Cycle Assessment (LCA) in the construction industry in South African is critical towards effective decision making and policy formulation towards increasing sustainability practices building and infrastructure delivery. In the global construction industry, focusing on the benefits of LCA to advance sustainable construction has become necessary approach to motivate the adoption and application of tools, techniques, practices and methodologies that has to do with the whole life cycle assessment and evaluation in site planning and organisation, re-use and recycling of materials, selection of materials, generation of waste and minimization of energy [1–3]. In the South African construction industry (SACI), recent initiatives aimed at promoting and achieving sustainable practices through embedding LCA in the processes of sustainable strategies can be enhanced through making known the absolute and practical benefits that can be gained from such integration to project stakeholders to support their decision-making [3, 4].

Conversely, there has been lack of progress encountered in making gains in achieving sustainable practices through embedding LCA in sustainable strategies and practices. The seemingly lack of clear and practical understanding of the benefits of LCA integration has become an obvious hindrance to it increased adoption and acceptance in the industry [2–4]. The role of LCA in promoting the sustainability concept in the SACI through advancing sustainable building design, sustainable construction process and sustainable construction practices to mitigate damages to the environment that have traditionally accompanied construction development is well acknowledged [2–5]. In the wake an era characterized by a strong focus on the environmental and physical facets of construction processes, the need to advance LCA adoption through the benefit approach has become more urgent, eminent and an apparent necessity.

In spite of the acknowledgement of some few existing evidence-based benefits of adopting LCA in the SACI, it has been practically perceived that, the prospects of LCA is yet to be rigorously reconnoitered in most construction projects primarily due to lack of understanding and consensus on it benefits to support their decision-making among stakeholders in sustainable practices in South Africa and other countries [1–3, 6, 7]. Additionally, to promote and guarantee the industry increase the adoption of LCA, understanding its key benefits can drive strategic planning and regulations for its application [8–10]. Hence, this study seeks to evaluate the perceived key benefits of LCA adoption to promote sustainability practices in the South African construction industry through a benefit index. From literature and in practice, it has become clear that there has been varied benefits to the integration of LCA depending on the context, industry and perspective of the stakeholders. In this study, the benefits to the South African construction industry from the perspectives of stakeholders will be the focus. It is expected that, the identified key benefits of LCA will increase adoption and application of LCA tools and techniques to promote a more sustainable construction development in South Africa [2, 4, 6, 7].

2 Overview of Life Cycle Assessment in Construction Project Delivery

Life cycle assessment (LCA) has consistently been defined as an approach of compiling and assessing the inputs, outputs and the possible impacts of a product system on the environment throughout its life cycle [2, 10, 11]. LCA is not a new idea and has been in use in manufacturing since the 1960s [5, 12–14]. In the construction sector, Ortiz et al. [10] and Khasreen et al. [2] noted that, the use of LCA dates back the onset of the 1990s with varied motives but aimed to proffer some benefits. In the construction industry, the implementation of LCA has entailed measuring and evaluating the environmental performance, which involves the selection and application of natural resources and the inherent environmental emissions through the production processes in the extractive industries [3–5, 13, 14].

Kwofie et al. [3, 4] and Ortiz et al. [10] acknowledged that, the lack of in-depth understanding of the benefits of LCA adoption and implementation especially in developing countries has contributed to the shrinking success at increasing sustainable practices and processes in the construction project delivery and industry particularly in the SACI. Generally, LCA encompasses the four phases of Defining the Goals and Scoping, conducting Life Cycle Inventory Analysis (LCI), Life Cycle Impact Assessment (LCIA), and Life Cycle Interpretation and Improvement [1, 13–15]. The first phase which is the goal definition and scoping ensures that LCA is performed consistently [1, 15]. Ortiz et al. [10] and Kwofie et al. [3, 4] affirmed that life cycle inventory analysis phase follows after goal setting stage and its and inventory analysis of all the environmental inputs and outputs associated with a product or service. The case of the Life cycle impact assessment (LCIA) phase entails the classification and understanding of the environmental impacts of materials and building elements and evaluation of what is most important to underline decisions [13, 15]. The final phase is where the results of the LCA are interpreted and conclusions are verified and well substantiated [14, 15].

Gustavsson and Joelsson [15] and Caplehorn [5] estimated that, the global construction sector and its related buildings and infrastructure directly utilizes almost 40% of global energy and at the same time accountable for about one-third of gas emissions annually. Against this background, there has been an urgent necessity to ensure construction process, inputs products, buildings and infrastructure more sustainable as an attempt to curtail the environmental effect of the industry [15–18]. In this regard, LCA becomes an absolute approach suitable to measure the usage of resources consumed and related environmental emissions, assessing the risk. This is largely because, the actual effect of the related known emissions are contingent on the manner they are released into the environment [3, 17, 18].

Globally, LCA has remained useful to the essential value of achieving sustainability through reducing the impact of a product or a process on the environment through its whole life cycle [12, 13, 16]. Hence, it can be argued that, an agenda to promote a clear understanding of the benefits of LCA can motivate its adoption and mitigate the barriers to it use and implementations proceeding from the collocation of prevailing tools, structural differences and theoretical concerns. Additionally, the understanding of the benefits of LCA and its prioritization may well be viewed as a remedy for facilitating the extent to which its approaches and procedures could aid in achieving the requirements for sustainability in building and construction process [1, 15, 19]. This could inevitably help decisions on the utmost practical solution to increasing the attainment of sustainability in the building industry resulting in reduced impact on the environment.

2.1 Benefits of LCA Adoption and Implementation

It is significant for a clear understanding of the key benefits of LCA and the interrelations between them towards a more pragmatic effort to increase its adoption and implementation in the SACI. Literature is replete with various benefits of LCA that include, environmental performance, strategic planning, policy and legislation and marketing [1, 2, 7, 20–22]. However, it is thus suggested that, these benefits are context dependent and influenced by the socio-economic, cultural, geo-political and structures that exist in the area of adoption and implementation [2, 7, 23–26]. Tshangela [20] indicated that, the LCA concept proffers various benefits and in the case of buildings, it associates directly with improving efficiency in the design and building process. It is also stated that, LCA increases effectiveness during the course of the whole life cycle of a building and affords the prospect of reducing costs, improving delivery dates, creating added value, and protecting the environment [1, 20]. According to Crawford [7] and Crosbie et al. [27], the use of LCA presents a strategic prospect for attaining rapid efficiency gains and improving the environment. Crawford [7] further maintained that, the benefits of LCA can be seen at the design phase of a project in its use to evaluate the possible impacts on the environments resulting from certain design decisions or choices. The Assessment of the environmental impacts of material production are imperative due to its ability to inform the criteria for the decisions on the design when choosing materials that have less effect on the environment compared to others showing similar performance for a given application [1, 28].

As noted in Babaizadeh et al. [29], analyzing the environmental performance of a building through its life cycle is crucial for its sustainable design. Hence, designers can make use of LCA in critical decision situations to appraise multifaceted decisions and vital innovations that could have unexpected environmental, social and economic impacts [19, 24]. Nonetheless, even though using LCA through the design stage could be beneficial before the actual construction, there are no assurances of what the impact on the environment will be for future phases of the building, such as the maintenance and disposal [7]. By conducting LCA across the various life cycle phases of a construction building, stakeholders could strive to achieve ultimate improvement in environmental performance of buildings across their entire life cycle centered on one early LCA that was conducted at the design stage [23, 27, 30]. One of the key rational for LCA is the conviction that, products, procedures, and other economic activities causing environmental harms that are not being effectively controlled and the natural resources that they use are not appropriately priced [28, 30]. Therefore, LCA becomes one of the probable tools or technique advanced largely due to the increase in environmental awareness. It is a tool that was initially established in order to support organizations to be environmentally friendly when undertaking production processes or activities.

The White Paper [31] that focuses on the built environment sector pronounced that architects, civil and services engineers, contractors, building clients, environmentalists and public officials demand guarantee that the materials and products being used in the design and construction of buildings are the most beneficial to the environment “from cradle to grave”. The work of Fava [30] noted and maintained that, LCA has become a useful tool aiding decision making, design development, marketing, choice of material, trade-offs in designs and improvements in business and the environment.

Environmental Performance Benefits

Extant literature Studies suggests that, many problems and challenges on the environment inherent from a product could be solved by LCA [2, 21]. In the opinion of Ampofo-Anti [21], LCA technique and processes examine variety of environmental impacts related to industrial products and materials and the contribution they make to climate change, soil and atmospheric acidification, ozone depletion and human toxicity. Notwithstanding, there are major positive variations that the usage of LCA can influence the environmental performance of buildings in both new and existing ones. Khasreen et al. [2] contended that LCA has turned into an extensively used methodology due to its integrated means of treating the framework, impact assessment, and data quality. It also allows recognized difficulties to be traced through all environmental media, specifically air, water and soil [21]. Additional benefit of LCA is that, it is centered on a selected functional unit and can include many geographic, technological, and temporal variations in its evaluation [7, 19].

Kohler and Moffatt [22] and Fava [30] noted that, LCA covers the complete environmental story of a product or process and remains a significant component of the sustainable construction concept. In LCA, there is no incidence of shifting problems from one life cycle stage to another, and from one location to another [9, 23]. Instead, Gundes [13] and Grant and Hes [24], suggested that, LCA assesses all phases of a product’s life from the view that they are interrelated. The LCA tool permits decision makers the prospect of studying the complete system of a product, thus preventing sub-optimization that might happen when just one procedure was the motivation for the analysis. Fundamentally, what LCA does, for example, when relating two products in order to make a choice of the one with less environmental impacts, is that it will apprise the underlying impacts that are not easily understood of other than just selecting a product founded on what we see.

Strategic Planning and Management Benefits

As noted by Gibberd [9], LCA can aid stakeholder and role players in choices about different methods as well as in the material selection in their effort to improve industrial environmental performance. In the opinion of Grant and Hes [24], LCA can be conceptualized as a thinking paradigm because it provokes an understanding of the effects of process or products on the environment to comprise upstream and downstream impacts of decisions as a strategic and management inputs. Environmental improvements of a product, method, or service acquired from LCA can prompt environmental and economic benefits to an organization [22]. Additionally, this may offer an organization with a competitive advantage over competing products or organizations and afford consumers with preferred options that are environmentally friendly. It also creates a conduit that can significantly reduce the overall environmental impacts [8]. The reason is that, as an outcome of LCA, decision makers are able to prioritize strategies for improvement and allocate funding in order to maximize any potential benefits of buildings on the environment.

A life cycle perception can serve as a strategic technique to help contribute resilient and enduring value to building styles and technologies [10, 22]. Significance of the value can be maximized in that respect since inefficient procedures or services may be adapted or changed, based on informed environmental inquiry [30]. LCA can likewise be used to ascertain probable opportunities for a business that might otherwise have been overlooked, and this in turn will increase the credibility of the business. Crawford [7] noted that, by adapting prevailing systems, procedures, or services, the organization will also become more prone to complying with future policies on environment, or probably minimizing future liabilities, risks or costs related to compliance or unstable and changing market expectations. Crawford [7] and Kohler and Moffatt [22] further alluded that the strategic benefit of LCA can be realized in the capacity to simulate performances of building and usage of energy. It also permits the examination of architectural design of buildings from the sustainability perspective, enable the evaluation and sustainable materials selection, components and systems for projects, reduce safety risks and improve project safety, health performance and support and improve project-related decision making in sustainable practices.

From the views of Kohler and Moffatt [22] and Fava [30] improving resource management across the value chain, facilitating building layout flexibility and retrofitting, possibility of early real-time sustainable design and analysis across the design phase, increasing building construction project efficiency and improving business conformity have become notable strategic benefits of LCA.

Policies and Legislations Benefits

LCAs can make significant contribution to the development and adaptation of companies', regional and national strategies and guidelines in areas such as managing waste and increasing the potential of recycling [25]. The DEAT [25, 26] further argued that, LCA could similarly be used to advise the development, application, and organization of public policy. Strategies and guidelines in this respect may be any policy regulation associated with the whole construction environment or the building sector. LCA can influence policy across all phases or each of the phases of a building. This is likely to encompass raw materials extraction ostensibly for manufacturing building materials, manufacturing methods, construction approaches, operational regulations for buildings and demolitions as well as building materials re-use and recycling laws [2]. When guidelines are made public, a substantial volume of reduction in impact on the environment may be realized as against when single organisations have their specific approach to handling the pertinent issues [28]. For instance, if the building material re-use and recycling is standardized through all the construction industry, it will afford governments means to ascertain the volume of environmental impacts each organization is accountable for, based on the volume of materials they recycle or re-use. LCA can also be used to evaluate the possible effect any existing or proposed future policy decisions may have on attaining beneficial environmental results [7].

In the opinion of Khasreen et al. [2], Crawford [7] and Malin [28] implementing LCA can facilitate the ability of accommodating the three key dimensions of sustainability, facilitate the incorporation of sustainability plans and policies with business planning through legislation, offer safer demolition methods as well as making tracking of environmental improvement possible. In South Africa, the Environmental Management Act has been noted as the examples of environmental laws and regulations that has arrangement and requirements across all sectors such as the construction industry and manufacturing sectors. The White Paper [31] is another policy framework that focus on response to climate change, dealing with pollution and waste management, environmental management, conserving natural resources and sustainable use of biodiversity and sustainable coastal development. In the case of the infrastructure and built environment sector, the National Building Regulation and the Occupational Health and Safety Acts are also notable polices that are available in South Africa. From the ISO 14040 [11], the SANS 204 Energy Efficiency in Buildings - Greenability stipulates the key standards and this must be made obligatory. Likewise, aspects such as Energy Efficiency Strategy initiatives that entails labelling schemes, energy reporting and auditing should be advanced and effected in the building and construction industry so as to guarantee improved environmental performance.

Marketing Benefits

Inherent from the DEAT [25, 26], it can be deduced that, LCAs are arranged and developed by manufacturers to generate and establish a base which can facilitate the improvement and development of a product or the means of production of the product. Hence, information from LCA studies can be used for the environmental labelling of products, which will help improve the competitive advantage of an organization [7]. Eco-labelling leads to green and clean information transfer to consumers and thus many people become aware of what their use of a certain product costs to the environment. This also supports and inform value for money because the customer knows that buying a product that is relatively expensive but environmentally friendly will cost less in terms of the environment. Examples of environmental labelling include fuel-consumption labels that disclose the fuel efficiency of motor vehicles, and energy or water rating labels indicating the energy or water efficiency of domestic appliances as well as building material labelling [7, 10]. When eco-labelling is associated with value for money, consumers will realize the necessity of being environmentally friendly as against seeing value for money being around cost only.

In terms of buildings, LCA may be used to improve green building ratings that are already in place. As green building ratings are mostly based on energy, LCA can provide more underlying information that includes all the environmental impacts associated with the building materials or components. For example, LCA will review the reasons behind the use of glass curtain walling as an incentive to reduce energy by allowing in natural daylight, and by assessing environmental impacts involved during the production processes.

3 Research Design and Methodology

This study followed a deductive research design using questionnaire survey to determine the key benefits from life cycle assessment (LCA), assess the relationships among the benefits, and prioritizing them. The use of quantitative design collecting data by questionnaire survey was primarily informed by it suitability in exploring, assessing, structuring, harnessing and organizing the judgement of professionals on a criteria or phenomenon and testing prior formulations in an objective and informed manner [32, 33]. The design of the questionnaire was preceded by an extensive review of literature on the benefits of LCA implementation that were summarized in Table 1. Given the intension of using the hybrid fuzzy method analysis as the analytical approach [34, 35], the four benefits in Table 1 were denoted as the benefit indexes (environmental performance benefit index (E1), strategic planning and management benefits index (S1), policy and legislation benefit index (L1) marketing benefit index (M1)). The questionnaire was structured into four sections with the first section focusing on ascertaining the background and suitability of the respondents. Sections 2, 3 and 4 dealt with the main objectives of the study that were determining the key benefits of life cycle assessment, assess the relationships among the benefits, and prioritizing them respectively.

The questionnaire was designed to follow a 9-point Saaty [34] scale pairwise comparison. Using a pairwise comparison questionnaire, it enables the comparison of the variables with each other in pairs [34, 35]. The respondents for the survey were selected from the main stakeholders in LCA implementation in South Africa with experience and knowledge encompassing professionals in practices, policy makers, research academics, sustainability 'think-thanks' analyst, regulators as they are deemed as key players in the subject area. These clusters of respondents are consistent with Kwofie et al. [3, 4]. In ensuring validity and reliability, the study relied on benefits of LCA, that are known and trusted from extant literature (see Table 1). This was done to guarantee theoretical validity and offer credence to the findings [32, 33]. In the case of ensuring reliability, the study relied on stakeholders in LCA with experience and knowledge to ensure consistency and credibility to their ratings of the variables [32]. The survey entailed 126 questionnaires distributed to building professionals, researchers and regulators and policymakers in sustainable building practices involved in sustainable practices and LCA in the construction industry in South Africa. The respondents were purposively selected through the Construction Industry Development Board (CIDB) in South Africa. As a condition, respondents could only respond to the questionnaire if they have a minimum of five (5) years' practice experience as this qualifies them for middle level management role [4].

From the total 126 questionnaires sent out, 105 were received after a twelve week period with a bi-weekly reminders. Two questionnaires were detected to be incomplete whereas one was found to have less than the minimum five year experience and were thus excluded. Consequently, 102 questionnaire responses were accepted and used. A hybrid fuzzy method analysis was subsequently used as the analytical approach. Dargi et al. [36] proved that, in cases of varied differing criteria for a problem, multi-criteria decision making (MCDM) methods have become useful technique to aid in making the most suitable and appropriate decision by ranking the criteria based on the opinions of experienced persons or experts. The fuzzy ANP method has become one of the grounded

Table 1. Summary of benefits of LCA

Typologies of benefits
E1 Environmental performance benefits
Reducing the impact on the environment across the value chain
Carbon risk minimization and energy efficiency improvement
Prevention and reduction in materials wastage by reuse and recycling and ensuring efficiency in materials
Ensuring indoor environmental quality and improved energy efficiency
Improves building designs and methods of construction by making them to be environmentally friendly
Facilitate the usage of renewable energy technologies
S1 Strategic planning and management benefits
Strategically motivate the application of clean technologies that involve less energy usage
Assists in giving value to building styles and resilient and long-lasting technologies
Ability to simulate the performance of building and their use of energy
Facilitate the selection of sustainable materials, components and systems for projects
Facilitating, supporting and improving decision making in project delivery
Improve resource management across the value chain
Enable flexibility in building layout and retrofitting
Promote early analysis and real-time sustainable design across the design phase
Facilitate progress concerning ecologically sustainable patterns of building materials consumption
P1 Policies and legislations benefits
Enhance the ability for accommodating the social, economic and environmental pillars of sustainability
Ease the integration of sustainability strategies with business planning
Facilitate the procedures to obtaining approvals and construction permits for building plans
Targeting and tracking of environmental improvement
Ability to develop and modify policies in waste management and increased recycling potential areas
Facilitate policy setting and legislation for buildings and processes
M1 Marketing benefits
Improve design products and promote multi-design alternatives
Facilitate sharing, exchange and management of product information and data
Ensuring improvement in organization brand image and competitive advantage
Gives construction business competitive advantage

(*continued*)

Table 1. (*continued*)

Typologies of benefits
Increase construction industry credibility
Facilitate conformity of construction business to green construction practices, laws, policies
Offers construction business marketing territory

Source [2, 7–10, 13, 21, 22, 24, 25, 28, 30]

and trusted MCDM methods applied in solving the problems in making decisions in which there are inter-relationships among multiple-criteria [36]. Khotimah et al. [37] referred to the fuzzy ANP method as being able ranking the criteria through relating their dependence on each other, and determining their correlations.

The Hybrid Fuzzy Method Analysis

The DEMATEL method was used to form the best decision matrix in ANP, the inter-relation of the factors by allowing allows for analyzing the importance of criteria and the causal relations among them [37]. Also a triangular fuzzy numbers (TFN) using the triplet L, M, U was used to translate the data into a set of numeric matrices. In the TFN, the 'L' represents the smallest likely value, 'M' stands the most probable value while the 'U' designates the largest possible value of any fuzzy event [36, 37]. The ability of TFN using simple algorithm of arithmetic operations and allowing for easy and intuitive interpretation and accuracy makes is most suitable compared to others [34, 36]. Recounting from Table 1, a standard 9-point scale pairwise comparison following after Saaty [34] was adopted, where a set of qualitative expressions were translated into a matrix of fuzzy numbers (see Table 2). That is, respondents were to evaluate the direct influence between any two factors by an integer score from 1 to 9. Accordingly, these numerical ratings were then translated into their corresponding TFNs.

Table 2. Translation of the qualitative pairwise comparisons to TFNs following Saaty [34]

Qualitative expressions	Numerical rating	TFNs	Inversed TFNs
Extremely significant	9	(9, 9, 9)	(1/9, 1/9, 1/9)
Very to extremely strongly significant	8	(7, 8, 9)	(1/9, 1/8, 1/7)
Very strongly significant	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Strongly to very strongly significant	6	(5, 6, 7)	(1/7, 1/6, 1/5)
Strongly significant	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Moderately to strongly significant	4	(3, 4, 5)	(1/5, 1/4, 1/3)
Moderately significant	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Equally to moderately significant	2	(1, 2, 3)	(1/3, 1/2, 1)
Equally significant	1	(0, 0, 0)	(0, 0, 0)

Next, the arithmetic average of all respondents' opinion and ratings was calculated using Eq. (1):

$$\tilde{Z} = \frac{\tilde{x}^1 \oplus \tilde{x}^2 \otimes \tilde{x}^3 \ldots \otimes x^q}{q}. \tag{1}$$

From Eq. 1, p represents the number of experienced respondents, x^(~1) to x^(~q). Denoted the pairwise comparison matrix for respondent 1 to respondent q and ž is a TFN in the shape of ž_k = l_ij^$'$, m_ij^$'$, u_ij^$'$. Following this, the average values were calculated and examined as summarized in Table 3. The matrix showing the direct relations among the major benefit indexes and their corresponding effects on each other are also represented. This was followed by the normalization of the matrix of the direct relations in the next stage. By this, the number became unitless and allowed an easier comparison of the values of elements. Using the DEMATEL technique, normalization is accounted for using Eqs. (2) and (3) and presented in Table 4.

$$\tilde{G}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l'_{ij}}{r}, \frac{m'_{ij}}{r}, \frac{u'_{ij}}{r}\right) = \left(l''_{ij}, m''_{ij}, u''_{ij}\right) \tag{2}$$

where 'r' is calculated by Eq. (3):

$$\mathrm{t} = max_{1<i<n}\left(\sum\nolimits_{j-1}^{n} u_{ij}\right) \tag{3}$$

Table 3. The direct relation matrix and the normalized matrix of direct relations from the DEMATEL questionnaires

The direct relation matrix				
	E1	S1	P1	M1
E1	(0.00, 0.00, 0.00)	(2.25, 3.25, 4.25)	(3.50, 4.50, 5.00)	(5.00, 6.00, 7.00)
S1	(2.50, 3.00, 3.50)	(0.00, 0.00, 0.00)	(3.50, 4.00, 4.50)	(6.25, 6.75, 7.25)
P1	(2.25, 3.00, 3.75)	(6.25, 7.00, 7.75)	(0.00, 0.00, 0.00)	(7.25, 7.75, 8.25)
M1	(3.25, 4.00, 4.75)	(3.25, 4.00, 4.75)	(4.25, 4.75, 5.25)	(0.00, 0.00, 0.00)
The normalized matrix of direct relations				
	E1	S1	P1	M1
E1	(0.00, 0.00, 0.00)	(0.119, 0.150, 0.208)	(0.138, 0.190, 0.238)	(0.259, 0.306, 0.339)
S1	(0.110, 0.137, 0.181)	(0.00, 0.00, 0.00)	(0.155, 0.191, 0.219)	(0.308, 0.349, 0.380)
P1	(0.131, 0.166, 0.197)	(0.303, 0.349, 0.391)	(0.00, 0.00, 0.00)	(0.349, 0.394, 0.408)
M1	(0.160, 0.208, 0.261)	(0.159, 0.208, 0.262)	(0.209, 0.261, 0.308)	(0.00, 0.00, 0.00)

Table 4. The total relation matrix ~T

	E1	S1	P1	M1
E1	(0.065, 0.134, 0.302)	(0.051, 0.116, 0.284)	(0.079, 0.154, 0.341)	(0.103, 0.181, 0.361)
S1	(0.042, 0.095, 0.231)	(0.061, 0.121, 0.271)	(0.068, 0.134, 0.294)	(0.088, 0.154, 0.309)
P1	(0.069, 0.136, 0.230)	(0.072, 0.139, 0.309)	(0.082, 0.155, 0.336)	(0.054, 0.122, 0.281)
M1	(0.062, 0.122, 0.269)	(0.089, 0.151, 0.302)	(0.049, 0.110, 0.268)	(0.110, 0.172, 0.327)

Following the normalization, the next stage calculated the total fuzzy relation matrix using Eqs. (4) to (7).

$$\mathrm{T} = \lim_{\mathrm{k}\to+\infty}\left(\tilde{\mathrm{H}}^1 \oplus \tilde{\mathrm{H}}^2 \oplus \ldots \oplus \tilde{\mathrm{H}}^{\mathrm{k}}\right) \tag{4}$$

where each matrix element is a TFN in the shape of $\tilde{t}_{ij} = \left(l^t_{ij}, m^t_{ij}, u^t_{ij}\right)$ which were calculated using Eqs. (5) to (7) as:

$$\left[\mathrm{I}^{\mathrm{t}}_{\mathrm{ij}}\right] = \mathrm{H_I} \times (\mathrm{I} - \mathrm{H_I})^{-1} \tag{5}$$

$$\left[\mathrm{m}^{\mathrm{t}}_{\mathrm{ij}}\right] = \mathrm{H_m} \times (\mathrm{I} - \mathrm{H_m})^{-1} \tag{6}$$

$$\left[\mathrm{u}^{\mathrm{t}}_{\mathrm{ij}}\right] = \mathrm{H_u} \times (\mathrm{I} - \mathrm{H_u})^{-1} \tag{7}$$

In Eqs. (5) to (7), ‘I’ represents an ‘n × n’ identity matrix with Hl, Hm, and Hu as the lowest value, most probable value, and highest value for each element of the normalized matrix Hij respectively. Notably, the elements of ‘tij’ represent the indirect effects that factor ‘i’ has on factor ‘j’, and then matrix ‘T’ reflects the total relationship between each pair of system factors. In Table 5, the total relation matrix is depicted and described. Equations (8) and (9) were used to calculate and ascertain the sum of rows and the sum of columns.

$$\tilde{D} = \left(\tilde{D}_i\right)_{n\times 1} = \left[\sum\nolimits_{j=1}^{n} \tilde{T}_{ij}\right]_{n\times 1} \tag{8}$$

$$\tilde{V} = \left(\tilde{V}_i\right)_{1\times n} = \left[\sum\nolimits_{j=1}^{n} \tilde{T}_{ij}\right]_{1\times n} \tag{9}$$

In Eqs. (8) and (9), $\tilde{D}$ and $\tilde{V}$ denoted an (n × 1) and (1 × n) matrixes respectively and thus showed the cause and effect groups of the factors. It must also be noted that, D_1 represented the sum of the ‘ith’ row in matrix T thus providing the summary of both the direct and indirect effects given by factor ‘i’ to the other factors. The ‘Vj’ represented the sum of the ‘jth’ column in matrix T; as such ‘Vj’ indicated both the direct and indirect effects by factor ‘j’ from the other factors. In situation where ‘i’ = ‘j’, the sum (Di + Rj) shows the total effects of the factors given and received by ‘j’. This means that, (Di

Table 5. The significance and effectiveness level of the major indexes (fuzzy numbers)

Index	(Di + Rj)	(Di − Rj)
E1	(3.641, 6.842, 14.599)	(−4.845, 0.541, 6.111)
S1	(3.277, 6.176, 13.21)	(−4.891, 0.035, 4.976)
P1	(3.731, 6.981, 14.821)	(−5.629, −0.139, 5.501)
M1	(3.545, 6.599, 14.181)	(−5.673, −0.239, 4.949)

+ Rj) suggests the significance level that factor 'i' has in the entire system. Conversely, the difference (Di − Rj) illustrates the net effect of the factor 'i' on the system. That is, if (Di − Rj) is positive, factor 'i' is a net cause, and if (Di − Rj) is negative, then the factor is an effect. The results in Table 6 shows the significance and effectiveness level of the main benefit indexes. Inherent from fuzzy numbers, the results were converted to normal numbers through 'defuzzification' to facilitate understanding and interpretation [36].

Table 6. The significance and effectiveness level of the major indexes

Index	D	R	$(Di + Rj)^{def}$	$(Di - Rj)^{def}$
E1	4.286	3.697	7.983	0.589
S1	3.603	3.582	7.185	0.021
P1	4.007	4.111	8.118	−0.104
M1	3.726	4.028	7.753	−0.301

The defuzzification is done to transfer fuzzy inference results into a crisp output realized by a decision-making algorithm that selects the best crisp value based on a fuzzy set. Against this background, Eq. (10) was used to defuzzificate the results of the TFNs presented in Table 5.

$$B = \frac{(a_1 + a_3 + 2 \times a_2)}{N} \tag{10}$$

In this equation, N represents the total number of benefit indexes (which is 4 here). The defuzzificated results are presented in Table 7.

4 Results, Findings and Discussion

Background Characteristics of the Respondents

From the 126 questionnaire accessed by respondents, 102 valid responses were gathered representing 81% response rate after the twelve weeks period through google forms.

Table 7. Geometric mean values of the pairwise comparisons

	E1	S1	P1	M1	Eigen vector
E1	(1, 1, 1)	(0.449, 0.488, 0.719)	(0.658, 0.773, 0.881)	(0.379, 0.412, 0.539)	(0.141, 0.151, 0.182)
S1	(1.382, 2.024, 2.211)	(1, 1, 1)	(1.101, 1.641, 1.743)	(0.691, 0.740, 0.961)	(0.241, 0.289, 0.319)
P1	(1.111, 1.281, 1.512)	(0.581, 0.609, 0.931)	(1, 1, 1)	(0.470, 0.483, 0.696)	(0.178, 0.179, 0.229)
M1	(1.838, 2.451, 2.618)	(1.051, 1.329, 1.459)	(1.438, 2.092, 2.181)	(1, 1, 1)	(0.310, 0.381, 0.388)
$CR^m = 0.001$ $CR^9 = 0$ … Consistent					

Out of this 102 responses received, 18 were project managers, 12 were architects, 21 were quantity surveyors, 9 were engineers, 7 were real estate developers. Additionally, those in policy and regulation were 15, 9 were in research and academia, with 4 being contractors and 2 as international collaborators. Other 5 respondents were noted to be suppliers. In case of their educational background, 57 possessed bachelor degree, 24 were master's holders, 12 had doctor of philosophy (PhD) and 9 were higher national diploma/certificate holders. This suggests, that, about 91% of the respondents had a minimum of first degrees. A banded breakdown of the level of experience of the respondents indicate that, those with 5–10 years experience were 52%, 11–15 years were 27%, 16% had 16–20 years experience and 5% had over 20 years of experience. From the cluster of professional roles, experience and educational background of the respondents, with these, it can be stated that, the educational level and experience of the respondents are adequate and thus the responses are more likely to be credible, offering credence to the results and findings. Additionally, the typologies of respondents suggests that, virtually all stakeholders in sustainability practices and LCA are covered. Hence the results and findings are more likely to reality of the benefit indexes of the SACI.

Reliability of the data was also checked using The Cronbach's Alpha Test [38, 39]. Following the test, a score of 0.801 was recorded, which is above the conventional minimum of 0.700. This indicates that, the rating scale in the measure of the benefit indexes for the study scale has a good and acceptable internally consistency. Hence the results are more likely to be consistent and reliable [38, 39]. Rho coefficient test was used to ascertain the degree to which the benefit indexes constructs actually and adequately measures so as to offer credence to the inferences, conclusions, and decisions made on the basis of the benefit index scores are appropriate and meaningful [39]. The Rho coefficient test result was 0.709. This score is deemed to be above the recommended minimum point of 0.700 [38, 39]. Hence, it can be said that benefit index scores and results are acceptable and offer credence to inferences, conclusions, and generalization made on the basis of test scores.

Results from the Hybrid Fuzzy Analysis

The results of Tables 3, 4, 5, 6 and 7 represents the direct relation matrix, the normalized matrix of direct relations, the total relation matrix, the significance and effectiveness level of the major indexes and the significance/effectiveness level of the major indexes.

The results of Tables 3 and 4 were used to calculate the significance and effectiveness level of the major indexes presented in Tables 5 and 6. In order to gain an in-depth visual understanding of the significance of the indexes against their effects, the data set of [(Di + Rj), (Di − Rj)] as presented in Tables 5 and 6 were evaluated and compared on the level of significance, and the effect level of the indexes.

From Table 6, the P1 Policies and legislations benefits index (8.118) has the largest value in terms of significance level. This suggests that, the Policies and legislations benefits index (8.118) has the highest significance. Likewise, a further assessment indicated that, E1 Environmental Performance Benefits index (7.983) was the second significant index followed by M1 Marketing benefits index (7.753) whereas S1 Strategic Planning and Management benefits index was regarded as the least significant index. It must be noted that, the calculations here have all been limited to the composite significance of the factors from the individual variables.

Following the understanding of the significance of each benefit index from the calculations of the DEMATEL method, the study explored a network structure from the data based on a fuzzy ANP method using a 9-point Saaty pairwise comparison resulting in the formation of a pairwise comparison matrix. This was aimed at determining the weights of elements with the ANP method. By this approach, Eqs. 11 and 12 were used to generate the geometric mean of pairwise comparisons and eigenvector values respectively. The inconsistency ratio often associated with such analysis was assessed using the Gogus and Boucher [40] method.

$$w_k^s = \frac{\left(\prod_{j=i}^{n} a_{kj}^s\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}^m\right)^{1/n}}, \quad s \in \{l, m, u\} \tag{11}$$

Here,

$$\overset{\vee}{w}_k = \left(w_k^l, w_k^m, w_k^u\right) \; k = 1, 2, 3, \ldots, n. \tag{12}$$

The results of the geometric mean values, their eigen vectors, eigenvector matrix for the benefit indexes, normalized total relation matrix and the final weight of each benefit index based on Eqs. (11) and (12) are summarized in Tables 7, 8, 9 and 10 respectively.

It must be noted that, the consistency ratio was accepted as under 0.1. From the results in Table 10, it can be seen that, Environmental Performance Benefits had the weight accounting for about 40% of the total benefits and was ranked first. Policies and legislations benefits emerged as the second accounting for about 34% of the benefits in the adoption of LCA in South Africa. In the case of the Strategic Planning and Management Benefits, the results revealed a definite weight of 14% whereas Marketing benefit index was about 12% and being ranked 3rd and 4th respectively.

From the results, policy and regulation benefits has emerged as the most significant and highest contributor in the benefit index (see Tables 7 and 10). This suggests that, policy and regulation benefits has the highest propensity to motivate large scale adoption

Table 8. The eigenvector matrix for the benefit indexes

Indexes	Eigen vector
E1	(0.181, 0.188, 0.238)
S1	(0.146, 0.156, 0.181)
P1	(0.307, 0.381, 0.394)
M1	(0.241, 0.289, 0.319)

Table 9. The normalized total relation matrix.

Indexes	E1	S1	P1	M1
E1	(0, 0, 0)	(3.25, 4.00, 4.74)	(3.20, 4.20, 4.70)	(4.70, 5.70, 6.30)
S1	(1.30, 2.25, 3.30)	(0, 0, 0)	(2.25, 3.35, 4.25)	(4.35, 5.25, 5.85)
P1	(4.25, 5.25, 6.25)	(7.25, 8.25, 8.75)	(0, 0, 0)	(5.25, 6.25, 7.25)
M1	(1.20, 2.25, 3.20)	(2.25, 3.15, 4.25)	(4.15, 5.25, 5.55)	(0, 0, 0)

Table 10. The final weight of each benefit index.

Indexes	Fuzzy weight	Definite weight	Rank
E1	(0.12, 0.33, 0.66)	0.339 2	2
S1	(0.10, 0.13, 0.33)	0.137 3	3
P1	(0.16, 0.40, 0.71)	0.401 1	1
M1	(0.02, 0.11, 0.29)	0.123 3	4

of LCA to promote sustainable practices in the South African construction industry. It can be suggested that, the emergence of policy and regulation benefits being more significant and higher over environmental benefits seems to be at variance with the position of Ortiz et al. [10], Kohler and Moffatt [22] and Fava [3]. However, it tends to corroborates with the position of Khasreen et al. [2] that, though environmental benefits is seen as the obvious reason to motivate LCA adoption, this can be meaningless if clear policies are not made to support these environmental benefits. Given that, Ortiz et al. [10] and Fava [30] have rated environmental benefits high over all other benefits, the revelation given by this study can suggest that, inspite of the significance of environmental benefits of LCA adoption, the focus should move towards formulating policies that embrace and regulate the environmental benefits. This is because, from a logical perspective, environmental issues in construction in many developing countries are often overlooked if there are no strict regulations and policy enforcement. Hence, with the right legal and regulatory policies, environmental benefits of LCA can be optimized in the SACI.

Khasreen et al. [2], Crawford [7] and Ampofo-Anti [21] and asserted that, a more sustainable construction industry through the adoption of LCA, other tools, practices and techniques can reduce environmental impact across the value chain, Minimize carbon risk and improve energy efficiency, Prevent and reduce materials wastage through reuse and recycling and ensure materials efficiency and improve building designs. In the light of this, it can be unequivocally be stated that, environmental benefits being the second significant index and contributing about 34% to the total index (see Table 10) corroborates this assertion. From this, it can be affirmed that, engendering the environmental benefits of LCA in the SACI can lead to energy efficiency and indoor environmental quality of building facilities, enhances Building construction methods by making them more environmentally friendly and facilitate the use of renewable energy technologies which have become precursors for sustainable building practices and development in many developing countries. Means and Guggemos [12] and Malin [28] noted that, using LCA allows for a clear understanding of the environmental impact of product on the environment that allows decision makers to compare various products. Hence given the significance and weighting of the environmental benefits, it reasons that, practitioners and stakeholders in LCA can now choose products that can mitigate environmental impact and eventually optimize environmental benefits and a more sustainable building process.

Marketing benefit from the perspective of significance and effectiveness was the 3rd whereas in the total benefit index, it accounted as the fourth contributing about 12% (see Tables 7 and 10). According to Crawford [7] and DEAT [25, 26] LCA information are useful for environmental labelling of products, which will help improve the competitive advantage of an organization. Likewise, it can be noted that, eco-labelling of products, materials and items can facilitate their sales and acceptance and thus help increase market shares of companies and promote competitive advantages compared to conventional ones. In this regard, the significance of the marketing index is that, the SACI can benefit from the development of more eco-friendly products and materials for the built environment. By promoting eco-labelling, it can facilitate green and clean information transfer to consumers and thus many people become aware of what their use of a certain product costs to the environment [10]. Hence the emergence of the marketing benefits corroborates the position of Ortiz et al. [10] and this can and this can help grow the economy through increased sales, job and returns on investments by increasing the production of green and sustainable materials driven by LCA information.

Lastly, the analysis has shown that, strategic planning and management benefits accounts for about 14% of the total benefits of LCA and was ranked 3rd in the weightings. It also proved that, it is indeed significant and has a good effectiveness towards motivating an increased LCA adoption. This finding aligns with similar positions of Ortiz et al. [10], Kohler and Moffatt [22] and Grant and Hes [24]. Accordingly, the study by Sadid and Khan (2006), Crawford [7], Ortiz et al. [10], Kohler and Moffatt [22] noted that the relevance of LCA in strategic planning and management in construction building and infrastructure process is that it helps give value to building styles and technologies that are resilient and long-lasting [10, 22]. The success and benefit of strategic planning and management inherent from LCA perspective can is that, it allows for identifying potential opportunities for a business that may otherwise have been overlooked, and this in turn will improve the credibility of the business. According to Crawford [7], by modifying existing systems, processes, or services, the organisation will also in turn be more susceptible to complying with future environmental policies, or possibly minimising future liabilities, risks or costs associated with compliance or shifting market demands. However, Kwofie et al. [3] noted technical constraints to life cycle assessment in the form of methodological gaps, lack of availability of LCI for buildings and lack of uniform standards governing the interpretation of life cycle assessment results for buildings limit sustainable strategic planning in the industry in South Africa.

Given the emergence of the significance of strategic planning and management benefit and it weighting contribution, it is thus an urgent necessity for the SACI to advance the course of LCA to optimize its benefits through actions to ameliorate notable bottlenecks such as those espoused by Kwofie et al. [38]. It can be said that, in the SACI, LCA adoption and agenda to promote sustainable building and infrastructure practices and industry is still at the infancy stage coupled with increasing evidence of the threat of climate change. Hence, the contribution of the strategic planning and management benefit should motivate and encourage initiatives that strategically push businesses, clients and policy makers to play active role in promoting sustainable built environment through LCA adoption. It also presents opportunity for more investments several opportunities such as manufacturing of sustainable materials.

Conclusions and Implication of Findings

The need to motivate and increase LCA adoption from the benefit perspective has become an apparent necessity in the South African construction industry. However, not much is known of and lack of consensus on the typologies of benefits of LCA that can engender increase adoption so as to optimize these benefits. The current explored the main benefits indexes of LCA adoption to the SACI. Through critical review of extant literature, four main indexes were delineated and formed the basis of an LCA adoption index development for the SACI. Consequently, environmental performance, strategic planning and management, policy and legislation and marketing benefits were the four significant benefits that were identified and significant in the benefit index. By using the hybrid fuzzy analytical DEMATEL approach, the data gathered through a 9-point Saaty pairwise comparison questionnaires revealed policy and legislation as the most significant benefit index followed by environmental benefit, marketing benefit and strategic planning and management index. Additionally, through the use of the fuzzy ANP method, the calculated calculate the weight and ranking of each benefit index affirm policy and legislation as having the highest contribution to the benefit index and thus the most important of them all. Environmental performance index emerged as the second most important ranked benefit in the index. Strategic planning and management was noted as the third important index with marketing being the fourth ranked important in the index model.

The need to engender sustainable practices and less environmental impact of construction activities have become imminent among stakeholders in South Africa over the past two decades. The findings from the study have underlined the significance and the importance weightings of the four benefits in the index model. From these benefits, it can be said that, stakeholders, policy makers, practitioners and clients can pursue some of the indicators of these benefits (see Table 1) through increased adoption of LCA in the SACI. This will serve as a precursor towards a more sustainable construction building process and industry to optimize the benefits of LCA. Hence these findings offers practical and methodological implications. By highlighting the benefits of LCA adoption towards increased sustainable building process and industry, it is imperative to be guided by these benefits to formulate policies and pursue an agenda to operationalize these benefits to the SACI. These benefits should arouse the necessity and desire for key stakeholders and construction firms to take keen interest in LCA and sustainability practices in the built environment in the SACI. There is no denying the fact that, given the evidence from these significant research findings and the weightings of the benefits that, increased adoption and implementation of LCA will play a major role in enhancing sustainability practices thereby increasing these concomitant benefits thereof to the construction project process and the built environment.

Limitation of the Study

One notable limitation of this study is that, data collection was limited to the SACI hence wider generalization and application of the findings may be affected given that, LCA adoption and implementation may be affected by economic, societal, cultural and political variations of countries and their construction industry. Thus, the findings in this study may not be applicable to other countries with varied economic, societal, cultural and political characteristics from South Africa.

Recommendation for Future Research

Given the variations in the economic, societal, cultural and political characteristics and the attendant limitation in the generalization and whole sale adoption of the findings, further studies are encouraged in other countries with varied socio-cultural, economic and political systems and structure in their construction industry. This will give a wider view of the findings here and theoretical lens to compare the variations in the findings. Additionally, the main focus of this study was on the composite benefits of the index without reporting on the contribution of the variables in the index. In this regard, further studies are needed to highlight the individual variables to the composite significance and weightings in the benefit index. This knowledge generated will offer clarity to enable pin point policies, strategies and agenda by focusing on the key variable in the various benefit indexes.

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Delay Minimising Measures Used on Road Construction Projects in South Africa

Faheem Vahed(✉), Mochelo Lefoka, and Abimbola Windapo

Department of Construction Economics and Management, University of Cape Town, Cape Town 7701, South Africa

vhdfah001@myuct.ac.za, {Mochelo.lefoka, Abimbola.windapo}@uct.ac.za

Abstract. Delays in road construction projects in South Africa are a common phenomenon. This study aimed to identify the minimizing delay measures stakeholders employ on South African Road Construction Projects. The study used a deductive quantitative research approach that used a structured questionnaire developed through a comprehensive literature review on the subject under study and a pilot evaluation by experts. The structured questionnaire was sent to clients, consultants, contractors, and other external stakeholders involved in SANRAL (South African National Road Agency Limited) projects. A total of 64 responses were received. The data received was analysed using the Relative Importance Index (RII) and Kruskal-Wallis Test. The Cronbach's Alpha value of 0.871 was obtained, in ensuring the reliability of the study. The results of the Kruskal-Wallis test revealed a statistically significant difference in the views of all project stakeholders on the delay minimising measures used on road projects. The RII indicated the top five delay minimising measures employed by stakeholders are early engagement with the community, improved communication with the community, improved management of subcontractors, effective strategic planning by contractors, and timeous payments to contractors and consultants. Based on these findings, the study concludes that until there is a consensus between stakeholders on strategies for minimising project delays, the continuation of delays on road construction projects in South Africa will remail a concern. Further studies are recommended using larger sample size and another context to produce generalisable findings.

Keywords: Construction · Road projects · SANRAL · South Africa · Strategic management

1 Introduction

The wealth of a country is judged by its infrastructure performance. Road infrastructure is the at the centre of most economies [1]. It is a significant influence in developing the country's socio-economic growth as it influences how citizens, goods, and services are

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accessed. Road infrastructure is a key prerequisite for the social and economic development of the country, and poor road infrastructure hinders foreign investments in the country [2]. In line with the South African government priorities and the medium-term strategic framework, the 2020 National Budget prioritised the expenditure of R815 billion on the social and economic infrastructure, wherein R308.3 billion (37.8%) is allocated to transport and logistics [3].

Project delays in the road construction industry are becoming more common, with SANRAL reporting a significant increase in construction delays on several major projects in the 2018/19 financial year [4]. Delay refers to a specified task not occurring as planned in the construction programme [5, 6]. Literature argues that project delays negatively impact projects further giving rise to over schedule, reduction in productivity, increased cost, contract termination [7]. An example of this delay is seen in a SANRAL project for the upgrading of National Route 1, Section 17 between Holfontein and Kroonstad. This was due to the conflict in the acquisition of land delayed by the expropriation process. Additionally, the discovered graves halted the project due to compensation complications with the families [8].

Although there is published literature on causes and effects of construction delays, there is sparce literature on South African road projects. Thus this research examines measures which can be implemented to minimise delays on road construction projects conducted mostly by SANRAL. The objective of this study is to assist policymakers such as SANRAL and the Department of Transport in formulating strategies that address and reduce road construction delays that can be adopted at a national level.

2 An Overview of Strategies for Minimising Delays on Road Construction Projects

Project delays are a common phenomenon in the construction industry. The effects are detrimental to the client, consultant, contractor, and the country's economic and social development. A review of construction project delay minimising strategies identified in literature can be divided into four categories as shown in Table 1: management and control; communication; financial and planning discussed in the following sub-sections.

2.1 Management and Control

Construction project management entails the planning, coordinating, and control of the project from the start of construction to the completion of the project, ensuring that the client's objectives are satisfied [8]. Control is achieved on projects by supervising and monitoring works as agreed upon in the contract document. In the minimization of delays on the project, choosing subcontractors with experience and a good reputation is necessary [9]. However, effective management and supervision of construction work, clients, and contractors can identify issues early and provide solutions to prevent delays [10]. A well-identified construction specification is one method to reduce project delays [11]. Adhering to the construction specifications prevents the contractor's rejection and

Table 1. Identified strategies for minimising delays on road construction projects in literature

Category	Mitigation measures	References
Management and control	Effective management and supervision of construction site	Aziz and Abdel-Hakam (2016); Meena and Babu (2015)
	Improved management of subcontractors	Aziz and Abdel-Hakam (2016); Khoiry et al. (2018)
	Employing appropriate construction methods	Divya and Ramya (2015); Khair et al. (2016)
	Adherence to construction specifications	Khair et al. (2016); Khoiry et al. (2018)
	Consultants to ensure that drawings and documentation are submitted on time without any errors	Sambasivan and Soon (2007); Mahamid et al. (2012)
Communication	Early engagement with the community	Rathenam and Dabup (2017)
	Establishing clear communication channels	Divya and Ramya (2015); Meena and Babu (2015)
	Improved collaboration between client, consultant, and contractor	Bagues et al. (2020); Mahamid et al. (2012)
Financial	Do not award an award based on technical experience and financial stability to the lowest bidder	Mahamid et al. (2012); Sambasivan and Soon (2007)
	Contractors to ensure they have sufficient funding before starting the project	Meena and Babu (2015); Sambasivan and Soon (2007)
	Timeous payments to contractor and consultant	Mahamid et al. (2012); Seboru (2015)
Planning	Effective strategic planning by contractor	Divya and Ramya (2015); Meena and Babu (2015)
	Adequate training of project staff	Mahamid et al. (2012); Sambasivan and Soon (2007)
	Contractor to develop contingency plans in the event of any delays	Bagues et al. (2020); Seboru (2015)
	Timely approval of variation orders by clients and consultants	Sambasivan and Soon (2007); Seboru (2015)

redoing of completed work. Another key criterion noted to minimise construction delays is the contractor's adoption of suitable construction methods [7, 11], allowing for the selection of the most optimum technique for implementation. Furthermore, timeous and error-free construction documentation minimises delays on construction projects [12, 13].

2.2 Communication

Effective communication is critical to the success of any project as it improves collaboration between project stakeholders, leads to better partnership development, reduces misunderstandings, and is effective in avoiding construction delays [10]. Furthermore, improved collaboration between stakeholders promotes successful project implementation [14]. Communication about the project also includes external stakeholders like the community through the representation of the Chief Liaison Officer (CLO). This ensures that communication and engagement with the community, the influence of the project on the community, and vice versa is understood [15].

2.3 Financial Strategies

Financial strategies found to minimise delays are tender awards based on experience and financial stability and not to the lowest bidder [12, 13], contractors having sufficient funding to execute the project [13, 16], and timeous payment to contractors for work done [17, 18]. Fast payment to the contractor will assist the contractor in financing the project [10]. Timely payments assist the contractor to finance the progress of future works, providing an adequate cash flow and motivation for the contractor to progress with the work and maintain a high-quality standard.

2.4 Planning Strategies

Project delays can be prevented through appropriate project planning and effective strategic planning as critical success factors for the project completion [14]. Key planning strategies identified in the literature are strategic planning by the contractor [7, 16], adequate training of staff [13, 17], contingency plans in place to address the incidence of delays [14, 18], and timely approval of variation orders by clients and consultants [13, 18]. Through effective strategic planning, the contractor sets out the client's objectives towards the completion of the project. Some of the aforementioned delays can be avoided by incorporating specific precautionary measures during the preparation stage [14]. This is achieved through a proper plan and schedule to conduct construction activities should the delay occur [14].

Fifteen methods used in minimising construction project delays were identified through the literature review and used in developing the research instrument.

3 Research Methodology

This study adopted deductive reasoning and a quantitative research approach. The theory covered the literature review relevant to measures that minimise delays on road construction projects in South Africa. This research adopts a quantitative method with a cross-sectional survey research design to answer the research question and meet the study's objectives. The study emphasises on road projects undertaken by the South African National Roads Agency Ltd (SANRAL). SANRAL is a state-owned entity responsible for 21,403 km of National Roads in the country. SANRAL has five offices, the head office based in Pretoria, and four regional offices serving South Africa. Therefore, the area of the study is the whole of South Africa. The population of the study comprises project stakeholders who have worked on SANRAL projects. This includes SANRAL project managers (clients), consultants, contractors, and other external stakeholders who have worked on a SANRAL project.

This study adopted a random sampling technique to allow for an equal chance of selection of all project stakeholders. No official population size could be determined as there was no SANRAL database with the number of consultants, contractors, and others who worked on SANRAL projects. Potential respondents who met the criteria of working on a SANRAL project were emailed to allow for random sampling and an equal chance to respond to the questionnaire. The number of stakeholders emailed per stakeholder group, the number of responses per group received, and the response rate is shown in Table 2.

Table 2. Number of surveys and response rate per stakeholder category

Category of stakeholder	Study population	Number of completed responses	Response percentage
Client	40	21	53%
Consultant	34	24	71%
Contractor	22	13	59%
Other external stakeholders	10	6	60%
Total	106	64	60%

At the end of the study period, the research received 64 responses, which equates to a 60% response rate. This is above the minimum sample size of 30 proposed by [19] and adheres to the central limit theorem. As per the research design, a structured questionnaire was used in data collection. A Likert scale was used to measure the degree to which the respondents ranked the methods used by contractors in minimising delays on road construction projects. The Likert scale used five ordinal measures from 1 - Strongly Disagree; 2 - Disagree; 3 - Undecided; 4 - Agree, and 5 - Strongly Agree. The questionnaire was set up using Microsoft Forms, and the link was emailed to all identified 106 participants. Data analysis methods used were the Relative Importance Index (RII) to determine the respondents' level of agreement with the proposed minimising methods. However the Kruskal-Wallis test was used to find out whether there are statistically significant differences between the respondents' level of agreement based on their category – client, consultant, contractor, and other external stakeholders. A calculated significance (P) value of less than 0.05 is considered statistically significant [20].

To improve the questionnaire's quality and ensure that the identified methods to minimise delays are relevant to the South African road construction industry, the questionnaire was reviewed by experts prior to distribution to the study respondents. Based on the feedback received, the questionnaire was improved to remove ambiguity in the wording of the questions and provide more clarity on the type of projects. Cronbach's Alpha was used to measure the reliability of the closely related items in the data obtained. Alpha values of 0.70 and above are considered a sufficient measure of the reliability of an instrument [21]. The Cronbach's Alpha value of 0.871 was obtained, indicating the measuring instrument's high degree of reliability. In line with the ethical considerations for conducting research, ethics approval to conduct the research was obtained from the University of Cape Town and SANRAL.

4 Data Presentation, Analysis and Discussion

The results are discussed in the following sub-sections.

4.1 Profile of the Respondents

The profile of respondents was assessed during the study by acquiring the gender, age, job profile, years of experience in the road construction industry and number of projects completed in the last five years. This was important in determining the representation of the respondents as a respondent profile is essential in acquiring broader views and opinions based on life experiences and understanding. The respondents' experience was significant in determining the value the respondents bring in terms of their professional experience and expertise in road construction projects. The results obtained gender-wise showed that 70% of the respondents are male while 30% are female. Additionally 82.82% of the respondents are over the age of 31 years. The highest response came from the Consultant group (38%), while 33% of the responses were from the Client group (SANRAL). This was followed by 20% of the respondents which came from the Contractor group, and 9% from the external stakeholders – six project liaison officers. The results also showed 54.70% of respondents have over ten years of relevant experience in the road construction industry; and 23.44% of the respondents completed more than ten projects.

4.2 Project Information

In terms of project information, 38.89% of the respondents used projects located in the Eastern Cape province to respond to the delay minimising strategies used on road construction projects. In comparison, 63.49% of the respondents used new works, upgrades, and strengthening to road construction works as a reference.

4.3 Analysis of Measures to Minimise Delays in Road Construction Projects

The study sought to know the measures used in minimising delays in road construction projects. Fifteen delay minimising measures were identified through a literature review and presented in the questionnaire for respondents to rate using the Likert scale. The responses received were analysed and ranked using the Relative Importance Index and distributed according to stakeholder group in Table 3.

Table 3 shows that from a ranking perspective, the top five delay minimising measures are early engagement and improved communication with the community, improved management of subcontractors, effective strategic planning by the contractor, and timeous payment to the contractor and consultant. The other delays identified by respondents

Table 3. Analysis and ranking of delay minimising measures used on road construction project.

Minimising measures	Total of all stakeholders		Client group		Consultant group		Contractor group		External group	
Number of respondents (N)	64		21		24		13		6	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Early engagement with the community	0.909	1	0.886	1	0.942	1	0.908	4	0.867	9
Improved communication with the community	0.909	1	0.876	2	0.917	2	0.969	1	0.867	9
Improved management of subcontractors	0.884	3	0.800	7	0.900	4	0.908	4	0.867	9
Effective strategic planning by contractor	0.872	4	0.810	5	0.917	2	0.862	8	0.933	2
Timeous payment to contractor and consultant	0.866	5	0.752	13	0.883	5	0.954	2	1.000	1
Establishing clear communication channels	0.853	6	0.848	3	0.875	6	0.846	10	0.800	15
Improved collaboration between client, consultant, and contractor	0.853	6	0.819	4	0.850	10	0.892	6	0.900	4
Clients and consultants to approve variation orders on time	0.853	6	0.781	10	0.875	6	0.923	3	0.867	9

(*continued*)

Table 3. (*continued*)

Minimising measures	Total of all stakeholders		Client group		Consultant group		Contractor group		External group	
Number of respondents (N)	64		21		24		13		6	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Effective management of construction site and supervision by the contractor through site diaries	0.853	6	0.800	7	0.875	6	0.877	7	0.900	4
Consultants to ensure that drawings and documentation are submitted on time without any errors	0.834	10	0.771	12	0.875	6	0.846	10	0.867	9
Employing appropriate construction methods	0.825	11	0.781	10	0.842	13	0.831	13	0.900	4
Ensuring adequate training of project staff	0.822	12	0.800	7	0.808	14	0.846	10	0.900	4
Contractor to develop contingency plans in the event of strikes, shortages of material	0.822	12	0.810	5	0.800	15	0.831	13	0.933	2
Adherence to construction specifications	0.813	14	0.752	13	0.850	10	0.831	13	0.833	14
Contractors to ensure they have sufficient funding before starting the project	0.806	15	0.695	15	0.850	10	0.862	8	0.900	14

not identified in the literature review are: Improved procurement process; Ensuring adequate technical capacity/experience/expertise amongst site staff for both Engineer and Contractor; Early and rigorous engagement with the community and local stakeholders appears to be delaying contracts more rather than less.

4.4 Data Analysis

The Kruskal-Wallis test was used to determine any statistically significant difference across the views of client, consultant, contractor, and external stakeholder groups for the top five delay minimising measures for road construction project delays in South Africa. The Kruskal-Wallis test shows a statistically significant difference in the scores of the top five delay minimising measures of road construction project delays amongst all project stakeholders ($X^2(3) = 8.016$, $p = 0.046$). The calculated Kruskal-Wallis H value of 8.016 is higher than the critical value of 7.815 for three degrees of freedom. The calculated p-value of 0.046 is lower than the significance level of 0.05. It can be inferred from this analysis that the respondents have different perceptions of the top five delay minimising measures based on their affiliation.

4.5 Discussion of Findings

The two minimising measures ranked first, which are early engagement with the community and improved communication with the community methods, are linked and relate to early and continuous engagement with the communities ensuring that they are heard. Their requests are met through the implementation of the project. These findings agree with the findings of previous studies by [15]. The view that improved management of subcontractors is a key minimising measure of delays on road projects agrees with the findings of [9, 10]. Subcontractors employed to complete a portion of the construction work may not have the technical experience and expertise of the main contractor and therefore require improved management techniques that guide and mentor them. This reduces the delay caused by rework, slow production rates, and completion of work using incorrect construction methods.

The delay minimising measure of effective strategic planning by the contractor resonates with the conclusion of [7, 16] that strategic planning ensures that focus is placed on critical items while less critical items are not given as much importance. This ensures that time is not wasted on non-critical aspects during project implementation. The fifth-ranked measure for minimising delays was timeous payment by the client to the consultant and contractor, which supports earlier findings by [12, 18] that timeous payments by the client will assist the contractors in managing their cash flow and making the required payments for all labour and material resources. The Kruskal-Wallis test reveals a lack of consensus amongst the project stakeholders as to the best delay minimising measures which may cause tension on the effective approach to use in minimising delays on road construction projects.

5 Conclusion and Recommendations

The study sought to determine the measures for minimising delays on road construction projects. A total of 15 delay minimising techniques were identified in the literature and presented to respondents working on SANRAL road construction projects to rate based on their level of agreement. The five primary methods of minimising delays from a ranking perspective emerged: early engagement with the community; improved communication with the community; improved management of subcontractors; effective strategic planning by the contractor; and timeous payments to contractor and consultant. However, it was found that there are differences of opinion as to key delay minimising techniques based on the respondents' stakeholder group. Based on these findings, the study concludes that projects that do not engage with the community before initiation will experience a delay. It, therefore, recommends the early involvement of the community in the project by SANRAL and other road construction clients through the establishment of community liaison meetings and the establishment of a Public Liaison Committee (PLC). Any concerns of the community should be addressed through the PLC without disrupting the project's schedule. Future research on the involvement of the local community in road construction projects in South Africa is also recommended.

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Improving Construction Productivity Estimation Techniques Through Realistic Labour Productivity Determinants

Mochelo Lefoka and Abimbola Windapo(✉)

Department of Construction Economics and Management, University of Cape Town, Cape Town 7701, South Africa
{Mochelo.lefoka,Abimbola.windapo}@uct.ac.za

Abstract. The lack of accurate and reliable techniques used to estimate labour productivity expended on construction projects has largely contributed to the poor levels of construction productivity. This is from a cost and time perspective. The lack of such techniques, contribute to the abysmal performance of construction organisations in South Africa. Previous studies provide significant evidence of the crucial need for a standardised or a formal matrix that can evidently express the imputation of resources and the equitable output produced. This study investigates the current techniques used in the construction industry to determine the level of labour productivity on site and how this subsequently contribute to the project performance. The study employs a quantitative research approach. The three kinds of projects that we assessed were building projects, road projects and infrastructure projects. A structured questionnaire survey was sent to 117 industry practitioners working for companies listed in Grades 2–9 on the cidb Register of Contractors. The data was analysed using descriptive and inferential statistics. The results reveal that environmental factors, management factors, work complexity and social factors relating to labour productivity are not considered during labour estimation process, which have an overall impact on estimate reliability. The study intended to assess the estimation techniques used in the estimation of labour productivity across concrete, masonry and plastering trades. And the results revealed that experience from past projects is prevalent across the trades. The study recommends an exhaustive assessment of more trades and consideration into the adjusted productivity estimation techniques of labour.

Keywords: Labour estimation · Labour productivity · Construction projects · Productivity

1 Introduction

One notable issue faced by the construction industry globally is the abysmal levels of labour productivity reported on construction site [1–3]. The basis of the study rests on the globally and national reported levels of poor labour productivity that are expended on construction sites which are reported to be considerably low [4–7]. These low levels

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of labour productivity on construction projects are attributed to a host of factors and these are not limited to those that impact the complexity of the project, environmental factors, social factors, and managerial factors [8–15]. These factors significantly impede the delivery of a construction project in terms of estimated cost and time of a project [4].

Multiple factors and systems are attributed to the levels of labour low productivity reported on construction projects [8–15]. Some of these factors are significant to the planning stage of a project and some are experienced once the project has started, thus difficult to envisage [1, 3]. In lieu of these categories of factors, a large focus on the estimation techniques and predictions of labour productivity expressed on site is subjected to inaccuracy. The limitation in accuracy is brought about the varying kinds of projects that are constructed in the construction industry and sometimes, the different types of materials used on projects [2, 17, 18]. This in retrospect, highlights the need for a monolithic estimation technique that considers all these factors on projects. As a result, the study aims to assess the techniques used in the construction industry to quantify and estimate the levels of labour productivity that is observed on site.

2 Background to the Study

As the study explore current techniques extracted from literature and which have been used vastly, it is important to understand them. Furthermore, explore their benefits of use or not, particularly across labour intensive trades.

2.1 Previous Construction Experience

Literature suggests that an experienced labourer can complete the task and perform above their contemporaries [32]. However, this definition does not always hold true in the construction industry as central to the industry, is the issue of lack of experience amongst construction workers or labourers [2, 10, 16, 17]. However, for a specific trade that requires a well knowledgeable labourer to execute the work, using a labourer's previous experience in the specific trade is considered a great measure of success for the project. This ensures that a perfect skill matching a particular activity or trade is achieved [32]. This further ensures that for each trade, a well-trained and skilled labourer is available to execute the activity. Moreover, the utilisation of this technique ensures that the project is equipped with the necessary skill for the ability to complete the project within the parameters of time and cost [18].

2.2 Labour Performance

The performance of the labour force on a construction project is the backbone of the delivery of the project. Many factors from equipment, material, managerial personnel can significantly affect the performance of the labour [19, 20]. It then becomes imperative to assess the utilisation of labour performance as a measurement of labour productivity on site [20]. This needs to be achieved with the awareness of factors affecting the said labour performance [20]. The use of labour performance assumes all else is equal which means that if the labour force is provided with all the necessary equipment and tools to execute the job, the project will be successful [20].

2.3 Time Study of Varying Trades

Time study is defined as the full analysis and study of all of the steps involved in the development or the operation of an activity to assess the actual time it takes to complete the task [21]. The core purpose of this method of estimation technique is to ensure that an organisation or a unit of the construction team (usually the quantity surveyor or the cost estimator) can allow adequate time for workers to improve the efficiency or productivity of their construction work on site [21]. This method significantly allows the workers to know that the allocated time to a trade, depending on the size of the project; can be completed in both the stipulated time and cost.

2.4 Activity Sampling

The activity sampling technique is one of the estimation techniques that can be used in the construction industry to determine the expected level of labour productivity [22]. This technique is defined as the observation of an activity over a set period of either an individual, equipment, or a specified method of construction to complete the designated task [22]. This technique is crucial in that it determines an almost close to accurate time of a particular activity to be completed. Moreover, the technique gives the number of labourers necessary time to finish an activity in an economical and efficient manner [22]. Therefore, in assessing the comparative polarities between the expected and observed level of productivity, this method affords a skilled worker to understand the scope of their work with regards to project completion time.

2.5 Work Sampling

According to various scholars, work sampling is defined as a measure that determines the time it takes to complete a specific activity or task on a project [23, 24]. Central to the construction industry, particularly in the execution of labour intensive activities, work sampling measures the average duration it takes for a labourer to perform a specific activity [23]. This practice further necessitates the supervisory response rate to any deflections that may arise, primarily looking into how the response is measured to circumvent the probable additional expenditure and increase the time designated to an activity (project) [4, 23].

However, as a method of estimating the level of output, work sampling as a method has both attributes about it that are beneficial to the success of the project and the adverse also holds true. Work sampling provides a simple and cheap assessment of non-repetitive construction activities. Additionally, work sampling allows an easy and quick way of determining problem areas that are crucial and their impact on the overall project [23, 24]. This method can only be used on projects which are to be executed for a longer periods of time as it will be uneconomical on projects with shorter period [23, 25].

3 Research Methodology

The study adopted a quantitative research approach for both data collection and data analysis. The statistical tool used to analyse the data was the SPSS (Statistical Package for the Social Sciences). The focal reason for the adoption of the quantitative research approach is so that the study can allow the observation of the techniques predominantly used with no bias across the different research participants. This is also largely due to the fact that the use of statistical tools and techniques through analysis yields generalisable results [26]. Various labour-intensive trades are selected for this study which are: concrete, masonry, and plastering trade. Additionally, the study adopts a cross-sectional survey research design. The main purpose of using the cross-sectional survey design is so that the different estimation techniques can be determined based on the various respondent's construction industry experiences.

The population for this study is primarily based on the various construction personnel that have a direct input in the trades being assessed. This is either directly or indirectly. As a result: director cadres, contracts managers, project managers, site agents, construction managers, site engineers, construction supervisors, quantity surveyors, estimators, and cost engineers employed by construction companies listed in Grades 2–9 on the cidb Register of Contractors were considered for this study.

Additionally, the study primarily considered trades that are labour intensive to assess the rudiments of how these trades are estimated in the inception stages of the project. This largely gives a close to an accurate economical representation of the skill and levels of employment demographic in the South African economy with an unemployment rate of 34.9% [27]. This further necessitates the need for analysing these trades as they are largely the ones that demand manual labour and the construction industry largely absorbs the labour force in South Africa [1].

This study used a random sampling technique in the selection of the study participants. This is primarily because all the probable candidates that are pertinent to the study will have an equal and fair chance of being selected for the study. According to the database collected and stored of the companies listed in Grades 2–6 of the cidb Register of Contractors, a population size of 8400 was used and a confidence level of 95% with a margin error of 5%. As a result, the sample size was determined to be 368 participants (https://www.surveymonkey.com/mp/sample-size-calculator/) [28].

It has been observed over several studies that the response rate across the construction industry professionals tends to be low, as a result, a 30% response rate is deemed adequate [29]. This meant that 1227 questionnaires were distributed randomly to the respondents to achieve a sample size of 386. At the end of the survey period and cleaning of the data, 117 completed responses were received and used in the analysis of the data. This further represented a 9.5% response rate. A Cronbach's Alpha test was conducted to ascertain the consistency and reliability of the data [30]. For the data to be deemed reliable, the Alpha value must range 0.7–0.95 [30] and the study has met this requirement as the alpha value across all the factor clusters tested ranged between 0.89 and 0.90.

4 Results and Discussion of the Results

4.1 Estimation of Concrete, Masonry, and Plastering Labour Productivity

To ensure that the research significantly addresses the need for a comparable measure of parameters and factors used to identify the estimation factors and gauge labour productivity on construction projects, three labour-intensive trades were identified. These are concrete trade, masonry trade, and plastering trade. Central to the research, particularly addressing this objective, it is crucial to assess and establish for each trade, how are levels of labour productivity forecasted and further interrogate the variance or digressions from the stipulated labour productivity expended on construction sites. Varying methods of estimating labour productivity in the construction industry (particularly on construction sites) are available. However, for the purpose of this study, through a thorough review of literature. Five methods were synthesised which are experience from previous projects, labour performance, time study, activity sampling and work sampling. These methods were approved and as a result, used as parameters to extract information from participants to determine the level of labour productivity expended. The results for the study are presented in Tables 1, 2 and 3 under various trades. The results represent the average response rate per method of estimation across the trades. A scale of 1–5 where 1 is never and 5 is always used. The Mean Item Score (MIS) is calculated for each estimation method and used to rank them.

4.1.1 Concrete Estimation

In the estimation of the concrete trade, Table 1 represent the results from the participants and the analysis is also presented. An estimation technique that is found to be significant across others in terms of estimating or forecasting the level of labour productivity across the concrete trade is, experience from previous projects (MIS = 0.807; R = 1), labour performance (MIS = 0.701; R = 2), time study (MIS = 0.655; R = 3), activity sampling (MIS = 0.631; R = 4) and work sampling (MIS = 0.615; R = 5).

Table 1. Concrete trade estimation

Estimation method	Never	Rarely	Sometimes	Often	Always	MIS	Rank (R)
	1	2	3	4	5		
Experience from previous project	18	1	6	26	66	0.807	1
Labour performance	24	4	19	29	41	0.701	2
Time study	23	8	29	28	29	0.655	3
Activity sampling	32	9	21	19	36	0.631	4
Work sampling	32	8	27	19	31	0.615	5

It can be observed that the one technique that is predominantly used in the assessment of the productivity of labour that is expended on a construction site that is considered paramount, is the labourer's experience from past projects. This can be partially attributed to that much of the concrete trade that happens on a site, would have had the aid of a mixing plant where a design mix is already utilised to combine the concrete elements and only requires labour to cast and vibrate the concrete on site.

4.1.2 Masonry Estimation

Using the analysed responses from the respondents in the determination of the estimation technique used to forecast the level of labour productivity across the masonry trade, it can be observed in Table 2 that experience from previous projects (MIS = 0.733; R = 1), followed by labour performance (MIS = 0.632; R = 2), time study (MIS = 0.593; R = 3), work sampling (MIS = 0.561; R = 4) and lastly, activity sampling (MIS = 0.538; R = 5) represents the order of estimation methods respondents use in determining labour productivity for the masonry trade.

Table 2. Masonry (superstructure construction) estimation

Estimation method	Never	Rarely	Sometimes	Often	Always	MIS	Rank (R)
	1	2	3	4	5		
Experience from previous project	25	3	11	25	53	0.733	1
Labour performance	37	5	14	24	37	0.632	2
Time study	40	7	19	19	32	0.593	3
Activity sampling	41	12	17	23	24	0.561	4
Work sampling	45	11	21	15	25	0.538	5

With regards to the masonry trade, a similar output is observed, which is the labourer's previous experience which is ranked number 1 (MIS = 0.733) as the most used factor to assess and measure productivity. This is not largely quantitative, but it is due to the work done based on the time and cost related to the trade. Contractors employ specialised tradesmen to do this job on site and largely rely on the experience of their other or former jobs to expend the required productivity.

4.1.3 Plastering Estimation

Table 3 reveals that the ranking of the varying estimation/forecasting techniques, the order of the various methods of estimation evidences the fact that experience from previous projects (MIS = 0.757; R = 1), followed by labour performance (MIS = 0.641; R = 2), time study (MIS = 0.583; R = 3), work sampling (MIS = 0.579; R = 4) and activity sampling (MIS = 0.579; R = 4) from a ranking perspective.

Plastering is another labour-intensive trade that significantly utilises experience from previous projects as a gauge of the ability of a labourer to perform optimally on a project and as a result, yield the desired productivity on both cost and time.

4.2 Discussion of Findings

The objective of the study is to assess the techniques used in the construction industry to estimate the level of labour productivity that be expended on a construction site. The

Table 3. Plastering trade estimation

Estimation method	Never	Rarely	Sometimes	Often	Always	MIS	Rank (R)
	1	2	3	4	5		
Experience from previous project	26	2	4	24	61	0.757	1
Labour performance	37	3	11	31	35	0.641	2
Time study	42	9	13	23	30	0.583	3
Activity sampling	42	5	18	27	25	0.579	4
Work sampling	43	4	22	18	30	0.579	5

study aimed to assess these techniques using the selected labour-intensive trades which are concrete, masonry and plastering trades. When assessing the concrete trade, it was revealed that experience from past experience is prevalent as the dominant technique used in the assessment of the level of productivity that can be measured or estimated for a construction project. This is congruent with literature in that the more experienced a labourer is in a particular trade, the more they can produce more or the adequate amount of expected productivity [2, 17, 18, 31]. As one of the most labour-intensive trades in the construction industry, much of what in expected of an experienced labour in the ability to understand the varying ways in which concrete forms part of an integral structure of a structure. This spans from infrastructure projects through to residential houses where the core foundation is concrete. As a result, this technique largely relies on the needs of the trade and the ability to minimise waste.

Masonry trade is largely specialised and requires that the labourers working on this trade understand the intricacies of the trade. Literature further purports the findings of this study in this regards [15, 17]. It is of no contention that study also asserts that experience from previous projects from a labourer is considered paramount in this trade. Similarly, to masonry and plastering trades, there is not much digression from how the accurate depiction of labour productivity is similar that of concrete. This is purported by literature that labourer's that are experienced in a trade tend to yield adequate productivity in their execution of work and as a result reduce the overruns in terms of cost and time [17, 18]. As a result, this technique aligns itself in the plastering trade and the envisaged levels of productivity output expected.

5 Conclusion

The study assesses the reliability of estimation techniques in measuring the productivity of labour on site. Three labour-intensive trades – concreting, masonry and plastering were observed to determine the most used technique across the three trades. It emerged that experience from previous projects is perceived as the most used technique as it was ranked number 1 across the trades studied. This is indicative that construction projects and contractors prefer experienced workers above inexperienced workers. This is logical from both an economic and project performance perspective. However, one would be remiss that with the inability of most labourers to gain experience in the construction industry, it becomes arduous for general labourers to gain experience. Additionally, the inability to gain this experience can limit the opportunities available to labourers from being employed on site in the future.

The limitation of this study primarily focused on the three trades: concrete, masonry, and plastering. More elaborate measuring techniques need to be employed to assess what other trades besides the ones explored in this study can be used for future studies. Additionally, this study was conducted before the COVID-19 pandemic. Further studies exploring the efficacy and implementation of measuring techniques employed during the pandemic (and post-pandemic) are critical. It would be a great exploration to see the innovative measures taken to ensure the management of other trades and the degree of the effect on them due to the pandemic. The contribution of this study to the construction industry is that it gives a glimpse into the ingrained biases that some contractors use in the employing their labourers. Furthermore, it pivots towards an exclusionary model of giving those entering the job market a hindrance to their lack of skill. Collectively as an industry, it would be crucial to have well developed skill development initiatives to improve on this. Especially given the lack of jobs in South Africa and the loss of jobs during the pandemic.

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Project Management Competencies for Embedding Sustainability in Construction Projects: A Delphi Study

Mosa Ramohlokoane[1] (✉), Bankole Awuzie[2], and Clinton Aigbavboa[1]

[1] Department of Built Environment and Department of Construction Management and Quantity Surveying, University of Johannesburg, Johannesburg, South Africa
ramohlokoanemm@gmail.com

[2] Department of Built Environment, Central University of Technology, Bloemfontein, South Africa

Abstract. Societal demand for a more sustainable construction industry remains prevalent. In response to such demands, a plethora of project management tools, techniques and competences have evolved to engender successful sustainability transitions within the construction industry. Although the salient contributions of these tools and techniques have been reported in extant literature, details of the contributions of the competence facet appears to be limited in extant literature. This study has been prompted by this observation. As such, this study, which forms an integral part of a wider study, seeks to identify, and determine the critical competences required by construction project managers to facilitate improved sustainability performance of projects, particularly during the construction phase of the construction lifecycle. This study adopts a Delphi technique wherein data was elicited from a purposively selected Delphi panel comprising of individuals with project management experience (n = 20), using questionnaires over two iterations. The data obtained was subsequently analyzed using descriptive statistics (median). Findings from the study elucidate the criticality of project management competences like planning, organizing, leadership, and technical knowledge in fostering the attainment of the desired levels of sustainability performance of construction projects. It is expected that the findings of this study will contribute to the corpus of emerging literature on this topic.

Keywords: Competencies · Construction · Lifecycle · Project management · Sustainability

1 Introduction

Achieving a sustainable (net-zero) society remains a contemporary challenge [1, 2]. The construction industry's contribution towards the perpetuation of this challenge has been reported in extant literature [3, 4]. Despite the heightened degree of knowledge relating to the measures for achieving sustainability within the construction industry, its incorporation in an integrated manner poses a challenge for relevant stakeholders [3, 5]. Also,

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the clamour for a paradigmatic shift from overt concentration on cost, quality, and time parameters as project management success criteria, towards the integration of sustainability dimensions during project execution persists [5]. To facilitate this shift, various project management tools, techniques, and practices have gained prominence within the construction project management discipline culminating in the emergence of '*sustainable construction project management*' as a distinct discipline [6, 7]. In this discipline, an overt focus on the deployment of these tools, techniques, and practices towards actualizing improved sustainability performance of construction projects remains prevalent [6, 8–10].

However, little attention had been given to the construction project manager's role in engendering improved sustainability performance of construction projects until recently [11–14]. For instance, whilst categorizing the critical success factors (CSFs) for sustainable construction project management, Gunduz and Almuajebh, [7] established the project manager-related CSF category. CSFs identified under this category included facets like experience, skills, coordination between all participants, etc., [7], hence reinforcing the pivotal role of the construction project manager in enabling sustainable construction practice. Similarly, other studies have sought to establish the extent to which these abovementioned facets influence the ability of construction project manager to engage in sustainable construction practice and by extension, deliver improved levels of sustainability performance on projects [15–19]. Despite this reality, studies seeking to unravel the nature of competences required by the construction project manager to perform optimally in fostering these scenarios remain limited.

As its central objective, this study seeks to establish the critical competences required by CPMs for fostering improved sustainability performance of construction projects in developing countries. As such, the study will try to answer the question; *what critical competencies are required by the construction project manager to deliver optimal levels of sustainability performance during the construction phase of a construction project (sustainable construction project management practice)*? The rest of the paper is structured as follows: a brief review of relevant literature, justification of the research method deployed for data elicitation and analysis, the presentation and discussion of the results and conclusion.

2 Literature Review

Sustainable Construction Project Management for Improved Sustainability Performance

The construction industry makes significant contributions to socio-economic advancement of society [2, 8, 9, 14]. Such reputation stems from the industry's role in infrastructure delivery, provision of employment opportunities, etc. However, this role involves a series of activities which degrade the environment hence undermining society's transition to sustainable futures. This realization has resulted in the advocacy for better approaches to carrying out industry activities, sustainably. Sustainable construction has evolved from a need to address the incidence of these anthropogenic activities which are associated with construction activities [7, 20]. As a concept, sustainable construction comprises of the integration of sustainability tenets in the construction process by various stakeholders with an objective of achieving desired levels of sustainability performance. This concept embodies the use of sustainable and circular materials, renewable energy, equipment, and sustainable construction practice [9]. However, scholars opine that the deployment of these facets towards implementing sustainable construction practices cannot be complete without the adoption of an effective management approach [8, 14, 21, 22]. Therefore, attempts at incorporating sustainability ethos into extant project management methodology is predicated on this understanding.

Sustainable Project Management (SPM) has been defined as the incorporation of the three dimensions of sustainability in an integrated manner into project management practice [14]. Similarly, Silvius and Schipper [5] described SPM as consisting of the "planning, monitoring, and controlling of project delivery and support processes, with consideration of the environmental, economic and social aspects of the life cycle of the project's resources, processes, deliverables and effects, aimed at realizing benefits for stakeholders, and performed in a transparent, fair and ethical way that includes proactive stakeholder participation" [5:79]. Suffice to state that the SPM concept has gained traction in construction projects due to its salient contributions towards reducing the impact of the anthropogenic activities associated with such projects [15]. To foster the implementation of SPM in construction projects for improved sustainability performance, guidelines such as sustainable project products, processes, organizational commitment to sustainability and availability of sustainability literate persons have become essential [20]. Despite the increasing adoption of sustainable construction practice, it appears that an overt focus on methods and practices has been the norm in its operationalization. This is deduced from the limited reportage of the role of the construction project manager in fostering sustainable construction project management and the competences required to perform such role creditably.

Competencies Required for Embedding Sustainability in Construction Projects

The possession of certain competencies by the project manager enables an integration of required skills, prediction of possible risks and being time cautious hence, ensuring that all tasks are completed within the stipulated timeframe [16]. Such competencies include team building, motivation, communication, decision making, political and cultural awareness, negotiation, trust building, conflict management and coaching as well as technical project management competencies [23].

Also, leadership and emotional intelligence (EI) are deemed vital for incorporating sustainability tenets into project management practice [12, 18]. The authors highlighted the existence of three leadership dimensions namely, emotional, managerial, and intellectual dimensions [12]. Leadership is identified by its traits and the effectiveness it imposes, the behaviour it has, variables which have an impact [24], relationship between the stakeholders, culture, emotional intelligence, and flexibility [12]. Leadership is associated with project success given the associated traits it possesses [25].

Similarly, EI has been defined as the ability to perceive accurately, appraise and express emotion or the ability to regulate emotions to promote emotional and intellectual growth [26]. Competencies relating to EI which have been identified as contributing to improved project success include communication, conscientiousness, emotional resilience, influence, intuitiveness, motivation, self-awareness, and sensitivity [26]. The potential of such competencies to aid the PM to effectively engage in the incorporation of sustainability into construction project management practice has been elucidated [18, 27]. Other competencies which deliver on the same mandate include, system thinking competences, anticipatory competencies, normative competencies, value engineering, lifecycle analysis, strategic competencies, and interpersonal competencies [5]. Although attempts have been made at investigating the influence of these competences on the PM's ability to deliver on sustainable construction project management practice and by extension, improved sustainability performance on construction projects [16, 19, 28], most of these studies have focused on the developed country context. Impliedly, scant attention has been given to the developing country context despite the identification of a lack of relevant competences among CPMs as constituting a hinderance to effective sustainable construction project management practice in this context [6]. This study seeks to bridge the gap through an identification of the core competencies required by CPMs to deliver desirable levels of sustainable construction project management practice in developing country contexts, based on a South African exemplar with emphasis on the construction phase of the project lifecycle for obvious reasons.

3 Research Method

A Delphi method was adopted in this study. The Delphi technique was undertaken as it allows for consensus to be gained using a systematic process of gathering data [32]. It is also helpful as it allows for the experts or professionals based within the topic to give their own opinions based on the proposed study, even without them being in one setting or place [32]. The technique allows for participants to assess the responses from other participants and reassess their initial responses [31]. The adaptation was due to the need to not only elicit the perspectives of practicing construction project managers within a particular locality (Free State Province) on their understanding of the phenomenon being understudied but also to achieve consensus amongst them. The criteria of respondents was based on their experience as project managers within the BE. The attainment of consensus was considered imperative as it underpinned the essence of the study as elucidated in the research question- the determination of the core competences required to mainstream sustainability tenets into construction project management practice. This process enabled a validation of the criticality of the sustainability competences gathered from the literature review. A sample of twenty-five respondents were initially identified and approached based on purposive and convenience sampling. However, only twenty participated. Table 1 below illustrates the demographics of the respondents.

Questionnaires were developed and deployed as a means of data collection. Although the questionnaires consisted of several sections, only the results from three sections, relevant to the current study- sections comprising of permissible biodata information and respondent's knowledge of sustainable construction practice and, ranking of sustainability competences required for the construction phase of the construction project lifecycle- would be presented herein. The questions in the questionnaire were structured to allow for ranking using a 5-point Likert-scale [29]. Consensus was reached after two iterations which occurred within a two-month time interval. This was determined by making use of the median as a measure of tendency. The Delphi Method relies on measures of

Table 1. Demographic of Delphi panellists

Demographic	Number of respondents
Sector of employment	
Private sector	18
Public sector	2
Academic qualification	
National diploma	1
Bachelor's degree	5
Honours degree	7
Master's degree	5
Doctoral degree	2
Profession within the built environment	
Engineer	3
Architect	7
Quantity surveyor	7
Town planner	1
Other	2
Years of experience with built environment	
0–5	5
6–10	4
11–20	6
21–more	5
Years of experience with built environment	
0–5	8
6–10	2
11–20	6
21–more	4

tendency like mean, median and mode to analyse the data [30]. However, due to the method's penchant to create clustering around two or more points during data analysis, the use of the median has been recommended as the mean and mode could be misleading [31]. The formula below was used in accurately determining the standard deviation, as a measure of dispersion, the closer to 0, the less the dispersion of opinion, taking into consideration the responses from the Delphi panel.

$$\sigma = \sqrt{\frac{\sum (x - \mu)^2}{n - 1}} \tag{1}$$

4 Presentation and Discussion of Findings

In this section, the findings from the Delphi method deployed towards achieving the study's main objective are presented under two themes; the level of knowledge relating to sustainable construction management practice and the critical competencies required to embed sustainability into sustainable construction management practice during construction proper.

Theme 1: Knowledge relating to sustainable construction management practice

Adequate knowledge of what sustainable construction management practice connotes remains central to its implementation by construction project managers on their projects [6, 7, 16]. Therefore, this marked the starting point for the engagement with respondents. All respondents (100%) indicated an appreciable level of knowledge concerning sustainable construction project management practice. This was indicated in the responses proffered to a question bothering on the identification of sustainability-based deliverables expected of the construction phase of the project lifecycle. Deliverables like effective construction and demolition waste management, zero-accidents and fatalities, effective material handling and storage, local sourcing, etc. were identified as being associated with the construction phase.

Theme 2: Critical competencies required to embed sustainability

Findings from the study highlights consensus among the respondents relating to the core competencies required for engendering the effective incorporation of sustainability tenets into extant construction project management practice by construction project managers during the construction phase of the project lifecycle. The findings have been presented from both rounds in relation to the competencies. The study focused more on the ranking three to five as this is where most of the respondents ranked. The results are presented in Table 2.

As can be seen from the results emanating from the two rounds as shown in Table 2 the data was refined to highlight competencies which majority of the respondents identified as critical. The following competencies were identified as critical. They are as follows, communication measures, quality management, problem solving, procurement management, intellectual capabilities, decision-making, motivation, creativity, self-confidence, instil authority, transparency, conflict management, team building, cultural awareness, negotiation, stakeholder and project team management, knowledgeable about other project teams' professions, digital literacy, project management tools, technical tools and knowledge of construction equipment and tools. All the mentioned competencies fall under the group of planning, organizing, leadership and technical knowledge. The results from this study are in sync with the findings reported in similar studies. For instance, whilst corroborating the relevance of these competencies, Sang, et al., [14] opined that problem solving, communication (transparency), forecasting of resources and finances were essential for sustainable project management practice. Similarly, Pathuri, et al., [13] established the salience of competences like financial forecasting and recognition. It can thus be concluded that all four categories of competencies, planning, organizing, leadership, and technical knowledge are critical competency categories which construction project managers should possess to engage in effective sustainable construction project management practice albeit within the construction phase of the project lifecycle.

5 Conclusion and Implications of the Study

This study set out to the determine the core competences required by construction project managers to engender successful incorporation of sustainability tenets during the construction phase of the project lifecycle in developing countries. The quest for improved sustainability performance on construction projects has led to the emergence of sustainable construction practices and sustainable construction project management practice as a managerial approach for its actualization. However, extant studies have focused on techniques and tools required for engendering sustainable construction project management practice with limited attention given to an identification of the core competences required by construction project managers for optimal engagement with this phenomenon, especially in developing countries. This study set out to contribute towards filling this gap by eliciting the views of practicing construction project managers in South Africa's Free State Province, serving as members of a Delphi panel.

From the study's findings, it is evident that the core competencies ($n = 21$) required by construction project managers to foster effective sustainable construction project management practice can be categorized into the following groups: planning, organizing, leadership and technical knowledge-related competences. The findings from this study are expected to herald further studies seeking to achieve statistical generalization of these findings among a broader population across South Africa and possibly beyond.

Furthermore, it will assist educators in evaluating the utility of the current construction project management education and training framework to facilitate the development of these competences and possibly culminate in a modification of extant frameworks to cater to any deficiencies identified. Also, a qualitative inquiry into understanding the cultural nuances of these competences is encouraged. Summarily, the study recommends continuous lifelong training of construction project managers in developing countries towards improving these competencies for incorporating sustainability across a construction project lifecycle.

Table 2. Results of study

Number	Competencies	Median (round 2)	Standard deviation (round 2)
1	Understanding project objectives and execution	5	0.32
2	Communication measures	4	0.32
3	Establishing project plan and project schedule	5	0.22
4	Political awareness	3	0.32
5	Quality management	4	0.32
6	Identifying and establishing project team	5	0.22
7	Problem solving	4	0.32
8	Time management	5	0.22
9	Procurement management	4	0.32
10	Intellectual capabilities	4	0.32
11	Emotional intelligence	5	0.22
12	Management	5	0.22
13	Intellectual capabilities	4	0.32
14	Communication management	5	0.22
15	Motivation	4	0.32
16	Creativity	4	0.32
17	Self-confidence	4	0.32
18	Instil authority	4	0.32
19	Transparency	4	0.32
20	Conflict management	4	0.32
21	Team building	4	0.32
22	Ability to handle stress	4	0.32
23	Cultural awareness	4	0.56
24	Coaching	4	0.32
25	Negotiation	4	0.32
26	Stakeholder and project team management	4	0.32
27	Knowledgeable about other project teams' professions	4	0.32
28	Digital Literacy	4	0.32

(*continued*)

Table 2. (*continued*)

Number	Competencies	Median (round 2)	Standard deviation (round 2)
29	Project management tools	4	0.32
30	Technical tools	4	0.32
31	Knowledge of construction equipment and tools	4	0.32

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Stakeholder-Related Causes of Cost Overruns in the Namibian Construction Industry

Menelik Negussie, Mochelo Lefoka(✉), and Abimbola Windapo(✉)

Department of Construction Economics and Management, University of Cape Town, Cape Town 7701, South Africa
ngsmen001@myuct.ac.za, {mochelo.lefoka, Abimbola.windapo}@uct.ac.za

Abstract. Cost and time are two primary parameters that require due consideration throughout the project lifecycle and the determining factors for project success. Literature shows that many projects fail to achieve their goal of being completed within the planned budget and schedule. However, limited studies on project time and cost overruns have been conducted in the Namibian construction industry and the stakeholder responsible for the overrun. Therefore, this research examines the stakeholder-related causes of cost overrun on construction projects in the Namibian construction industry during the implementation stage. The study adopted a quantitative research approach that employs a cross-sectional survey research design in data collection from a sample drawn from a population of professionals in the Namibian construction industry. The data collected was analysed using descriptive statistics comprising of means, percentages, Relative Importance Index (RII), and Spearman Correlation. The study found that five of the main factors contributing to cost overrun on the construction projects in Namibia from a ranking perspective are contractors' financial constraints, inadequate contractor experience, inefficient project planning and scheduling by the contractor, poor site management, and delay in progress payment by the client. Furthermore, the study revealed that four out of the five factors causing cost overrun are related to contractors, while one was client-related. Based on these findings, the study concludes that projects on which an inexperienced contractor is engaged and poor payment regimes exist will experience cost overruns. The study recommends that activities undertaken at the execution stage should be monitored appropriately to prevent cost overruns on construction projects.

Keywords: Construction projects · Cost overrun · Namibia · Performance · Quantitative research performance · Stakeholder management

1 Introduction

Globally, the time and cost on construction projects have become a research area of concern, and there have been numerous studies conducted in many countries [1–6]. Cost overrun is described as the project's actual cost exceeding the planned cost where the project requires more funding than what is allocated at the bidding stage [4, 7]. The

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construction sector is vital for many developing countries as it accounts for the delivery of infrastructure projects [8]. In Namibia, the construction sector is a major contributor to the Namibian economy and provides the bulk of the employment [9]. Traditionally construction projects are inundated by cost and time overrun [7, 10]. A further study was conducted on cost overruns on transport projects in 20 countries and determined that 90% of the projects faced cost overruns [10].

Cost overrun is predominantly severe in most developing and sub-Saharan countries [11]. The Gautrain and ten Stadia projects for the 2010 world cup in South Africa showed significant cost escalation [12, 13]. The initial cost of the Gautrain project, which was estimated to cost R7 billion in 2002, escalated to R25 billion, which is a 257% cost escalation [12], whereas it was established that the cost of construction for the stadia experienced an average 45% cost increase [13]. Three leading causes of cost overrun were identified as: the owner's financial constraints, material-related problems, and contractor-related problems [14].

Cost escalation has become a significant bottleneck to infrastructure development within Namibia. Previous research that focused on factors contributing to cost overruns on road projects implemented by the Roads Authority of Namibia (RA) had a limitation in that only road projects constructed within five years (2008–2013) in Namibia were considered a small subset of the construction industry and not representative. Furthermore, only secondary data collection methods were used in the study. There is a lack of adequate studies and limited knowledge on stakeholder-related causes of cost overrun within the construction industry in Namibia and whether the blame is equally distributed amongst stakeholders. Therefore, this study evaluates the stakeholder-related causes of cost and time overrun within the Namibian construction industry towards developing sustainable construction projects.

2 An Overview of Factors Causing Cost-Overruns on Construction Projects

The cost performance on construction projects is the most significant indicator of the success of the project [15, 16]. It shows or measures the profitability of the construction projects. However, for a project to be successful, it would have to be completed within the cost budget that was planned for it [10]. Several studies have been conducted where several factors causing cost overrun were reviewed. A total of 36 factors were drawn from literature and scored based on the number of times they were cited. Fifteen top-rated factors, including fluctuation of prices (inflation), change order or scope change, inadequate experience in project planning and scheduling, poor experience in site management, and underestimation of project costs which influence cost overrun on construction projects, are presented in Table 1.

Price fluctuation results from scarcity of materials or when demand exceeds supply. This leads to an increase in the price of raw materials, which will, in turn, increase project costs. Price fluctuation is key to the underestimation of cost in several construction projects. The fluctuation of material prices is ranked top to cause cost overrun [6]. This factor results from suppliers' monopoly, scarcity of material locally, and inflation in the country. In concurrence with this result are findings from [17–19].

Table 1. Factors influencing cost overruns on construction projects ranked based on the number of times cited.

S/No	Source	Cost overrun Factors														
		Fluctuation of prices (Inflation)	Change order or scope change	Inadequate experience in project planning and scheduling	Poor Site management Experience	Underestimation of project cost	Frequent Design Changes	Mistakes during construction	Experience in Project management	Financial difficulty of Contractor (i.e., cashflow difficulty)	Delayed progress payment	Financial difficulty of Owner	Lack of Contractor experience	Inaccurate quantity take-off	Lack of coordination between parties	Shortages in Material & Equipment
1	Simushi and Wium (2020)		✔										✔			
2	Akinradewo and Aigbavboa (2019)		✔			✔			✔	✔			✔			
3	Asiedu and Adaku (2019)		✔	✔											✔	
4	Durdyev et al. (2017)		✔		✔	✔			✔							
5	Shimete and Wall (2017)		✔	✔	✔					✔	✔			✔		
6	Wanjari and Dobariya (2016)	✔	✔					✔		✔					✔	
7	Rahman et al. (2013)	✔		✔	✔		✔	✔	✔	✔	✔	✔	✔			✔
8	Aziz (2013)	✔	✔	✔	✔			✔	✔			✔				
9	Baloyi and Bekker (2011)	✔	✔			✔								✔		
10	Ameh et al. (2010)	✔	✔	✔	✔		✔		✔				✔			
11	Cantarelli et al. (2010)	✔	✔	✔			✔									
12	Olawale and Sun (2010)	✔				✔	✔				✔				✔	
13	Kaliba et al. (2009)					✔										
14	Enshassi et al. (2010)	✔		✔										✔		✔
15	Azhar (2008)	✔	✔	✔	✔	✔										
16	Le-Hoai et al. (2008)	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔				✔
17	Kaming et al. (2006)	✔					✔							✔		
18	Koushki et al. (2005)	✔														
19	Frimpong et al. (2003)	✔	✔	✔				✔			✔					
20	Kaming et al. (1997)	✔				✔						✔				
	Total Score	**14**	**13**	**`10**	**7**	**7**	**6**	**6**	**6**	**5**	**5**	**4**	**4**	**4**	**3**	**3**

The most critical and top-ranked factor that causes cost overrun on construction projects is a change order, as opined by [14]. A change order is associated with contract modification and most cost overruns on construction projects [8]. Clients' change orders are a major influence that exasperates the completion of construction projects within the proposed cost at the beginning of a project. However, [20] observed that change order is impacted by the timing of the change order and due to unforeseen circumstances, while [17] noted that scope change or change order arises from extensive variation due to change in brief and redesign. Underestimation of the project cost is when the owner's agent estimates the project cost to be lower than the market price. This factor is attributed to the fact that projects only go ahead if the estimate from the contractor is within the estimate for that of the consultant as the owner's agent [10].

3 Research Methodology

This research adopts a quantitative research approach, as it aims to form an accurate description of the survey respondent's perception of the causes of cost overruns. The research population consists of professionals - architects, quantity surveyors, project managers, engineers, and construction managers active in the construction industry. The population size of 1883 was obtained from the list of professionals in the membership directory of the Engineering Council of Namibia (ECN), Namibian Council for Architects, and Quantity Surveyors (NCAQS), and the Construction Industries Federation of Namibia (CIF). These professionals are versed in the cost management of construction projects in the Namibian construction industry. The distribution of the professional population per group is shown in Table 2. Study Population Size distributed by Professional Group.

Table 2. Study population size distributed by professional group.

Professional Group	Study Population
Quantity Surveyors	199
Architects	141
Engineers	1543
Total	1883

This study used a random sampling technique in selecting 320 respondents from the professionals listed in the directory of professional associations in the Namibian construction industry. The sample size of 320 was determined using Cochran's statistical formula [21]. Three experts reviewed the research instrument to validate it before distribution to the target group. At the end of the survey period, 114 questionnaire responses were received, equating to a response rate of 36%. According to [22], it is expected that survey response rates obtained are around 20%. According to the central limit theorem, where you have a population with a mean and standard deviation with a random sample size greater or equal to 30, the distribution of the sample mean can be approximated reasonably well by a normal distribution [23]. Therefore, taking [22, 23] into consideration, the sample of 114 responses is sufficient to carry out the quantitative analysis and answer the study objective. The research questionnaire was distributed via Survey Monkey, a cloud-based software platform. The questionnaire used in data collection employs interval Likert scales. The sections of the questionnaire used in the study are shown in Table 3.

Table 3. The sections of the questionnaire used in the study.

Section	Description
A: Background information.	This provides the demographic characteristics of respondents in this questionnaire.
B: Determining the factors causing cost overrun.	This section presents the factors causing cost overrun from the literature review. In this section, respondents rate the level of impact each factor has on cost overrun based on the five-point Likert scale regarding the project chosen for the survey.

The data collected was analysed and ranked using the Relative Importance Index (RII). Cronbach Alpha (α) test was conducted to measure the reliability and consistency of the questionnaire data. Cronbach Alpha (α) value less than 0.3 is not reliable and unacceptable. In contrast, a Cronbach Alpha (α) value of more than 0.7 has a high-reliability level [24, 25]. The Cronbach alpha (α) reliability score obtained for factors that cause cost overrun was 0.933, greater than 0.7. The result suggests that the responses provided are highly reliable and suitable for further analysis and interpretation. The consent of participants was obtained prior to the commencement of the research. The participants were anonymised, and all communications with the respondents were done transparently.

4 Data Presentation, Analysis, and Discussion

This section outlines the demographic characteristics of the respondents and data obtained on factors causing cost overruns on projects in the Namibian construction industry.

4.1 Background Profile of the Respondents

The results of the data analysis show that 69.1% of the respondents are between the age group of 31–35 and 41–45 years old; 82.5% were male; while 58.8% of the respondents hold a Bachelor's degree, followed by 36.8% who have a Master's degree. Furthermore, 49.1% of the respondents were engineers, followed by 19.3%, 14.9%, and 9.6% project managers, quantity surveyors, and architects. Site agents constitute 0.9% of the participants. A significant number of the respondents – 33.3% have between 6–10 years of experience, followed by 28.9% of the respondents who have between 11–15 years of experience. Combining educational background and experience is imperative in identifying the factors that cause cost overrun in the Namibian construction industry. 50.9% of the respondents have more than ten years of experience in the construction industry, and 95% have a university degree which shows that the respondents are competent enough to provide valid answers in response to the research objectives.

4.2 Level of Cost Overrun on Construction Projects in the Namibian Construction Industry

The study sought to know the level of cost overruns. The respondents were asked to identify a project they are familiar with and completed within the last five years (2016–2021). Table 4 summarises the responses obtained on the level of cost overruns from the study respondents on the level of cost overruns on the identified projects.

Table 4 shows that approximately 42% of the clients, 36.4% of the consultants, and 50% of the contractors that participated in the survey indicated that their projects experienced cost overruns of 0 to 20%. At the same time, 19% of the consultants and 9% of clients indicated that the identified projects experience between 30–50% cost overrun. Overall, about 33% of the identified projects are completed within or under the planned

Table 4. Level of cost overrun on construction projects in the Namibian construction industry

Range (Percentage overrun)	Clients	Consultants	Contractors	Total
<= 0	25.0%	31.8%	43.3%	32.7%
0-10	24.8%	22.0%	20.7%	20.9%
10-20	17.4%	14.4%	29.3%	18.2%
20-30	16.5%	4.8%	1.2%	7.2%
30-50	9.1%	19.0%	2.3%	13.7%
50-100	5.3%	6.4%	2.8%	5.4%
>100	1.9%	1.6%	0.0%	1.9%

budget. This shows that many construction projects in the Namibian construction industry experience cost overruns. Further analysis of cost overrun within the different project types reveals that all the six groups of project types identified as part of this study experience cost overruns but to different degrees. Electrical infrastructure, housing, specialist, and civil infrastructure projects experience cost overruns of 23%, 23%, 20%, and 19%, respectively. Table 5 shows the top ten factors causing cost overruns on construction projects distributed according to the stakeholder group.

Table 5. Ranking of overall factors causing cost overrun on construction projects.

Cost Overrun Factors	Extremely High (5)	High (4)	Moderate (3)	Low (2)	Minimal Impact (1)	RII	Rank	Category
Availability of Finance to execute the project	34	34	32	8	6	0.744	1	Contractor
Contractor experience	28	39	25	13	6	0.726	2	Contractor
Experience in project planning and scheduling	30	35	26	17	4	0.725	3	Contractor
Experience in Site management	27	37	22	23	3	0.711	4	Contractor
Delayed progress payment	32	27	23	18	13	0.683	5	Client
Late delivery of construction Material and Equipment	21	33	38	14	8	0.679	6	Material & Equipment
Fluctuation of prices (Inflation)	20	35	32	20	7	0.672	7	Material & Equipment
Extension of time claim	23	29	30	21	8	0.668	8	External
Availability of Finance	32	22	29	14	17	0.667	9	Client
Availability of skilled labour	19	40	25	18	12	0.663	10	Labour

Four of the top ten factors identified to have caused project cost overrun are contractor-related factors. In contrast, client-related and material-related factors are two, each with labour, and external factors were one each. From a ranking perspective, it can be seen from Table 5 that the lack of available finance/cash flow by the contractor is considered as the most important factor that causes cost overrun with an RII of 0.744. This was followed by inadequate contractor experience with an RII of 0.726. The other factors making up the top ten factors causing cost overruns on construction projects in Namibia from a ranking perspective are experience in project planning and scheduling by the contractor, experience in site management by the contractor, delay in progress payment by the client, late delivery of construction Material and Equipment, fluctuation of prices/inflation, the extension of time claim, availability of finance by the client and availability of skilled labour.

4.3 Discussion of Findings

The study sought to know the level and causes of cost overruns on construction projects in Namibia. It emerged that two-thirds of the construction projects identified by the respondents experienced cost overruns. Previous research revealed that globally, across construction projects, nine out of ten projects experience a 50–100% cost overrun [10]. This is aligned with previous findings by [7]. The top five factors causing cost overrun from a ranking perspective – availability of finance to execute the project, contractor experience, experience in project planning and scheduling, experience in site management, and delay in progress payment do not follow the ranking according to the number of times the factor was cited in the literature review and presented in Table 1. These findings are supported by [26]. Similar studies in Vietnam and Ghana ranked the availability of finance to execute the project as fourth and fifth, respectively, supporting the findings [15, 18].

The lack of contractor experience as a major cause of cost overrun in the study of telecommunication projects in Nigeria supports the research findings [19]. Lack of experience leads to contractors' inability to complete projects accurately and results in rework to correct the mistakes, which requires more capital to hire labour, hire plants, and purchase material. The lack of experience in project planning and scheduling was supported by previous studies by [27]. Poor site management by the contractor ranked the fourth-highest cost variation contributing factor in the study is supported by previous studies in Malaysian, Vietnam, and Indonesian construction industry [6, 18, 28]. The fifth-ranked factor found to cause cost overrun – delay in progress payment, which is the only client-related factor in the top five findings is aligned with the findings of previous studies in Ghana, Saudi Arabia, and Malaysia [15, 16, 29, 30].

5 Conclusion and Recommendations

Based on these findings, the study concludes that projects in the Namibian construction industry also experience cost overruns like those of other construction industries. Competency in project management and finances are the leading causes of cost increases on construction projects and are contractor-related factors. It can be inferred that contracting skills in the Namibian construction industry are deficient. The study, therefore, recommends that contractors should invest in relevant training to their workforce for them to have the required skill set to implement the latest project management techniques, implement adequate project planning and scheduling, ensure the workforce is adequately trained to plan, schedule, and supervise construction projects appropriately. This research will assist the Namibian government being the largest project owner of infrastructure projects in Namibia, to make use of the identified stakeholder-related causes of cost overrun as a tool to prepare a mitigating strategy that will address cost overruns on construction projects. The study findings will also help clients, consultants, and contractors update the operations of their respective disciplines to eradicate cost and time overruns.

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Examining the Expanded Public Works Programme in the Limpopo Province of South Africa

Olusegun A. Oguntona[1](✉), Boitumelo Kgoetyane[2], and Clinton Aigbavboa[2]

[1] Department of Built Environment, Walter Sisulu University, Butterworth, South Africa
ooguntona@wsu.ac.za

[2] cidb Centre of Excellence & Sustainable Human Settlement and Leadership in the Built Environment, University of Johannesburg, Johannesburg, South Africa

Abstract. Unemployment, skills shortage, and poverty are a few of the numerous problems ravaging the African continent. Out of the 17 sustainable development goals (SDGs) of the United Nations (UN), goals 1, 2, 4, 5, 8, 9, and 10 are specifically focused on addressing most of the socio-economic aspects of human life. To mitigate these socio-economic issues, initiatives and programmes are strategically established and funded with support from international governmental and non-governmental organizations. Hence, the establishment of the Expanded Public Works Programme (EPWP) by the South African government. This paper is aimed at assessing the EPWP in South Africa using the Limpopo province as a case study. The study examined the barriers hindering the effectiveness of the EPWP and the ways of enhancing the effectiveness of the programme. The quantitative research method was employed in the study. A structured questionnaire survey was administered to 104 relevant EPWP stakeholders (officials and beneficiaries). Findings from the study identified eighteen factors hindering the EPWP. Changes and improvements are significantly required in the EPWPs to ensure that the programme meets its mandate and outlined objectives. Conclusively, the study opined that proper implementation, monitoring, and evaluation mechanisms will ensure the EPWP realizes the objectives of its establishment.

Keywords: Africa · Construction industry · Developing countries · Sustainable development goals · Unemployment

1 Introduction

High levels of unemployment, poverty, and skills inadequacy are predicaments faced by most developing countries, of which South Africa is no exception. The sudden and overwhelming outbreak of the coronavirus (Covid19) deflated the socio-economic development of all nations of the world thereby worsening the situation in developing countries. However, the causal factors of unemployment and poverty in South Africa and other African countries are more diverse and complex [1]. After 1994, the African National Congress (ANC)-led government promised to address the threefold economic challenges

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of South Africa namely unemployment, poverty, and inequality [2]. Due to the paucity of work in the country, many South African citizens live in abject poverty and are unable to support their families [3]. As reported by Statistics South Africa in the study by McCutcheon and Parkins [4], the magnitude of the unemployment crisis in South Africa is such that in September 2003, about 4.6 million people were unemployed under the category of people who took active steps of finding a job but did not find a one. According to the South African Institute of Race Relations [5], youths aged between 15 and 24 years have the highest unemployment rate of 51%, which is almost twice the national average. In the period between the years 2000 and 2004, there was little change in the unemployment rate, which saw a moderate increase from 23.3% in 2000 to 26.7% in 2004 among males, and from 20.4% in 2000 to 22.6% in 2004 among females. The unemployment rate also increased from 26.5% in 2000 to 31.7% in 2004 [6].

Due to the enormity and severity of the impacts of unemployment, poverty, and inequality on the socio-economic status of the people, there is a global call and determination to address these challenges. For example, the United Nations (UN) sustainable development goals (SDGs) 1, 2, 4, 5, 8, 9, and 10 are specifically aimed at addressing the global socio-economic issues facing the people. To effectively tackle these issues, each member country of the UN has developed strategies and initiatives to achieve these goals. Consequently, initiatives aimed at promoting development and learning [4] have the potential to minimize the menace of unemployment, poverty, and inequality. However, one of the South African Growth Development Summit (GDS) identified the following as some of the reasons why the country is plagued by high unemployment rates and lack of skills: Apartheid education intended to intentionally provide poor quality training to the majority, resulting in several black adults being analphabetic and having low levels of work skills; and changes in production line such as in the mining sector, which initially employed a significant number of workers in the past but has since reduced hundreds of thousands of jobs in recent years. Other reasons are the use of more robots instead of humans in the manufacturing sector, and the inability of the economy to grow fast enough to build adequate jobs for the unemployed and new school leavers.

As a strategic short to medium-term measure, the South African government in the year 2003 convened the GDS to address the unemployment crisis. The resolution from this summit lead to the establishment of the Expanded Public Works Programme (EPWP). The programme is one of the cardinal programmes of government targeted at giving income and poverty relief to the unemployed citizens through temporary work opportunities. As declared during the State of the Nation Address (SONA) parliamentary speech of former President Thabo Mbeki in 2003, the main mandate of the EPWP was to generate one million jobs over five years. The creation of the EPWP to resolve high unemployment rates, poverty, and unskilled work issues is evidence that the South African government is knowledgeable and conscious of these challenges. EPWP is a five-year programme established in 2003 and started operating in 2004, to provide jobs including skills and training to reduce poverty by providing salaries to beneficiaries while working on a temporary or contract basis [3]. To optimize and increase the effectiveness of the programme, Antonopoulos and Kim [7] proposed a massive scaling up of EPWP if the program is to reduce unemployment, as the existing scale was incommensurate with the unemployment problem at hand in the country. Hence, the need to examine the EPWP to determine the performance and shortcomings of the programme since it was established. Therefore, this research paper is aimed at providing answers to the following research questions namely: what are the barriers hindering the effectiveness of the EPWP; and what are the ways of enhancing the effectiveness of the EPWP in South Africa?

2 An Overview of the Expanded Public Works Programme in South Africa

According to Thwala [8], the EPWP is an initiative with specific objectives of decreasing the number of unemployed or jobless citizens by providing them with job opportunities. The EPWP is a national program that extends across all government and state-owned enterprises. The programme focuses on four sectors encompassing Infrastructure, Social, Non-State, and Environment and Culture. The EPWP is considered the biggest and major response of the South African government to the socio-economic challenges facing the citizens. The EPWP is regarded as one of the world's most ambitious and all-encompassing initiatives with multiple objectives of job creation, poverty alleviation, infrastructure development, community outreach, and skills training [9]. The concept of the EPWP emerged from the GDS in 2003 and the adopted theme for the initiative was, "More jobs, better jobs, and decent work for all" [10].

As one of the government's broader strategies to eliminate poverty through the alleviation of unemployment, the EPWP implementation roll-out was in five-year phases. Phase 1 will span from the year 2004 to 2009 with a work opportunities (WOs) target of 1 million. Phase 2 from the year 2009 to 2014 with a target of 4.5 million WOs. The commutative five-year target for phase 3 was 6 million WOs. Each phase had novel innovations to ensure better promotion, monitoring, data capturing, reporting, and budget expenditure. Although the intended WO targets were reached, a brief analysis of the programme indicates that the intended benefits were not achieved.

2.1 Expanded Public Works Programme Objectives Based on Phases 1–4

Each phase of the EPWP has its objectives in realizing the targeted outputs. Phase One is focused on skills development, employment, and exit opportunities; growing diverse sectors and work opportunities; and mainstreaming the EPWP. Phase Two is focused on making work the primary objective, with a focus on job creation outputs; clear accountability for targets; mobilizing technical support, mobilising non-governmental arms; and introducing incentives for expansion. Phase Three is aimed at targeting income transfer and work opportunities to the poor, unemployed, and marginalised communities; contributing to poverty alleviation; providing a common platform for EPWP programmes; ensuring the provision of quality services and the creation of quality assets; targeted expansion; and streamlining monitoring and evaluation (M&E). Lastly, Phase Four entails maximising and developing services for children and girls, such as participation in mass sports and assistance with school homework; reinforcement of the control of key EPWP values to strengthen compliance with EPWP guidelines; expansion of the initiative by duplicating and developing the programme in all sectors; improving cooperation and organizational arrangements between the EPWP; strengthening the EPWP impact assessment and ensuring greater transparency and accountability through social audits, and; strengthening private sector partnerships and Technical and Vocational Education and Training (TVET) schools.

2.2 Sectors of the Expanded Public Works Programme

The EPWP focuses on four sectors to deliver on its mandate. These are Environment and Culture Sector, Infrastructure Sector, Social Sector, and the Non-State Sector.

Environment and Culture Sector. There are five programs in the Environment and Culture sector of the EPWP. These include Water Working, Fire Working, Energy Working, Wetland Working, and People and Parks Working. The environment and culture sector has grown in the management of natural resources to understand its importance and to offer people the power to protect natural resources and manage their environment. In the meantime, the purpose of the sector is to reduce the number of disadvantaged people who are not employed using public works in the short term, initiate the small-medium and micro enterprises and give skills that will generate employment. The sector's goal was to enable communities to create job opportunities for entrepreneurship by using the five programs to achieve their goals.

Infrastructure Sector. The infrastructure sector of the EPWPs consists of infrastructure projects including construction, stormwater, roads, electricity, waste, water supply, and management. Construction works are the largest followed by road-related works, gulping about 28% of expenditure and creating 57% of job opportunities [11]. From 2004 to 2009, the sector was recognised as one of the sectors employing more people to provide 900 000 job opportunities. Based on the employment generation prowess of the construction sector, the government also significantly increased the total infrastructure budget to generate more employment opportunities. This sector encompasses the use and combination of labour and heavy machinery techniques in the construction and maintenance of infrastructure projects funded by the public sector. It also involves the use of labour-intensive techniques to build employment opportunities for people who do not work in rural areas, create training and skills development, transfer knowledge to the local unemployed, and build low-cost, high-quality assets [12].

Social Sector. This sector includes the Home Community-Based Care (HCBC), Early Childhood Development (ECD), Community Safety, and other community-based programs. The social sector is part of the Department of Social Development, Department of Education, and the Department of Health with support from non-governmental organisations, community-based organisations, and faith-based organisations to achieve the goals and objectives of cooperation with the Department of Labour (DoL) and Sector Education [12]. The social sector used social services to meet its goals of creating job opportunities and increasing the sector in the first phase (from 2004 to 2009). It focuses on the effects of human development and improving the quality of life in the areas of education, nutrition, welfare, security, and protection as well as contributing to community development. The social sector of EPWP offers employment opportunities to non-employed people: ECD, HCBC, national school nutrition programme, community safety programme, mass participation programme, and "Khari Gude" Venda, meaning let's learn.

Non-State Sector. The non-state sector offers and generates job opportunities to meet its objectives through cooperation with non-state organisations, and through programs for small businesses, training, and incubation to promote community participation.

3 Research Methodology

The quantitative research approach was employed in this study. Quantitative research methods are used to compare, control, contrast, describe, and formulate concepts and theories of data to examine relationships [13]. Primary and secondary data were utilised to present factual evidence of the state of the EPWP in the Limpopo Province of South Africa. The study area is the Limpopo Province which is one of the nine provinces that constitutes the Republic of South Africa. The targeted participants in the questionnaire survey were sampled purposively based on the following yardsticks: be based in the Limpopo Province; be fully involved in the EPWP; be willing to participate in the research; and be any of EPWP managers, monitoring officers, facilitators, coordinators, project managers, construction project managers, construction managers, project technicians, project engineers, site agents, and beneficiaries. A three-section questionnaire survey consisting of close-ended questions was administered to the respondents. One hundred and four (104) of the questionnaires were completed and returned for analysis.

Section A of the questionnaire survey contained questions on the background information of the respondents. Section B of the questionnaire survey contained questions to unearth the barriers hindering the effectiveness of the EPWP. The last part (Section C) of the questionnaire survey contained questions to identify the ways of enhancing the effectiveness of the EPWP. Questions on Sections B and C of the questionnaire survey were based on a five-point Likert scale (Strongly Disagree = 1, Disagree = 2. Neutral = 3, Agree = 4, and Strongly Agree = 5). The Statistical Package for Social Sciences (SPSS) was employed to analyse the data. The study also employed descriptive data analysis with the aid of the standard deviation (σX) and mean values ($\overline{x}$) to rank the variables. The standard deviation (SD) and mean item scores of the identified factors for the barriers, and ways of promoting the effectiveness of the EPWP were further tabulated and presented.

The Cronbach's alpha coefficient was adopted to conduct a measure of internal consistency to determine the reliability of the measuring instrument. Cronbach's alpha describes the extent to which all items in a test measure the same concept [14]. The less variation an instrument produces in repeated measurements of an attribute, the more reliable the instrument is. Cronbach's alpha aims to determine the degree of correlation of items in a set [15]. The calculated Cronbach's alpha for Sections B and C of the questionnaire survey is 0.911 and 0.908 respectively. It can be discovered that all the values are more than 0.7 indicating that the data for the study had satisfactory internal consistency. According to Taber [16], and Farrahi Moghaddam et al. [17], Cronbach's alpha values of 0.7 or higher are considered acceptable reliability.

4 Research Findings and Discussions

4.1 Background Information of the Respondents

Table 1 presents the demographic information of the respondents. The majority of the respondents have a Diploma certificate (32.7%) and Bachelor's degree (32.7%) respectively, followed by those with Matric/Grade 12 Certificate (17.3%), Postgraduate Diploma (8.7%), Grade 9 certificate (4.8%), while 3.8% of the respondents possess Master's degree. From Table 1, the beneficiaries formed the largest part of the respondents (32.7%), followed by Site Agents and Project Technicians both representing 8.7% respectively, while EPWP Monitoring Officers, EPWP Coordinators, Project Managers, and Project Managers are all 7.7% of the population. Also, from Table 1, most of the respondents (43.3%) are affiliated with the Infrastructure Sector of the EPWP, followed by the Non-State Sector with 28.8%, Social Sector with 16.3%, while 11.5% of the respondents are affiliated with the Environment and Culture Sector. From the findings, it can also be revealed that the Infrastructure Sector can accommodate many beneficiaries. This is seen as a justification for the huge infrastructural investments embarked upon by the South African government. This authenticates the global assertion by various researchers that the CI remains beneficial and linked to the provision of infrastructure, employment generation, and economic development in every nation [18, 19].

4.2 Barriers Hindering the Effectiveness of the Expanded Public Works Programme

Results from Table 2 present the level of agreement of respondents on the barriers hindering the effectiveness of the EPWP. It can be deduced that the respondents perceive all the eighteen (18) barriers are highly significant because they have means values greater than 2.5 [20]. Based on the descriptive analysis of the study presented in Table 2, 'Corruption' is ranked first with a mean score of 4.19 and SD of 1.199. Ranked second is 'Political interference' with a mean score of 4.13 and SD of 1.180. The factor 'Lack of accountability' was ranked third with a mean score of 3.86 and SD of 1.136. Ranked fourth with a mean score of 3.78 and SD of 1.214 is 'Wrong beneficiaries' selection' while the duo of 'Low skills' (MIS of 3.73 and SD of 1.184), and 'Delay in payment of participant's remuneration' (MIS of 3.73 and SD of 1.367) are ranked fifth. However, the least ranked factors are the trio of 'Lack of discipline from participants' (MIS of 3.49 and SD of 1.269), 'Lack of commitment from coordinators' (MIS of 3.48 and SD of 1.262), and 'Insufficient recruitment of participants' (MIS of 3.41 and SD of 1.297), occupying the sixteenth, seventeenth, and eighteenth places respectively.

The result from this study is in tandem with the public and global perception of corruption as cancerous and detrimental to the socio-economic development efforts in Africa. To prevent and combat corruption, South Africa has developed a legal framework coupled with relevant security agencies [21]. Despite the criminal stance on corruption, recent investigations into the event of state capture in the country showed that this endemic is still massively ravaging the country for years to date [22, 23]. It is also established in the literature that corruption and political interference go together as significant factors hindering service delivery, governance, and economic development

Table 1. Background information of the respondents.

Variables	Frequency	Percentage (%)
Highest educational qualification		
Grade 9 certificate	5	4.8
Matric certificate (grade 12)	18	17.3
Diploma	34	32.7
Bachelor's degree	34	32.7
Postgraduate diploma	9	8.7
Master's degree	4	3.8
Total	104	100
Status of respondents		
EPWP manager	4	3.8
EPWP monitoring officer	8	7.7
EPWP facilitator	4	3.8
EPWP coordinator	8	7.7
Construction project manager	7	6.7
Construction manager	5	4.8
Project manager	8	7.7
Project technician	9	8.7
Project engineer	8	7.7
Site agent	9	8.7
Beneficiary	34	32.7
Total	104	100
EPWP sector affiliation		
Infrastructure sector	45	43.3
Non-State Sector	30	28.8
Environment and culture	12	11.5
Social sector	17	16.3
Total	104	100

in South Africa [24–26]. With corruption and political interference, an ordinary citizen lacks the necessary confidence in the government and various programmes initiated by the same government to address poverty and unemployment in the country. A globally applauded initiative such as the EPWP is expected to be isolated from corruption and political gimmicks of politicians if its objectives are to be realised. Hence, the government through its various agencies is expected to show genuine political will against corruption to drastically minimise interference in governance and service delivery to the people.

Table 2. Barriers hindering the effectiveness of the EPWP.

Barriers	($\bar{x}$)	(σX)	Rank
Corruption	4.19	1.199	1
Political interference	4.13	1.180	2
Lack of accountability	3.86	1.136	3
Wrong beneficiaries' selection	3.78	1.214	4
Low skills	3.73	1.184	5
Delay in payments of participant's remuneration	3.73	1.367	5
Limited duration of training of participants	3.67	1.218	7
Lack of communication between stakeholders	3.66	1.137	8
Lack of continuous training of coordinators	3.65	1.229	9
Non-standardised participant's remuneration	3.63	1.191	10
Poor monitoring and evaluation by coordinators	3.59	1.274	11
Poor reporting and information management by coordinators	3.58	1.172	12
Lack of commitment from participants	3.58	1.267	12
Limited government funding	3.55	1.291	14
Inability to incorporate disabled people	3.51	1.262	15
Lack of discipline from participants	3.49	1.269	16
Lack of commitment from coordinators	3.48	1.262	17
Insufficient recruitment of participants	3.41	1.297	18

4.3 Ways of Enhancing the Effectiveness of the Expanded Public Works Programme

Table 3 presents the perception of the respondents on the most important measures to enhance the effectiveness of the EPWP. According to Field [20], a factor with a mean value of 2.50 or more is agreed to be significant to a study. Hence, all the seventeen (17) measures for enhancing the effectiveness of the EPWP are significant. Based on the descriptive analysis of the study presented in Table 3, 'Improved reporting from coordinators/facilitators' (MIS of 4.19 and SD of 0.956) and 'Increased participation in community-based projects' (MIS of 4.19 and SD of 0.893) are both ranked first. The adoption of strategies to ensure improved commitment from contractors is ranked third with a mean score of 4.18 and an SD of 1.012. The factor 'Increased funding for EPWP projects' is ranked fourth with a mean score of 4.13 and an SD of 0.992. The duo of 'accelerated capacity-building programmes with accredited facilitators' (MIS of 4.12 and SD of 0.958), and 'Increased number of participants' (MIS of 4.12 and SD of 1.017) ranked fifth. The least significant way of enhancing the effectiveness of the EPWP is 'reduced political interference' (MIS of 3.93 and SD of 1.201), and 'Inclusion of disabled people' (MIS of 3.89 and SD of 1.023) both ranking sixteenth and seventeenth respectively. In support of the results of this study, Van der Waldt [27] indicated that the effective use of government relations will address coordination and administrative challenges in public service. The study of Mkhize [28] also suggested the need for regular communications from and among officials to ensure a clear understanding of the objectives of the programme. Initiating and bringing forward a robust exit policy and strategy for the EPWP has the potential to improve the lives of the participants after the programme.

Table 3. Ways of enhancing the effectiveness of the EPWP.

Drivers	($\bar{x}$)	(σX)	Rank
Improved reporting from coordinators/facilitators	4.19	0.956	1
Increased participation in community-based projects	4.19	0.893	1
Adoption of strategies to ensure improved commitment from contractors	4.18	1.012	3
Increased funding for EPWP projects	4.13	0.992	4
Accelerated capacity-building programmes with accredited facilitators	4.12	0.958	5
Increased number of participants	4.12	1.017	5
Continuous training of programme coordinators	4.11	1.014	7
Efficient monitoring and evaluation of participants	4.11	0.954	7
Life skills programme for participants	4.08	1.002	9
Robust exit plan for participants	4.04	1.014	10
Improve beneficiary's selection methods	4.00	1.052	11
Improved recruitment of participants	4.00	0.995	11
Improved remuneration of participants	3.99	1.075	13
Timely payment of participant's remuneration	3.98	1.123	14
Increased communication amongst stakeholders	3.97	0.950	15
Reduced political interference	3.93	1.201	16
Inclusion of disabled people	3.89	1.023	17

5 Conclusion and Recommendations

With the recent occurrences and economic downturn experienced globally, the issue of poverty and unemployment is not only prevalent in developing nations but also in advanced countries such as Germany and the United States of America. Hence, the acceptance and adoption of the previous Millennium Development Goals (MDGs) and the present Sustainable Development Goals (SDGs) by the United Nations are not far-fetched. However, solutions to the inherent challenges facing the citizens of every nation of the world are only responsive to consideration of factors such as the geographical location, tribe, religion, and socio-economic situation of the people among others. For a country such as South Africa which is yet to fully heal from the trauma of the apartheid era, the effectiveness and success of programmes such as the EPWP are highly important to improve the lives of the people. This study identified eighteen (18) factors hindering the EPWP and seventeen (17) factors with the potential to enhance the effectiveness of the programme. The study was able to identify corruption, political interference, and lack of accountability as the top barriers hindering the effectiveness of the EPWP. Also, improved reporting from coordinators/facilitators, increased participation, and adoption of strategies to ensure improved commitment from contractors as the top ways of enhancing the effectiveness of the EPWP.

It is therefore recommended that stringent measures and strong political will against corruption and interference on the part of the government be established to restore people's confidence in government initiatives and programmes. Increased funding and involvement of the private sector are also recommended to increase the number of beneficiaries of the EPWP, and similar programmes aimed at addressing poverty and unemployment in the country. An effective inter-ministerial monitoring and evaluation team consisting of people of unquestionable character should be in place to check and balance any form of excesses identified in the implementation of the EPWP and similar initiatives. Taking these decisive steps and carrying along the stakeholders will ensure the objectives of the programmes are met and improve the socio-economic status of the people.

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Toward an Integrated SCM Model for the South African Construction Industry: Lessons from Shipbuilding

Zanele S. Matsane(✉), Molusiwa S. Ramabodu, and Chimay J. Anumba

Department of Construction Management and Quantity Surveying, University of Johannesburg, Johannesburg, South Africa
zmatsane@uj.ac.za

Abstract. The design and manufacture of ships was catapulted by the adoption of digitalisation and lean manufacturing. The key factors to shipbuilding success have been the application of tools that include multiskilled training, VSM, 5S processes and adoption of key enabling technologies (KETs) for waste elimination in the value chain. The construction industry shares some similarities with shipbuilding that provides a good foundation of comparisons and lessons for improving some of the inherent difficulties construction faces. The purpose of this paper is to provide a comprehensive literature review of the shipbuilding industry's lean techniques and KETs that have practical application for construction to improve the industry's efficacy. Moreover, a study of shipbuilding SCM enhances practical knowledge of SCM implementation, especially since shipbuilding, like construction, has had challenges with the implementation of SCM and have successfully overcome these challenges to achieve competitive advantage and global economic success. From the review it was discovered that lean construction is broad in its application and numerous studies exist covering its application in modern construction. However, the lack of industry support or practice-related research on lean principles fails construction from reaping the full benefits of lean production. Digitalisation and lean in construction are seen as management tools, limiting their application and overall influence on a construction site, especially in production. The adoption of multi-skill training and a move toward greater forms of digitalisation would ensure construction has a skilled workforce ready to improve the quality of the structure they produce.

Keywords: Digitalisation · Lean shipbuilding · Lean construction · SCM shipbuilding

1 Introduction

The shipbuilding industry is responsible for most of the world's trade, making shipbuilding both vital and challenging [1]. Shipbuilding around the globe is a big contributor to a nation's economic system [2]. Once a Western-Europe dominated industry it is now like automobile manufacturing, dominated by Asia, namely China and Japan [3, 4].

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Interestingly, this fact has encouraged the adoption of Asian production systems such as lean production in shipbuilding [5]. Prahasi et al. [6] states that shipbuilding is traditionally characterised as an engineer to order (ETO) industry. As a result, shipbuilding employs the ETO strategy to design and construct its products as and when a customer commissions it. The shipbuilding industry shares some similarities with the construction industry (CI). Firstly, the shipbuilding industry faces challenges to the management of supply chains [7]. Other issues faced by the shipbuilding relates to unstable economic cycles, empty container repositioning, seafarer shortages and port closures. Secondly, Shipbuilding relies heavily on government support both as a regulator and fiscal support [8]. Thirdly, the ETO strategy is like construction in that, tasks such as design, material and labour sourcing, procurement and production are done concurrently which employs the use of a production Work Breakdown Structure (WBS) [9]. Admittedly, a production planning system which has proven rudimentary to the scope and magnitude of these industries (ibid). The complexity and competitiveness of the shipbuilding market requires manufacturers to decrease cost and enhance the quality of its products. Lastly (for an exhaustive list and/or see Boton et al. [10]), the cost of resources such as material and equipment constitute over 50 percent of all building costs [11]. Shipbuilding comprises of vessel construction, vessel repair and maintenance and spans across several industries such as commerce, good delivery, and national defence [12]. Cheng et al. [11] hypothesise that in shipbuilding an effective SCM requires the purchase of all resources according to the production schedule. In turn, this must be done under request of the client/buyer while leaving zero inventory and delivered timely. Baginski et al. [13] posits the following attributes of shipbuilding industry:

- Made-to-order with a deadline of 12 months or more for construction
- Complex production processes
- large scale production
- intensive manual labour
- High value-added good with long lifecycles
- Require large, fixed capital investment.

In this paper we seek to add to existing research on SCM and its application and practical implementation to construction by presenting the analysis of manufacturing industry techniques and technologies that have yielded success in shipbuilding. The aim of this research is to review the application of SCM in shipbuilding with the view identifying the critical success factors, best practice, the procedural and organisational behavioural barriers, and generic inter-disciplinary benefits. To enable the conceptualisation of an integrated SCM model for the construction industry, a comprehensive review of lean shipbuilding namely value-stream mapping, 5S and multi-skilled training as well as key enabling technologies are discussed. To set the premise for comparison, the sequential format followed in this paper includes brief discussions on the nature of supply chains (SC) in shipbuilding, critical success factors for SC integration, enablers, and barriers for SCM implementation and features of SCM modelling. Thereafter, the gaps and lessons for construction are discussed to highlight the way forward. This paper is part of a literature review undertaken for a doctoral study on SCM and is a supported by the numerous studies that called for the adoption of manufacturing techniques for optimisation and continuous improvement.

2 Shipbuilding Industry

According to Sender et al. [14] shipbuilding must deal with highly complex building process that results from having to construct and commission a complex ship structure that is made up of a large variety of parts and components. The shipbuilding process consists of two main stages, that of design and manufacturing. The first stage of design is the procedural phase of obtaining buyer's requirements, establishing contractual basis, and refining and finally detailing the design [10]. The second stage, manufacturing, comprises of the erection and commissioning processes. Erection is made up of several activities ranging from fabrication of components to assembly and finishes (ibid). Successful commissioning begins with launching and testing the product and upon successful completion results in delivery of the product to the buyer (see [10] Fig. 1). Interestingly, Mandal [15] states that the elaborate design stage is based on only four inputs from the buyer i.e., type of cargo, volume, or weight of cargo to be carried, ships route of operations and cruising speed. The entire design and subsequent details are left to the manufacturer/ship builder(ibid).

2.1 The Nature of the Shipbuilding Supply Chain

The shipbuilding supply chain (SBSC) consists of three key players, the shipyard as prime contractor and SC integrator, their suppliers of equipment and third-party suppliers of material [16]. As an ETO, Gosling and Naim [17] states that shipbuilding SC has unique characteristics, which include:

- Production flow is driven by actual customer orders
- Decoupling point is located at design stage
- Companies modify existing designs or develop completely new designs
- Several types of supply chain organisations exist

As brought out by Chu et al. [18], the SBSC is shorter as it does not include distribution of mass products to customers, but the unit production characteristic of shipbuilding means the SC ends at project completion. Noteworthy, the SC, while shorter than most industries (e.g. automotive) consists of a great number of second and first tier suppliers who provide machinery, components, raw materials by the thousands from different sizes and locations thus requiring a coordinated supply and delivery that fulfils the technical specifications of the contracted design [18]. Corroboratively, Diaz et al. [19] asserts that the non-repetitive nature of SBSC relies on internal dependencies as well as a volatile political and industrial environment. In addition to a multiorganizational SC players, SBSC includes regulatory intervention [20].

2.2 Critical Success Factors for SC Integration

Alfnes et al. [20] states that shipbuilding products comprise over 50 percent supplied inputs. The one-time ETO nature of shipbuilding means great reliance and emphasis on an effective SC (ibid). As stated by Hicks et al. [21], the establishment of long-term collaborative relationships is an important driver of SC implementation in shipbuilding. Some researchers [22, 23] posit that the coordination of engineering and production processes plays an even greater role in an effective SC. Strandhagen et al. [24] notes that the efficient coordination of information and material flow result in an effective management of SC operations. The outsourcing of non-core activities is another factor to SC integration in shipbuilding [25]. For the successful coordination of the supplier network great emphasis is placed on information sharing [26]. Closer to the point, Rød et al. [27] states that information sharing should result in the utilisation of the information shared. Moreover, effective SC depends on rapid reaction and adaptability to changes to avoid re-work [22]. Noticeably, the factors that make for SC implementation are scarcely studied. Table 1 provides a summary of the critical success factors for SC implementation as sourced from several studies.

Table 1. Summary of critical success factors for supply chain implementation.

Critical success factor	Source
Outsourcing of non-core activities	(Oluyisola, Salmi, and Strandhagen, 2018)
Establishment of long-term collaboration relationships	(Hicks, McGovern, and Earl, 2000)
Coordination of supplier network	(Junge, Kjersem, Shlopak, Alfnes, and Halse, 2015)
Coordination of engineering and production processes	(Bejlegaard, Sarivan, and Waehrens, 2021) (Mello, Strandhagen, and Alfnes, 2015)
Coordination of information and material flows	(Strandhagen, Buer, Semini, and Alfnes, 2019)
Information sharing	(Junge, Kjersem, Shlopak, Alfnes, and Halse, 2015)
Utilisation of shared information	(Rød, Shlopak, Junge, and Alfnes, 2016)
Rapid reaction and adaptability to changes	(Mello, Strandhagen, and Alfnes, 2015)

2.3 Enablers and Barriers if SCM Implementation

Shipbuilding SCM as detailed by Diaz et al. [28] entails the management of upstream activities such as material and component procurement and multi-organisational suppliers. The SBSC framework proposed by Diaz et al. [28] provides a guide of the processes in shipbuilding as they relate to tools and technologies adopted in shipbuilding namely lean and digitalisation.

Lean

An effective tool used in shipbuilding to create value while eliminating waste is Lean thinking, known as Lean shipbuilding (LSB). Lean is the utilisation of less of everything, that is, human effort, materials, space, equipment, and engineering systems [29]. According to an empirical study conducted by Sharma and Gandhi [29] LSB employs the use of three lean management tools i.e., multi-skill training, value stream mapping (VSM) and Five Ss (sort, set in order, shine, standardise, and sustain) to eliminate waste in the value chain.

Mahalaskmi and Murugesan [30] states that multi-skill training is the training of a worker in one or more skills in addition to their assigned/hired qualification. This ensures a balanced workload and results in less human resource [29]. Woods et al. [31], in their report further state that the changes in organisational stucture implemented by management to include team leaders and teammates supported by HR improves coordination of multi-trade activities and better work environment.

Braglia et al. [32] define value stream mapping (VSM) as a tool that is used to map out the production process that also includes material and information flows. As the basis for lean production implementation, VSM links product planning and demand forecast to production scheduling to eliminate waste and optimise the value created [32]. According to Braglia et al. [32] VSM is based on three fundamental steps, selecting the product family that needs improving, identifying, and analysing waste and future production that is ideal without waste. Romero and Arce [33] states that VSM improves the understanding of work systems to establish strategic directions for better decision making.

Phogat [34] postulates that for lean to be effective, the entire organisation should support and create a lean environment. To achieve this, five processes known as 5S is applied to reach a level of standardisation, workplace organisation and continued improvement (ibid). Effective implementation requires the application of all 5S processes. Phogat [34] outlines the five processes for establishment of a lean environment as:

- Sort – organise and tidy workspace
- Set in order – materials organised in efficient and effective storage methods
- Shine – effective housekeeping as regular practice
- Standardise – standardize best practice
- Sustain – uphold the established and changes made.

Digitalisation

Digitalisation takes the form of digital modelling, simulation, and optimisation in shipbuilding [35]. Digital shipbuilding allows for digital modelling, digital prototyping, and digital simulation of the product from the time it is designed, manufactured, and tested [35]. Shipbuilding technologies aimed at automation mechanisation, modular, integrated, and intelligent directs are developed and tested via simulation modelling. Table 2 summarises shipbuilding key enabling technologies (KETs) as highlighted by Ramirez-Pena et al. [36].

Table 2. Key enabling technologies (KETs) in shipbuilding.

Key enabling technologies (KETs)	Description/application	Source
Additive manufacturing	Allowing manufacturing of complex and lightweight design	(Berman, 2012) (Holmstrom et al., 2010) (Mellor t al., 2014)
Big data	Allows for storing and evaluating a large amount of data that can be used to support real-time decision making	(ATKearny, 2015) (Raman et al., 2018)
Cloud computing	Improving reaction times and enabling more data-driven serves for system production	(Bhoir and Principal, 2016) (Jain and Mahajan, 2017)
Augmented reality	Providing workers with real-time information to improve decision-making and work procedures	(DeKoster et al., 2007) (Mourtzis et al., 2017)
Autonomous robots and vehicles	Tackling complex assignments and to work in teams with humans	(Lee and Lee, 2015) (Posada et al., 2015) (Fitzgerald, 2018) (Gaurdeno et al.,2019)
Blockchain	Allows for efficiency and transparency within the supply chain enabling all members access to the issued instructions, approved transactions	(Casado-Vara et al., 2018) (Chang et al. 2019)
Cybersecurity	Security assessment tools, databases that identify and may key suppliers, tracking and tracing tools and design defects	(Boyens, 2016)
Horizontal and vertical integration system	Horizontal - internal digitalisation of the company, service product, etc. Vertical – activities that one company assumes and that traditionally delegated to another	(Nagy et al., 2018)
Artificial intelligence	Allows for communication and exchange of information between different companies that make up the supply chain	(Aksoy and Ozturk, 2011) (Huang and Lin, 2010)

(*continued*)

Table 2. (*continued*)

Key enabling technologies (KETs)	Description/application	Source
Internet of Things	Allows for field devices to communicate and interact between them and with centralised controllers enabling real time responses	(Lee and Lee, 2015) (Ping et al., 2011)
Simulation	Allows for managing data in time through virtual models of products, materials, and production processes with all its components, workers, machinery, and final product	(Terzi and Cavalieri, 2004) (Garvia and Ortega, 2006) (Schunk and Plott, 2002)

3 Lessons for Construction

Construction can learn a lot from shipbuilding. This paper summaries four lessons that can help construction overcome its inherent difficulties and improve performance. These lessons are discussed briefly. Construction needs to:

- Foster a culture of lean among construction professionals and practitioners
- Adopt lean philosophy across management and production levels on site
- Adopt VSM in project planning and 5S in site management
- Develop KETs that are inclusive work collaboratively with other technologies and applications.

The most frequently mentioned barrier to lean construction is lack of awareness of lean construction and lack of management commitment to lean [37–39]. Construction needs to establish long-term lean philosophy by fostering lean culture within their respective organisations.

According to Saini et al. [40] the construction SC (CSC) is disjointed in nature due to a lack of process integration and collaboration. To create an integrated SC construction must apply lean to various divisions, subdivisions, and activity processes and subprocesses of a construction project both at management and production levels. It is noted that some criticize the relevance of lean application in construction as the one-time nature of construction projects makes it difficult to universally apply it to the CSC [41]. Studies brought out in this paper have shown ETOs can successfully apply lean principles. One pilot study by Eriksson [42] where lean was applied indicated significant improvement to reduction of cost and time of the entire project. In fact, even though not all aspects of the core elements of lean were applied, those that were applied resulted in successful project execution with regards to good quality and client satisfaction which was due to outstanding performance by the SC.

The SBSC framework presented by Diaz et al. [28] detail the use of lean tools and technologies for value creation along the SC. To improve workflow and collaboration, VSM must be used in project planning and control system to aid the visualisation of production processes allowing for early analysis and elimination of waste for efficient problem-solving [43]. For the standardisation of workplace method and processes flagged by Egan [44], 5S needs to be used as an on-site management to facilitate the core of element of lean, continuous improvement of the construction site processes as well as create good and working conditions for construction activity [43].

The process of digitalisation notes Barkokebas et al. [45] is the use of digital technologies to transform processes and produce value-adding opportunities. As reported by Singh [46] it has taken over 40 years for construction to go digital. Now that the industry has gone digital, building information modelling (BIM) is at the centre of most digital advancements made to date. Furthermore Singh (2019) goes on to highlight some enabling technologies that are more or less likely to penetrate construction: Integrated BIM, Prefabricated building components, Real-time mobile collaboration, Advanced project planning tool, Wireless monitoring/IoT, 3D printing of components, Self-healing materials, New active materials, Augmented reality, 3D laser scanning, Contour crafting of buildings, Drones and Big data analytics. In addition, Demirkesen and Tezel [47] states that as construction enters the 4th industrial revolution, technologies such as machine learning, artificial intelligence, virtual reality will become common tools. However, digitalisation in construction is deterred by the costs that comes with implementing these technologies, that is the cost of the technology and training personnel [48]. At present, construction uses seven out of the eleven key enabling technologies (KETs) employed in shipbuilding, the majority of the seven used in silos. The development and application of these KETs needs to take a more collaborative approach to circumvent some of the inadequacies and/or limitations that come with these tools.

4 Conclusion

The application of SCM in the shipbuilding industry revealed lean and digitalisation which improves efficiency in the SC. Through the adoption of lean tools such as multi-skill training, VSM and 5S, waste can be eliminated from the value chain leading to more efficiency. Moreover, the use of KETs, digitalisation in shipbuilding has allowed for modelling, simulation, and optimisation of shipbuilding processes such as design, manufacturing, and testing. Lean construction is broad in its application and numerous studies exist covering its application in modern construction. However, the lack of industry support or practice-related research on lean principles deters the industry's from modifying lean principles to best suit construction production. The barriers to lean are widely studied in literature, the focus on these barriers have not advanced beyond the stated challenges to potential solutions aimed at easing these barriers. Lean construction has a few barriers, however current lean application is focused on construction safety and neglects the possibility of waste elimination of the whole construction process. One noted barrier of lean and digitalisation is the cost of implementation. This is an opportunity for government as a policy maker and employer to create a platform where these initiatives are mandatory on flagships projects to promote contractors' acceptance of these cost-effective principles. The utilisation of VSM and 5S in well documented in construction literature but construction is yet to explore multi-skill training which when used in conjunction with VSM and 5S reduces project duration, workload balance and operating costs, a triangulation that has proven effective in shipbuilding. Digitalisation in construction is improving, but like lean most of the technologies identified are still exploratory in nature. Research on the use of digital tools is still vague and still at fact finding stage. The identified KETs in construction lack uniformity and collaboration unlike in shipbuilding where KETs are developed for the common goal of information sharing, teamwork, and effective collaboration. The common objective in these KETs offsets deficiencies of other technologies. The development of the KETs in construction is limited by lack of information privacy and security, which in shipbuilding is a technology developed to curb the challenges that arise from the use of technology. Digitalisation and lean in construction are seen as a management tool, limiting its application and overall influence on a construction site, especially in production.

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Evaluating the Effect of Land Use Management Processes on Property Development in the City of Johannesburg

Yamkela Fanisi(✉), Ockert Rudolf Pretorius, and George Okechukwu Onatu

Department of Town and Regional Planning, University of Johannesburg, Johannesburg, South Africa
yamkelafanisi@gmail.com, 219128701@student.uj.ac.za, {opretorius, gonatu}@uj.ac.za

Abstract. Land use management (LUM) regulates and governs land use with the aim of suitable development of the built environment. Property development is important for the economy of countries and cities as it supplies in residential and business needs, provides jobs and stimulaties several industries. The study identified the causes of challenges facing LUM processes in the city of Johannesburg (COJ), and possible interventions to alleviate the challenges. Key to this was understanding the role of LUM in facilitating property development, and determining the reasons for delays in the land use approval process. This study evaluated the effect LUM has in facilitating property development in the COJ, and assessed the application process. Furthermore, it determined the roles of the private and private sectors in the process, investigated challenges and their impacts, and made recommendations to improve the process. Qualitative research design and an interpretative paradigm was applied to understand LUM processes. The literature was studied, documents were analysed, and purposively sampled respondents were interviewed to gather data, which was analysed thematically. Suboptimal stakeholder management and insufficient communication by public and private-sector stakeholders cause delays in LUM applications, as do incompetent consultants/developers, lack of alignment of applications with policy, and incomplete applications. Furthermore, applications are done in series instead of parallel, stakeholders are bent on profiteering, interacting with city officials is fraught with problems, online submission systems are disfunctional, and public objections and specialist studies cause delays. The study recommends that collaboration between the COJ and the private sector must be explored, the process streamlined, bylaws simplified and staff trained. Developers must be encouraged to avoid submitting incomplete applications.

Keywords: City of Johannesburg · Land use management · Property development · Stakeholder engagement and submission challenges

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1 Introduction

Property development, often known as real estate sector, makes a substantial contribution to the stability of the nation's economy. According to the South African Property Owners Association (SAPOA), a number of industries, including manufacturing, retail, and business services, profit from property development. [15]. It is a labour-intensive industry, and employment creation is one of its other key advantages. A 2012 analysis of the property sector's contribution to the South African economy revealed that it was a significant driver of government income, employment, and economic growth. Land use management (LUM) is a legally necessary process that consists of rules that enable developers to achieve desirable and harmonious built environment development [2]. Additionally, LUM oversees the procedures for determining land use, creating new property, and regulating land operations [7]. LUM is necessary to facilitate organised, coordinated planning and development that is effective, and it should promote a healthy, harmonious, and welcoming built environment. Sustainability takes into account both the demands of the community and the development, and it should not overlook the preservation of the built environment's essence and historical significance.

The LUM's primary goal is to direct real estate sector spatial planning in order to promote economic, social, and environmental prosperity. LUM provides spatial standards for the planning of residential areas, public spaces, and commercial and industrial spaces. The competing interests of the public and private sectors must be balanced in this process. The public sector must aid in and direct urbanisation, sustainability, and revitalisation. Instead of being regulated, property development should be encouraged, supported, and directed in the correct direction. A increasing population necessitates more residential, commercial, and industrial uses and developments, which makes property development essential. The need to alter our cities and make them more socially (and economically) inclusive must be emphasised. Property development, which is carried out effectively and in accordance with correct principles to meet South Africa's developmental objectives, is a tool to help reach this goal. It is directed by spatial planning and LUM. LUM is crucial for a number of reasons, including social, economic, and environmental aspects.

2 Literature Review

2.1 Land Use Management in the City of Johannesburg

The land management plan for Johannesburg, like that of the majority of South African cities, was established during the apartheid era. As stated by [14], the totality still has to be examined. The methods and patterns of land development are remarkably similar to those of the apartheid era, despite the addition of some policy to the earlier canon. In order to respond to shifting demands from citizens and developers and to realise the goals and objectives of a post-apartheid society, the COJ and the Provincial Government of Gauteng have established additional policies. The Growth and Development Strategy, the Johannesburg Integrated Development Plan, the Human Development Strategy, Johannesburg 2030, and the regional spatial development frameworks are some of the policies that make up this group [14]. Only the most experienced specialists with a ton of expertise are able to get land and the approval that they need because land management systems have grown to be complicated [14]. As a result, the city is implementing a land regularisation initiative that aims to examine, verify, and transfer council-owned properties in underprivileged townships.

2.2 Significance of Land Use Management in the South African Context

This study examined the significance of LUM from an environmental, economic, and socio-spatial perspective. [6] suggests that LUM systems can be utilized as a tool to help South Africa create low-carbon cities. According to a report by the Sustainable Livelihoods Foundation [3], LUM formalisation in townships serves as a catalyst for the state to regulate business practices (to encourage competition and new entrants), ensure social standards are upheld, secure tax revenue, stop the production and distribution of illegal goods, and increase the possibilities for corporation boom through investment. [17] draw attention to the necessity of just socio-spatial planning, which calls for integrating planning to take into account social, environmental, and economic benefits, as a way to rectify the past.

By developing a more effective urban shape that supports sustainable transportation, by utilising more sustainable energy sources, and by carbon sequestering, LUM could help to reduce carbon emissions and promote environmental preservation [5] (Swilling et al., [18]). In order to assist township businesses and so support the economy and investment, LUM must be adaptable and inclusive. Workplaces, public areas, and private dwellings have become physically entwined and interdependent due to land pressure and organic township growth [4]. Entrepreneurs may have difficulty acquiring business permits, official credit, government aid, and contracts due to insufficient land use and zoning rights. Businesses may also face threats from municipalities and other public bodies if they do not follow land use restrictions. Municipalities utilise LUM to ensure that spatial planning is equitable, integrated, and in accordance with SPLUMA principles, which is of socio-spatial value. LUM has a long history of promoting health, safety, and sustainable development [1].

2.3 Land Use Management Challenges in Property Development

Development delays brought on by various application procedures also affect the proposed development's economic impact and may even negate any potential financial gains. When speaking with developers from the private sector, the [16] indicates, "It is often not direct project costs that causes project to fail but financial implications that are escalated due to time delays". These challanges have an impact on the property development industry, particularly financially. Potential local economic benefits from the property sector, such as business sales, contributions to the GDP, income, and employment prospects, are postponed [16]. This demonstrates how the property development industry is severely impacted by application procedure delays. The study's main objectives were to examine how LUM procedures affected property development, with a focus on the COJ, and to evaluate the entire application process. Based on the opportunities found, recommendations were made regarding policy revision, staffing changes, skill upgrades, staff experience, governance committee changes, and other variables.

3 Research Methodology

This is a qualitative study that uses conversational approaches to gather data. Open-ended questions are posed to participants, and their non-numerical responses were gathered. This approach aids a researcher in comprehending not only the participants' thoughts, but also the reasons behind such thoughts. Getting the opinions of public and private sector representatives on how they interpret LUM processes with regard to property development was essential to this research. These factors led to the qualitative approach being deemed appropriate for the study paradigm and purpose. Data was gathered for this study through primary and secondary sources, respectively. The systematic collection of information that reflects the viewpoints and experiences of particular participants or stakeholders is called evaluation. Interviews with chosen participants and stakeholders provided the primary data. The primary method of gathering data for this research project was conducting interviews, which were supplemented by gathering secondary material, such as relevant reports and policy documents. The researcher collects data created by people and organisations for documentary analysis, which provides background knowledge on the views and opinions of the pertinent stakeholders. For this study, these written sources could be policy documents and reports, both published and unpublished. Semi-structured individual interviews were used in this study. Both structured and unstructured interview techniques were used in this type of interview, which had certain benefits. The ability to ask both closed- and open-ended questions was essential to these benefits. All participants had similar interviews. In order to cover the same topics with each interviewee, the interviewer had an established set of pre-planned core questions that directed the path of the interview. The interviewee was given the chance to add more pertinent material as the interview went on. Every participant was subjected to a semi-structured interview by the researcher. One person is interviewed at a time, and the researcher only asks questions that she has prepared in advance. This kind of interview may take as long as 20 to 30 min to conduct.

The key informant strategy, which identifies one or a small number of people and invites them to provide direction for the study, serves as the primary example of this sampling technique. These informants are keen observers who ponder on their surroundings and are prepared to offer their expertise. For this study, which looked at the opinions and experiences of pertinent stakeholders in the public and private sectors, purposeful sampling was determined to be the best sampling approach. When conducting exploratory qualitative research, this knowledge may be needed to identify potential new areas of interest or to introduce potential participants. Participants in this study included public and private sector stakeholders in the LUM and property development fields. Regarding the stakeholders in the private sector, there were two associations relevant to planning and LUM: two respondents, private property developers: one respondent, and two COJ entities related to planning and LUM: four respondents for the stakeholders in the public sector. Since they engage in LUM processes, these representatives were specifically chosen. City officials decide whether to grant or deny requests for permission to develop a property using LUM procedures. The planning that must be done before development can begin is kept by one association, while interaction between the other association and the development-related processes makes the latter association relevant. Private developers in this context refer to businesses that exist to develop real estate, who do not hire consultants but have internal resources for making investments in real estate.

4 Findings and Discussion

According to SPLUMA, the public sector is responsible for maintaining LUM. Local municipalities are given the power by SPLUMA to manage and regulate land usage through IDPs, SDFs, and other rules and regulations. Most importantly, localities help LUM applications by using representatives. The study's findings are listed below.

a. **Public sector finding/public sector challenges**

Stage 1: Pre- consultation with municipality official:

Challenges: "Land development application processes has different important stages, prior the launching an application its crucial for one to begin with consulting the local municipality to determine what is permitted to be done where and how, this speaks to checking if the application is in harmony with the municipality's spatial development framework, and also if what document are required attached to the particular proposed application" [11].

- The difficulty people have understanding specified guidelines is occasionally brought on by consultants who are under qualified, experienced, and equipped.

Before submitting an application, it is necessary to seek guidelines and conduct preliminary consultation with the application procedure.

- Application that is not in line with city policy has negative effects. Guidelines and prescriptions for spatial planning are an example of places to visit. Applications must be in conformity with rules and regulations.

Stage 2: Submission of LUM application

Challenges: "There are various departments internal and external play a role, they tick boxes on the readiness of the development considering a manner of things such as services and infrastructure" [11].

- Applications that are incomplete because of missing paperwork. This delays things. Failure to obtain a power of attorney is one instance of this.
- Lack of technical innovation makes it difficult to submit applications through online portals and creates too much paper-based administrative work.

Stage 3: Public participation

Challenges: "The public is expected to give its comments after the application is submitted. This process encompasses advertising in community and local media houses such as local newspaper" [12].

- Public objections often result in application being referred to the Tribunal, which suffers from backlogs.

Stage 4: Application inspection

Challenges: "The public participation process allows the application to be inspected by the municipality to ensure that required documents are attached to the application, afterwards the application gets passed on to relevant internal and external departments for comments" [11]. Lack of infrastructure can create delays in development since it may prevent access to services, which would hinder progress.

Stage 5: Supplementary analysis required

Challenges: "In different cases, the departments require that the applicants conduct research with regards to the impact of proposed development before giving their comments. Resulting from public participation and application circulation process for departments' comments, are approvals or objections to the application" [13]. The intensity of the development may call for additional internal or external research to be conducted. The private sector frequently participates in the LUM application process as consultants, investors, and developers.

b. **Private sector findings/private sector challenges**

Stage 1: Pre- consultation with municipality official

Challenges: "The consultants, the lawyers, the town planners, everyone is making a living out of this process unnecessary, so we are all running around. At the end of the day probably the winners are consultants, the professionals who are running around being paid for this whilst if the system was simple the contractors and construction workers were going to get work. More than ever, we need development to happen soon so that we can get out of this Covid-19 situation" [8].

This increases the expense of development for the developer while also making it more accommodating to protesters, which lengthens the delays.

- Often the experienced professionals are not seen facilitating the development; private developers are often viewed as profiteers, since the longer the delay, the more they earn.

Stage 2: Submission of LUM application

Challenges: "The officials themselves are not available, especial now during Covid-19 pandemic to interact with them" [9].

- There seems to be little interaction between officials, making their accessibility difficult, therefore; needs improvement.
- Emails were not interactive enough for stakeholders.

Stage 3: Application inspection

Challenges: The public's concerns are seen as outweighing developers' interests, despite developers having complied with all applicable regulations and policy. "Council can have a policy that you can do residential development in a certain place but still there can be objectors though you have followed the policy 100%, In Germany if the RSDF says we approve student accommodation in this area there's no room to object, its only when the policy says in 100 houses and then you do 150 then public participation is required because you are outside the policy" [9].

- The application process is more time-consuming and labour-intensive than necessary due to the lack of personnel, especially industry experts.

"lots of vacancies and capacity is also one of the issues that affects the process, one example there are lot of similar situations where if one person doesn't respond things takes time and get delayed" [9].

- There is a shortage of skill and experience among certain senior staff. Sometimes employees leave the public sector in search of higher income. Due to inadequate management, non-compliance with the bylaws, and violations of the land use plans' restrictions, this causes extremely lengthy delays. "Sometimes there would be insufficient employees in certain departments, less experience there would not be enough managers for guidance" [10]. LUM application delays seriously affect a number of factors, including the economy, society, geography, and the environment.

5 Conclusion

Both the public and private sectors are involved in the LUM application process, with the former serving as a facilitator and the latter as the client (local government in this case) (COJ). If this aspect is thoroughly investigated, it seems that these issues have repercussions for the financial, social, political, and even environmental spheres. Concerning the private sector, difficulties were found in interacting with city officials (bureaucrats), processing applications in series rather than parallel, profiteering by consultants and other professionals rather than prioritising development. Furthermore, the municipality lacks experience and good management, has a dysfunctional online submission process, and has a developer-unfriendly process for public objections to developments. To ensure that the profession is protected, the public sector identified a need for planners in both the private and public sectors. By doing this, both sectors will face fewer challanges with relation to the convenience of application delays. Comprehensive proposals were provided by public and private sector representatives. This study has successfully identified the role of LUM in helping to facilitate property development, established the roles of private and public sectors in the application process, examined the challanges and/or success factors associated with the application process within LUM, demonstrated how the application process affects property development in the COJ, identified ways to improve LUM, and ensured critical infrastructure investment was not hampered.

In terms of recommendation, it is crucial that planners in the public and private sectors ensure that they conduct professionally and are thorough in their approach to submitting applications. The private sector must create comprehensive applications that are easy to grasp by public officials and are clear and unambiguous. Second, developers must be highly skilled and professional individuals. As a result, they will be working with knowledgeable professionals and not only those looking for high profit margins. In order to facilitate access to authorities and information and to produce a quick, dependable, and simple application process, collaborative approaches to applications should be used. These partnerships may include discussions and forums held by governmental officials and the private sector. Fourth, the LUM process should consist of a single, unified process rather than a disjointed, laborious series of processes. The policy and guidelines must be comprehensive and collaborative right from the beginning in order for the final result to be fully accepted and capable of driving progress without the need for follow-up consultation. Fifth, Land Use Schemes and bylaws need to be streamlined and simplified, and the personnel needs to be adequately trained to follow the legal deadlines. The procedures need to be managed correctly. Last but not least, it is crucial that the public and private sectors forge effective ties that will advance the LUM process for the benefit of all parties involved.

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Occupational Stressors Among Small and Medium Sized Enterprises in the Zambian Construction Industry: A Preliminary Study

Charles Poleni Mukumba(✉), Mohlomi Raliile, Kahilu Kajimo-Shakantu, and Theo Haupt

Faculty of Natural and Agricultural Sciences, University of the Free State, Bloemfontein, South Africa

poleni2000@yahoo.co.uk, KajimoShakantuK@ufs.ac.za

Abstract. Globally, SMEs have a major impact on the social and economic welfare of countries, as they constitute over 90% of the non-financial business economy and employ more than 60% of the working population. The construction industry is no exception with SMEs representing approximately 93.5% of all registered contractors with the National Council for Construction (NCC) in Zambia. However, compared to larger construction companies, SMEs in construction have limited human resources, limited financial resources, often undertake subcontracting work and business survival is their top priority. These challenges present distress among SME owners and their employees. Despite the prevalence of studies on physical injuries among SMEs, it remains unclear what occupational stressor SMEs are confronted with especially in developing countries. Therefore, the purpose of this study is to investigate the prevalence of occupational stress among SMEs in the Zambian construction industry. The study further investigates the level of awareness with occupational stress and mental ill-health, attitudes and perceptions as well as coping strategies. An extensive literature review on the topic was conducted and semi-structured interviews with Likert quantitative questionnaires based on literature were formulated to conduct a preliminary study on occupational stressors and mental health issues among SMEs in the Zambian construction industry. This preliminary study forms part of an ongoing empirical research. The findings of the study revealed that most SMEs are aware of the common mental health issues and burnout was the most well-known disorder. Furthermore, 53% of the respondents said that they were stressed at work. While stigma towards mental ill-health in the workplace was ranked the highest (60%). This study only focused on the Zambian construction industry and psychological stressors affecting managers.

Keywords: Occupational stress · Mental health · SMEs · Construction industry · Zambia · Coping

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1 Introduction

Small and Medium-sized Enterprises (SMEs) have a major impact on the socio-economic welfare of many countries [36]. SMEs represent more than 90% of the non-financial business economy and employ more than 60% of the workforce [21, 32, 36]. SMEs account for a disproportionately huge share of new jobs, especially in developed countries [32] and improving competitiveness of SMEs contributes to socio-economic developments, subsequently leading to poverty reduction [2, 40]. As a result, SMEs are described as job creators, and the foundation of big businesses, and the fuel for national economic growth [40]. Therefore, the performance of the SMEs sector is linked with the economic growth of any nation [2, 35].

SMEs dominate the construction industry in many developing countries [2]. In Zambia, SMEs represent about 92% of all registered contractors with the National Council for Construction (NCC) [30]. Majority of the SMEs are building contractors who are often confronted by high competition which results in difficulties securing ongoing contracts and subsequently, low capacity to operate [17]. Furthermore, majority of SME contractors in Zambia operate informally which makes it difficult for the government to support them efficiently (ibid). Adendorff et al. [1] contends that SMEs face numerous challenges when delivering projects, and this leads to poor project performance. Poor project performance happens due to unskilled workforce, poor health and safety measures, lack of financial resources and also the fact that SMEs in most instances undertake subcontracting work and business survival is their top priority [27]. Despite the fact that SMEs employ the majority of the workforce, they have fewer financial and human resources compared to larger companies [36].

Several current studies have revealed that psychosocial demands among SMEs are unique to those of large companies [13, 16]. The unique challenges faced by SME contractors cause distress among owners and employees of these companies [9]. Work-related psychosocial stress can cause mental and physical illnesses resulting in high costs for the individual, the economy and society [15]. According to the HSE (2021), stress, depression and anxiety are the second largest causes of occupational ill-health in the construction industry. Furthermore, [15] contents that mental ill-health, psycho-social risks and occupational stress are among the most challenging work-related health and safety issues for construction workers. Although it is widely accepted that stress and other mental ill-health affect the workforce in construction, it is also known that these difficulties are under reported and therefore, individual who are affected may not be accessing the much-needed support (ibid).

Despite the prevalence of studies on physical injuries among SMEs, it remains unclear what occupational stressors SMEs are facing, especially in developing countries. Therefore, the purpose of this study is to investigate the prevalence of occupational stress among SMEs in the Zambian construction industry. The study further investigates the level of awareness with occupational stress and mental ill-health, attitudes and perceptions as well as coping strategies. This study is based on the assumption that occupational stress aggravates mental health issues. Therefore, discussions about mental ill-health existing independently are beyond the scope of this study.

2 Literature

The issues of occupational stress have gained significant attention in recent years [28]. Occupational stress can be defined as the individuals' perception about the discrepancy between the environmental demands/stressors and individuals' abilities to satisfy these demands [3, 34, 39, 41, 42]. Occupational stress is a process that involves a transaction between an individual and the job environment [23]. Cooper and Marshall [11], indicated that negative environmental factors known as stressors associated with a specific task, determine occupational stress. Therefore, the occupational stress refers to the processes in which stressors could lead to physiological, behavioral or psychological manifestations of stress (strain), and subsequently result in negative health effects (ibid). Although there are several definitions for occupational stress, this study shall adopt the definition by Cox and Graffinths [12] who defined and conceptualized occupational stress as an individual's perspective and their interaction with the workplace.

Numerous studies have been published on the causes of occupational stress among the construction workforce and the issues have remained somewhat similar throughout the studies [4–8, 10, 18–20, 22, 24–26, 31, 37, 38, Molen (2000)]. The researchers have revealed that generally, adverse working conditions such as long hours working under pressure with tight deadlines, high levels of conflicts, low job control, lack of managerial support, job insecurity and lack of work-life balance are major causes of stress in the construction industry.

Clarke et al. [9] conducted a qualitative study and interviewed Small Medium Enterprises (SMEs) in the Irish construction industry about their attitudes and perspectives concerning mental health and wellbeing. Based on the understanding of the respondents, mental ill health was ascribed to feeling down, feeling alone, and being stressed. The respondents associated stress with worrying, negative thoughts and unhappiness. Furthermore, several respondents indicated that mental health and wellbeing were serious issues due to the nature of the industry. Some respondents alleged that the construction industry is more stressful compared to other industries. Major stressors linked to mental health issues were attributed to late payment by clients which led to cash-flow issues and also, long working hours. However, commuting time ranked lowest. Participants further revealed that the temporary nature of construction projects in another major stressor and often, contractors relied on hearsay and their reputation to secure future projects. It was however noted that none of the respondents had any procurement strategies for work and therefore, were not being proactive in reducing stress because of future uncertainties about securing other projects upon completion of current projects. Further research in this area is required to identify the effects of not having procurement strategies on mental health of the workforce especially among SMEs (ibid).

Similarly, according to reports by ECA [14], 37% of SMEs across all industry sectors are experiencing mental ill-health and the causes are attributed to unfair payment practices. Overall, 71% of SMEs across the entire economy are paid late. The worst affected sectors were legal (90%) and construction (82%) sectors. Late payments, unfair payment practices including; mid-contractual changes, withholding of a proportion of monies due (retentions) and fees for being paid within the correct timeframe are paramount issues among SMEs.

3 Methodology

An extensive literature review on the topic was conducted and semi-structured interviews based on literature were formulated to conduct a preliminary study on occupational stressors and mental health issues among SMEs in the Zambian construction industry. For this qualitative study, data were collected among grade 4 and grade 5 contractors registered with the National Council for Construction (NCC). The study focused on grade 4 and grade 5 contractors. Although grade 6 contractors rank the lowest in the NCC grading, they were excluded from the study because most operate informally and the registration requirements do not compel owners to have obtained any formal training in construction [30]. The questionnaire was divided into 6 constructs covering Knowledge about mental health, Stress, Attitudes, Stigma, Coping and Interventions. The interviews were conducted on 15 participants each taking between 15 and 20 min. The interviewees were mostly management personnel employed by contractors with work experience ranging from 3 to 25 years.

4 Results

Knowledge about mental health

Participants were given a list of common mental health diseases and asked to rate their level of knowledge on a 5-point Likert scale. The diseases were depression, stress, anxiety, burnout, insomnia/sleeplessness and panic disorder. The results showed that most of the participants had knowledge about burnout, depression, stress, anxiety and panic disorder. However, few of the participants seemed to lack understand about insomnia/sleeplessness. It is not clear why since sleeplessness/sleeping disorder ranks among the most common problems leading to stress/mental health in most studies [29, 33, 38]. Burnout was the most known mental disorder among the participants. However, further studies about the extent of knowledge are necessary.

Stress

The interviewees were asked whether their job was stressful. Results revealed that 40% of the participants agreed that their job was stressful while 46% of the respondents said that their job was not stressful and the remaining 14% were neutral. Furthermore, respondents were asked if they were stressed at work. The findings revealed that 53% of the participants agreed to being stressed at work while, 20% indicated that they were not stressed. About 27% were neutral. With regards to the most stressful aspect of their jobs, respondents were asked "what is the most stressful part of your job?". Most of them said that "..too much workload is the most stressful aspect of my job…", others said "..demand to meeting deadlines…" while others said that "…working long hours is the most stressful aspects of my job…". Participants were asked "what worries you most about your job?". Results indicated that most of the participant said that "…my job is temporary and it has no job security…" while others said that "…my salary delays and this affects my household responsibility as a breadwinner in my household…" while others said that "..my salary is too low to meet my needs…". Further results indicated that since their works are 'piece-jobs', and it is the most worrying part of their job.

Stigma

The respondents were asked "…is there stigma against mental health problems at your workplace?". Most of the respondents (60%) had agreed that there is stigma against mental ill-health at work. The most common response was "yes there is stigma in the workplace". Additionally, the respondents had indicated that people would judge them at work if they had a mental problem. Although it is unclear why the respondents indicated that they would be judged about mental ill-health, the findings are in line with other studies [9, 15, 38]. Ellis et al. [15] contents that stigma prevents construction workers from getting the necessary help in relation to mental ill-health.

Coping

The interviewees were further, asked about their coping strategies for relieving stress. Being with family was the primary coping strategy. This was followed by sleeping, undertaking sporting activities/exercises, social drinking, smoking and recreational drugs such as cannabis.

Intervention strategies for to address suicidal thoughts, stress and mental issues at work

With regards to what the respondents would they do if someone expressed suicidal thoughts, most respondents (46%) recommend professional counselling. Another 40% suggested talking to someone helps, while the remaining 14% of the respondents indicated that they would refer the person for spiritual counselling. Furthermore, participants were asked to what they think should be done to address stress and mental issues at work. All the interviewed respondents indicated that there was need to talk and educate workers about stress and mental issues at work.

5 Discussion and Conclusion

The results show that most of the respondents are aware of stress and mental ill-health, although the awareness of anxiety, panic and insomnia/sleeplessness is low among the SMEs in the Zambian construction industry. The awareness of the respondents on occupational stress and mental ill-health gives a good indication as the owners of the SMEs are in a position to put in measures that would lessen the causes of mental stress on the workers. However, it is worrisome to note that a very low percentage of the respondents are aware of mental health diseases such as anxiety, panic and insomnia/sleeplessness. This may cause serious repercussions on both the workers and SME firms as this may result in negative health for the workers and low productivity for the firms. Awareness levels of prominent mental health diseases can be brought to the attention of the workers through education. This has been suggested by the results which have shown that all the respondents indicated the need for mental ill-health education at their places of work. Education about mental health diseases will increase workers' awareness and make them know what strategies to employ to avoid and cope with mental ill stressors.

The findings further reveal that the most prevalent mental ill-health diseases among SMEs in the Zambian construction industry are stress and burnout. The results are suggestive of the much workload, the demand to meet deadlines and working long hours.

These findings of the study show that there is little attention paid to the management of the mental ill-health within the industry [15]. Moreover, most of the SME contractors are not ready to address mental ill-health due to several factors such as struggling for business survival suggestive by the workers' responses in relation to low wages and sometimes late payments, long working hours to ensure completion of works and also, workers indicated the lack of mental health education in the workplace.

Mental ill-health does not only affect workers and SME contractors, but the construction industry and the economy at large [35]. As such, there is a need for SMEs to pay attention to addressing the issues surrounding mental ill health (ibid). According to the SMEs, an immediate intervention to address mental ill-health is to introduce mental ill-health education in the at workplace and to promote a positive culture which encourages seeking counselling.

This preliminary study provides an insight into the prevalence of occupational stress among SMEs in the Zambian construction industry. The study further investigated the level of awareness with occupational stress and mental ill-health, attitudes and perceptions as well as coping strategies. This study forms part of an ongoing empirical research and only grades 4 and grade 5 contractors were contacted. Furthermore, based on the qualitative nature of the study and the sample size, the findings of this study may not be generalized. Some of the issues addressed in the study need further investigation to gainer deeper understanding.

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Upshots of Flood Prevalence on Ala River Basin and Connecting Neighbourhood in Akure, Ondo State of Nigeria

Julius Oluranti Owoeye(✉) and Fayokemi Sarah Abe

Department of Urban and Regional Planning, School of Environmental Technology, Federal University of Technology Akure, Akure, Ondo State, Nigeria
joowoeye@futa.edu.ng

Abstract. This research investigates the upshots of flood prevalence on residents along Ala Riverfront and its connecting neighbourhood in Akure, Nigeria. One percent (1%) of the 26,525 total populations at 40 m buffer on both sides of the river on a mainland of 110 km^2 was served with 265 questionnaires, using simple random sampling technique. Specifically, variables including lives lost, properties damaged and disease outbreak were examined to determine the intensity of flood prevalence in the study area. Data obtained were analyzed using descriptive statistics, area mapping and photo-snaps to illustrate the observation made during field survey. The results posed serious threats to the general welfare of people in the study area as it revealed huge loss of lives and properties, and outbreak of diseases like cholera, dysentery, malaria, among others. The study, therefore, recommends regular sensitization on the dangers of erecting structures near river banks as a measure to inhibit the major cause of flood prevalence in the area. Besides, the state government was advised to provide engineering and technical solutions that can mitigate the menace of incessant floods prevalence in the area. Regular clean-up of drainages should be done to ensuring free flow of water while dredging of waterway will arouse its absorptive aptitude during heavy downpours. Also, adequate disposal facilities should be provided to impede the crude wastes disposal into drainages and water channels which in turn will curb the problem of regular outbreak of diseases in the study area.

Keywords: Absorptive capacity · Connecting neighbourhood · Flood prevalence · Watercourse dredging

1 Introduction and Background to the Study

Merriam Webster Dictionary (2012) define flood as inundating of dry lands with water. It is a common experience in flood plain areas across several nations. Although, it occurs differently; sometimes, it can be a sudden event or may take days or months before it subsides. Whichever form it takes, it has effects on both socio-economic life of individuals and environmental condition in each contiguous community. The upshot of flooding generally can be negative or positive depending on the location, intensity,

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level of vulnerability and value of the environments affected. According to Suleiman et al. (2014), flooding is mostly instigated by high precipitation rate, reservoir failure, melting of snow and glaciers. They associated flood risk with a number of factors like rainfall intensity, river flow and tidal surge data, topography, flood control measures and changes occasioned by new development and construction of buildings on flood plain areas.

In Nigeria, flooding is an annual occurrence with notable effects; especially, with the populations located around dammed rivers in the North and Niger-Delta regions. [6] observed rainfall as the major cause of flooding in Niger-Delta area. In the history of Nigeria, the most devastating flood occurrence was experienced in the year 2012 [15]. From past researches, record shows that more than 2.3 million people were displaced, 363 lives were lost and 16 million people were adversely affected in one way or the other [7, 8, 10]. [14] estimated total losses at US$16.9 billion. In view of flood cases experienced in Nigeria, this study was set to address the following questions with particular reference to Ala River Basin in Akure: (i) what are the areas vulnerable to flood risk in the river basin? (ii) What are factors responsible for incessant flooding prevalence in the area? (iii) What are the immediate and remote effects on residents and the environment? Findings from the study are expected to offer possible mitigation measures that can be adopted in curtailing the menace in the study area.

2 Literature Underpinning the Study

Flooding has become the most challenging natural disasters in urban environment that most countries of the world are presently contending with; especially, in developing nations. Studies revealed that annual losses attributed to flooding are enormous when compared to other natural disasters suffered [5]. Thus, the study adopts the concept of vulnerability to illustrate "cause and effect" of flood prevalence in Ala river basin. This concept explains natural and human-induce factors that usually instigate flood prevalence or make an area susceptible to damaging effects of flood hazard. According to [16], vulnerability emanates from social and physical conditions that instigate parts of urban system to be susceptible to flood actions. Also, Fuzzy Logic Approach was adopted to assess the level of vulnerability. This was used by [18] to appraise flood vulnerability catalogs of urban watershed in Iran using fuzzy rule-based method. The result helped them in selecting six indicators that specify areas vulnerable to flooding based on the prevailing socio-economic factors, physical exposure and susceptibility level.

Cases of severe flood prevalence abound in different parts of the world; developed and developing nations alike. For instance, overwhelming flood prevalence occurred between December 2010 and January 2011 in Queensland, Australia. Findings obtained from this menace, as documented in Queensland Floods Commission of Inquiry [11], showed that 78% of the populations were severely affected with death record of thirty-three (33) persons. The report further revealed that 48 flood cases occurred in Australia between 1980 and 2010 out of the total number of 162 natural disasters recorded. The 2010/2011 floods in Queensland were the most devastating flood disaster in the history of Australia with the total economic losses amounted to US$7.3 billion [3]. To mitigate this, Australia government innovated management policies, which included early warning signs erected in vulnerable flood zones as well as sensitization and restraining residents from risk activities [4]. These strategies have proved effective to check flood prevalence in Australia over the years.

Developing countries like Egypt in North-Eastern Africa also had its own fair share of flood disaster. [13] Acknowledged that Egypt suffered from ostentatious flooding, which is difficult to predict and control. Although, floods have been beneficial to Egypt in the area of agricultural production, nonetheless, it has continued to suffer its varying forms of negative impacts. According to the Red Cross Crescent [12], Egypt experienced nine different flood incidences between 1980 and 2010 with death record of, at least, 74 lives in each event; 17,000 people were affected and 3,648 families left homeless. A total number of 4,000 houses were destroyed, which further exacerbate the damage to the country's economy. In view of this, Egypt advanced more sophisticated method of predicting flood occurrence, including early warning system (Cools et al., 2012). This facilitated effective response to flood occurrence. Besides, [13] posited the use of Global Satellite Mapping (GSM) of precipitation which has aided the prediction of ostentatious flood effects in Egypt. Generally, GSM can be useful in feigning the likelihood of precipitation resulting in floods since it works in predicting weather condition and intensity of the precipitation.

In Nigeria, flood upshots are obvious from available records that irretrievable mayhems have been incurred from flood incidences, which have become a recurrent natural disaster in major cities in the country. Apart from building collapse; school premises, bridges and several markets were inundated for weeks and occasionally eroded by floods [7]. Devastating upshots of floods are not limited to houses and people. Many arable lands and agro-forestry are washed away while animals' lives are lost to flooding and many electric poles are destroyed [10]. The case of flood prevalence in the study area is not different from these scenarios as stressed in the work of [9]. Observations made in their study show that floods do not only damage properties and endanger lives of humans; it also engenders the outbreak of diseases as clearly observed in this study.

3 Materials and Methods

3.1 The Research Setting

Research location for this study is Akure, in South-western Nigeria with particular focus on Ala River Basin. The basin consists of riverfront residential areas, occupying 40m buffer on both sides of the river on a mainland of 110 km^2; located from latitudes 7° 14′ N – 7° 19′ N of the equator and longitudes 5° 8′ E - 5° 16′ E of the Greenwich Meridians [10]. Largely, Akure is located within the tropical rain forest with yearly high rainfall in about 8 to 9 months. It is the capital city of Ondo State and administrative headquarter of Akure South Local Government which had expedited its growth. Ala is a major river that drains the city with a total spatial coverage of about 57 km, flowing across regional boundaries from Akure through Oba-Ile to Edo State [1]. This is well explicated in Figs. 1 and 2. However, this study is limited to the river basin and its connecting residential neighbourhood; comprising of Oke-Ijebu, Isolo, Ehin-Ala/Ologede, Oba-Ile, and Alagbaka Extension II as clearly epitomized in Fig. 3.

With rapid increase in population and physical development of the city, the floodplain along the River basin has been greatly affected. For instance, lands at the river border had witnessed massive invasion for physical developments. The consequence of this invasion into the wetland area of the river has always manifested in recurrent flood discharge into the living environment and dislodgment of residents in this area at the peak of every rainy season. [9] and [10] case studies on the study area revealed huge loss of properties worth billions of naira and loss of lives suffered annually by different neighbourhood connecting to this river.

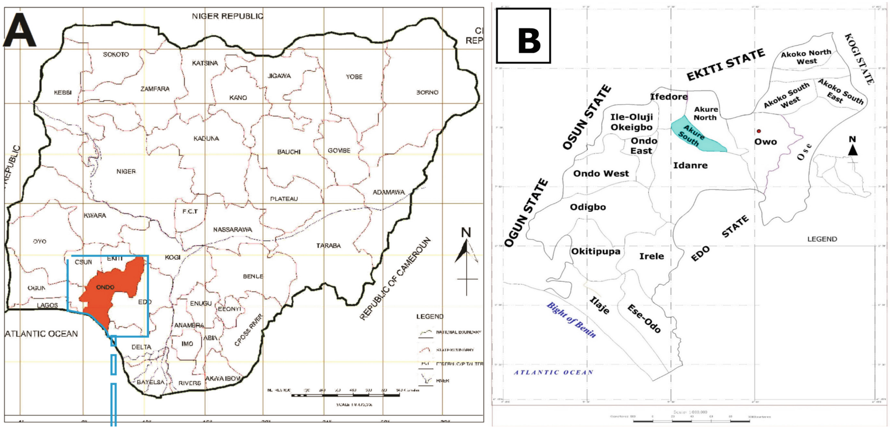

Fig. 1. a Ondo State in the National setting. Source: Ondo State MPPUD (2019), b Akure South LGA in State context. Source: Ondo State MPPUD (2019)

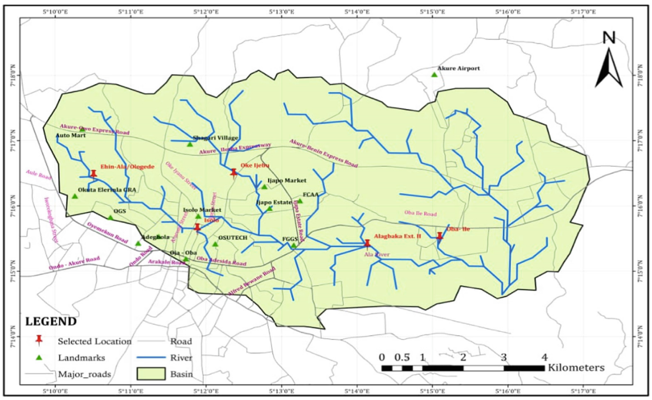

Fig. 2. The study area (Ala River Basin) showing the River course and its tributaries. Source: Shuttle Radar Topography Mission (SRTM) Imagery (ArcGIS, 2019)

3.2 Research Databank

For the purpose of data collection, building demographic survey of the research locale was carried out using GIS digitized Google Earth Imagery device to arrive at 1061 buildings. The Ondo State Bureau of Statistics (ODSBS, 2012) estimated average household size in Akure urban and other major cities in the state at five persons per family (5 ppf) and five households per building (5 hpb). This was used in estimating the research population of the study area at 26,525 from which a 1% (265 persons) of the estimated population was taken as sample size, using simple random sampling. This was considered practically reasonable considering the homogeneous status of residents in the study area in terms of physical morphology, socio-economic status and cultural background of residents. Meanwhile, a questionnaire was nullified due to mutilations, leaving 264 for the analysis. The interpretation was done with the aid of descriptive statistics, area mapping and photograph snapping to illustrate prevailing condition in the study area.

4 Results and Presentation of Findings

Result of findings on the upshots of flood prevalence in Ala riverfront residential area in Akure is presented logically with a view to address research questions set for the study:

4.1 Mapping of Zones Vulnerable to Flood Prevalence in Ala River Basin

Figure 3 is a flood vulnerability map generated via Shuttle Radar Topography Mission (SRTM) Imagery which classifies the study area into high, medium and low vulnerability. Places with high drainage density are classified as highly vulnerable to flood while other areas that are less affected because of their distances from the main river course are classified as medium and low vulnerable areas. As shown in the figure, areas mainly affected include Ehin-Ala/Ologede, Oke-Ijebu and Isolo communities. The drainage system of the study area, shown in Fig. 4, was also generated from the SRTM Imagery using hydrological analysis tool in ArcGIS. It reveals poor state of drainage pattern in the study area, as not having requisite capacity to absorb large volume of water often generated during heavy downpour.

4.2 Factors Responsible for Incessant Flooding in Ala River Basin

A number of factors are found responsible for flood prevalence in Ala riverfront residential neighborhood in Akure ranging from poor drainage system to crude methods of waste disposal and socio-cultural lifestyles of residents. As shown in Fig. 4, the drainage system in the study area is very narrow and inadequate to accommodate the passage of sufficient surface run-off of water during rainfall, which often result in frequent prevalence of flooding in the area. This expresses the need of adequate channelization of drainage system to accomodate the volume of run-off generated during rainfalls. Areas with high drainage density should be provided with effective drainage system that can allow the free flow of water. Figure 5 shows typical condition of drainage system in most parts of the study area.

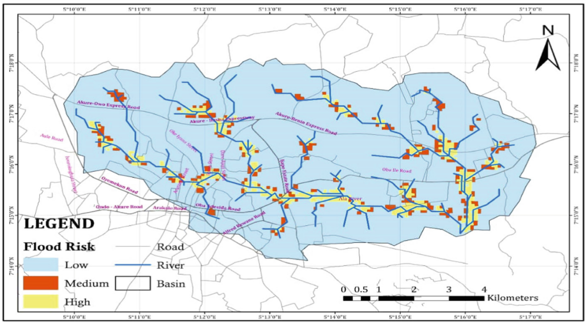

Fig. 3. Flood vulnerability Map of Ala River Basin. Source: Shuttle Radar Topography Mission (SRTM) Imagery (ArcGIS, 2019)

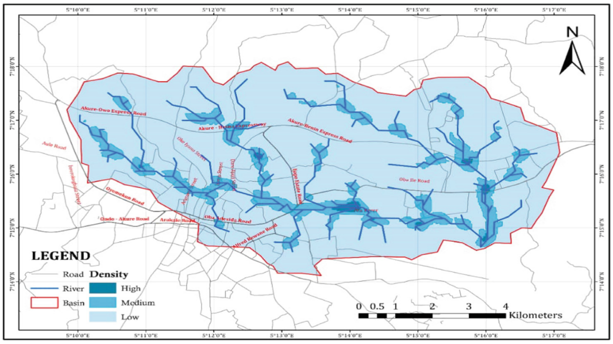

Fig. 4. Map showing drainage system in Ala River Basin. Source: Shuttle Radar Topography Mission (SRTM) Imagery (ArcGIS, 2019)

Fig. 5. Typical drainage pattern at Ehin-Ala/Ologede area. Source: Field Survey (2019)

Human induced factors that play prominent role in instigating ceaseless flooding in the study area include, most essentially, building of structures closer to the river banks and regular deposit of solid wastes into river channels which often cause blockage to free flow of water during rainfalls. As depicted in Fig. 6, it is clear that 70% of the respondents build their houses closer to the river banks; they failed to observe the minimum 30m setback from the river bank. Hence, closeness of buildings to river banks increases vulnerability to regular flood prevalence. No doubt, as urban populace rises, the poor are pushed into the friable land-areas that are well disposed to flooding thereby making them more susceptible. Figure 7 shows the upshot of regular practice of waste deposits into river channels as a potent factor that cause flood incidences in the study area.

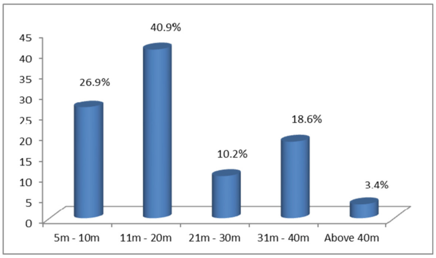

Fig. 6. Building location from river banks. Source: Field survey (2019)

Fig. 7. Blockage of water channel with refuse. Source: Field Survey (2019)

4.3 Immediate and Remote Effects of Flooding on Residents and the Environment

Table 1 displays the upshots of flooding on residential neighbourhood in the study area. A total of 26.5% of respondents opined that the main adverse effect of flooding on residents is building collapse wherein water covers some buildings with flood for long period and for many days. Sinking of buildings takes 9.8%, blocking of access roads constitutes 0.8%, loss of lives and properties takes another 54.2%. Other effects of flooding like destruction of crops constitute 1.1%.

As seen in the table, lives and properties along Ala River are not safe, which is in agreement with findings of [9], who posited that the unsafe condition of lives and properties along Ala river in Akure has been an issue of major concern to individuals and governments. According to them, properties worth billions of naira are damaged yearly. Generally, from observation, rainy season is worse period for people living in this area as residential buildings and business premises are submerged making life unbearable and awkward for the residents.

Table 1. Analysis of flood effects on residents in the study area.

Variables	Frequency	Percent
Building collapse	70	26.5
Sinking of building	26	9.8
Building inundated for days	16	6.1
Blockage of access roads	2	0.8
Loss of lives and properties	143	54.2
Others	3	1.1
No response	4	1.5
Total	264	100.0

Source: Field survey (2019)

In reality, Akure does not possess the type of excessive rainfall regime that could cause frequent flooding, yet the city is one of the most frequently flooded non-coastal cities in Nigeria; often ravaged by flood waters of swollen rivers and streams. In the recent time, so many people were rendered homeless and properties worth millions of naira damaged. This has led to physical, economic and social effects on its residents. Figures 8, 9 and 10 show pictures of flood victims of regular water inundation in residential premises during heavy downpour, leading to loss of lives and properties.

Fig. 8. Picture of flood victims. Source: Field survey (2019)

Aside physical damage, flooding is perceived as cause of some water borne diseases like cholera, dysentery, amoebiasis, schistosomiasis among others. These are commonly experienced in most southwestern cities in Nigeria where flood disasters are prevalent [2]. According to World health organization [17], diarrhea disease alone amounts to an estimated 3.6% of the total daily global burden of disease and it is responsible for the deaths of 1.5 million people every year. As shown in Table 2, diarrhea cases in the study area accounts for 34.1% while a total of 25% believes that flooding increases the rate at which resident in the study area are prone to cholera, malaria disease (24.6%), tuberculosis (9.1%) and 7.2% gives no response on the effect of flooding on residents.

Fig. 9. House submerged by flood. Source: Field survey (2019)

Fig. 10. Inundating drainages that caused water overflow during heavy rainfall at Ojaoshodi area. Source: [10]

This report conforms to the findings of [9], where they lamented that floods do not only damage properties and endanger lives of human and animals but also produce other secondary effects, especially, the outbreak of diseases like diarrhea, cholera and malaria. From Table 2, water borne diseases are mostly rampant in the study area, which has significantly affected the general health condition of residents in the study area since some of them make use of this water to perform household chores. Also, waste disposal into the river channel increases their vulnerability to water borne diseases.

4.4 Conclusion and Policy Recommendations

Flooding has inflicted much injury on residents of Ala river contiguous communities in terms of loss of lives and properties, as well as health hazards brought about by flood prevalence. Therefore, there is need for concerted efforts of all stakeholders to collaborate with relevant professionals in environmental and urban studies in combating the long raging effects of flooding in the study area. In view of this, some policy recommendations are proffered with a view to mitigating the upshots of flood prevalence in Ala River basin. Firstly, the study recommends construction of dams along Ala river course to control water discharge from the basin. This can be supported with building of embankments to raise the height of the river bank to check the overflow. Also, the construction of artificial lake that will serve as collector of large volume of water discharged from watersheds

Table 2. Prevalent diseases in Ala River Basin

Variables	Frequency	Percent
Diarrhea	90	34.1
Cholera	66	25.0
Tuberculosis	24	9.1
Malaria	65	24.6
No response	19	7.2
Total	264	100.0

Source: Field Survey (2019)

that lead to the river basin. This will be a noble innovation to check flood prevalence in the area, which could also be used for urban agricultural practice around the study area in the form of sustainable irrigated farming and fish production. Furthermore, the study suggests afforestation method wherein trees are planted near the river course. In recent urban studies, this is a fairly low-cost option that will enhance the environmental quality of the drainage basin and serve as interception of rainwater to lowering river discharges. Generally, the residents need adequate sensitization efforts to educate them on dangers of living in flood-risk zones, erecting of structures closer to the river bank as well as dumping of wastes into the river course and drainages. Regular clean-up of drainages by the residents should be encouraged; particularly, during the monthly environmental sanitation that is normally observed on last Saturday of the month. Finally, efficient waste disposal method should be provided as hygienic mode to curtail indiscriminate waste disposal that foster the outbreak of diseases in the study area.

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Appraisal of Locational Impacts of Akure Shopping Mall on Connecting Environments

Temitope Akinbode, Oluranti Owoeye(✉), and Adeola Oshikoya

Department of Urban & Regional Planning, School of Environmental Technology, Federal University of Technology Akure, Akure, Nigeria
{takinbode,joowoeye}@futa.edu.ng

Abstract. Shopping malls are a modern style of shopping center, rapidly taking the place of traditional shopping streets. Though the purpose of malls is for shopping, people also visit for eating, leisure, sightseeing, and socializing. As desirable and beneficial as shopping malls are to humans, the development often brings about negative impacts that can have disastrous implications on surrounding areas and adjoining land uses when there is a lack of proper planning. In view of this, the study examined the locational impacts of Akure Shopping Mall on the adjoining land uses. It adopts Survey Research Design (SRD) using primary and secondary data analysis. The primary data were acquired through reconnaissance surveys and well-structured questionnaires, while the secondary data were obtained from journals, books, and the internet. Statistical Packages for Social Sciences (SPSS) was employed to analyze the data. The study revealed that the mall contributed significantly to the surrounding areas. It also revealed changing land use around the study area over the years due to the existence of the mall. There is an influx of commercial centers in form of small-scale businesses around the mall. It also increases traffic congestion, noise pollution, and the development of unplanned small-scale businesses around the mall. Hence, proper planning for the location of small-scale businesses and enforcement of appropriate transportation regulations among others were recommended to aid policy formulation towards the physical planning of the area.

Keywords: Connecting environment · Location impacts · Shopping mall · Small-scale businesses

1 Introduction

A shopping center is a group of retail establishments, planned, developed, and managed as a unit, owned by one individual or a corporation provided with off-street parking space and generally located in an outlying or suburban area [16]. While Shopping malls are a modern style of the shopping center, rapidly taking the place of traditional shopping streets. Shopping malls are typically known to be indoor shopping centers, though some have outdoor areas with the shops having their own indoor space [15]. As good and beneficial as Shopping malls are to humans, their development often brings about various negative impacts, some of which include job displacement, pollution, traffic congestion,

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increased population in the adjoining areas, etc. Malls are big energy consumers and as a result, generate greenhouse gases. They are also known to be generators of various kinds of pollution on the environment. Examples of this pollution are plastic waste, air pollution from the exhaust of the power generating set and cooking furnace, noise from traffic and sound systems within the mall among others. The development of malls also leads to overpopulation of the adjoining area [1].

The physical environment is the aspect that is most visibly affected by the development of shopping centers. It is a generally accepted norm that larger shopping centers tend to attract a more economically active population and can sometimes rejuvenate or gentrify a neighborhood [2]. It is on this background that this study finds out the planning implication of the Akure shopping mall on the residents of the adjoining environment with a bid to enlighten the public on the implications of living close to the shopping mall.

2 Literature Review

The shopping center had its origin in the 1920s and has been in existence for more than 1000 years in forms of ancient market squares, bazaars and commercial districts at seaports [6]. Shopping centers have continued to serve the social and economic needs of the community where it is located with a combination of fashion, foods, entertainment and services. Present day shopping malls offer varieties of activities to users, like fast-food courts, restaurants, video arcades, movie theatres, beauty salons, dental clinics and more. [7], pointed out some different types of shopping malls such as convenience shopping mall, neighborhood shopping mall, community shopping mall, regional shopping mall and super-regional shopping mall. Shopping malls have turned into social centers and recreational and entertainment facilities for various activities and are characterized as venues that provide a comfortable shopping experience [9]. Customers visit shopping malls not only for searching for particular products, but they also view these visits as leisure and entertainment activity that provides fun and pleasure especially after work and during holidays [8].

In Nigeria, Shopping mall has grown from just a handful in the 90s to over 30 in the 21st century [2]. The development of shopping malls has changed the landscape of several cities in Nigeria. The emergence of malls and mall culture in Nigeria reflects broad trends on the continent, including a growing middle class with spending power and the rapid expansion of cities like Akure that are little known outside the region.

Shopping malls have become an integral part of the built environment in Nigeria, in many cases causing marked socio-economic and environmental effects, both positive and negative (Iroham et al., 2019). In Nigeria, the larger shopping centers attract a significant number of shoppers to an area which creates an influx of traffic. With the influx of traffic, improvement to road infrastructure is required to cater for the additional traffic flow which often times are not. The larger the center, the greater the need for the improvement of infrastructure to accommodate the increase in traffic. At the same time, Shopping Mall in Nigeria can be one of the biggest culprits when it comes to the consumption of electricity, waste and noise pollution, and carbon emissions, congestion among others [10].

3 Materials and Method

3.1 Research Location

Akure is one of the notable towns in the old Western Region in Nigeria, located within latitude 7° 15′ and 7° 15′ north of the Equator and longitude 5° 14′ and 5° 15′ east of the Greenwich Meridian. It is the administrative headquarter of the Akure South LGA and the capital of Ondo State, Nigeria. The State is bounded in the north by Ekiti/Kogi States, in the east by Edo State, in the west by Osun and Ogun States, and in the south by the Atlantic Ocean.

Fig. 1. Ondo State in the National context. *Source: Ministry of Physical Planning and Urban Development, Akure (2021)*

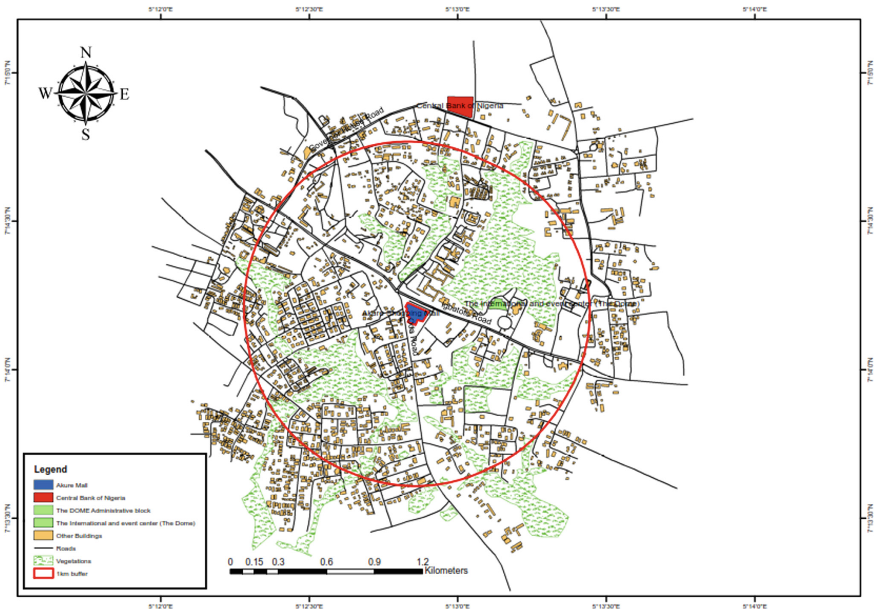

Fig. 2. Locational Map of Akure Shopping Mall. *Source: Google Earth Imagery Digitized by Authors (2022)*

The population of Akure as at 2021 is given as 691,000, which is in accordance with the UN-World Population Prospects (2021). The rapid increase in annual population growth resulted from its administrative and long-standing roles as center of economic activities which keeps attracting a large number of immigrants [4]. Akure mall is located in the southern part of the city and was opened in 2015. It has a let-able area of 10,000 m^2 located on a total land area of 2,6491 m^2 containing over 60 shops within. Figures 1 and 2 express the study location in both the nation and local context.

3.2 Research Database

This research adopts descriptive approach to identify its research problem and obtain data for the locational impacts of Akure Shopping Mall in Akure South LGA of Ondo State. The study dwells on secondary sources of data. The research population was a product of the number of buildings and the average household size in Nigeria, which is 4, based on the National Population Census (2006). House survey was conducted within a 1 km radius from the shopping mall (using ArcMap 10.5) to give a total of 2152. Thus, the total population was estimated at 8,608. According to [5] and [11], larger populations permit a smaller sampling ratio for an equally good sample, because as the population size grows, the returns in accuracy for sample size shrinks. In view of this, 10% of the total 2,152 houses within a 1 km radius from the shopping mall were selected randomly for this research. This accounted for the 215 questionnaires distributed to one household head in each of the residential buildings selected for questionnaire administration. Data obtained from this were supplemented with direct observations and personal interactions with residents. Relevant maps were obtained from Google Earth and Ondo State Ministry of Physical Planning and Urban Development. Data analysis was done with the aid of Microsoft Excel, IBM SPSS 26 and ArcMap 10.5.

4 Results and Discussion

4.1 Age Distribution of Respondents

Age distribution of any population is characterized by dependent and independent age range, which is the active and inactive age range. Age distribution of respondents, as shown in Fig. 3, shows that majority of the respondents are within 46 years and above, representing 85.1%. This is an indication of a population who are in the latter part of their working age. The implication of this, in case of any environmental disaster, is that it may easily lead to terminal health challenges like hypertension, stroke, etc. or early death of the victims since this age group is very sensitive to environmental changes due to low immune system to some ailments (Fig. 4).

4.2 Level of Education of Respondents

Almost half of the total sample population (45.12%) had tertiary education, 24.65% with post-tertiary education while 20% and 10.23% had only secondary and primary education respectively. The inference drawn from this is that a larger percentage of the populace are literate with formal education. This is an indication that the residents are well informed on the benefits of living in a serene environment.

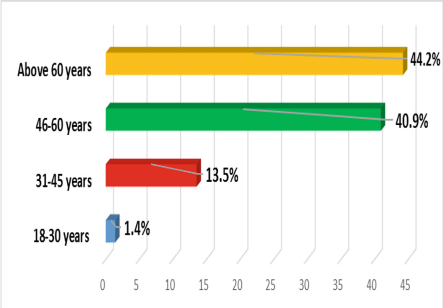

Fig. 3. Age of respondents. ***Source:*** *Field Work (2021)*

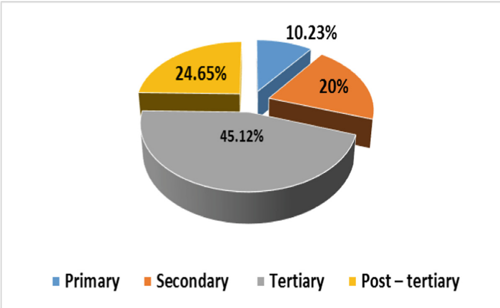

Fig. 4. Level of education of respondents. ***Source:*** *Field Work (2021)*

4.3 Household Size

Research findings show that over half of the total sampled population (51.16%) has a household size of 4–6, while 25.58% of the total sampled population has a household size of 1–3, and lastly 23.26% have a household size of above 6. The most common household size conforms to Nigeria's average household size, which are 5 (Tables 1 and 2).

Table 1. The household size of respondents

Household size	Frequency	Percentage (%)
1–3	55	25.58
4–6	110	51.16
Above 6	50	23.26
Total	215	100.00

Source: *Field Work (2021)*

Table 2. Income level of respondents

Monthly Income	Frequency	Percentage (%)
Below 30,000	24	11.16
30,000–60,000	35	16.28
61,000–100,000	70	32.56
Above 100,000	86	40.00
Total	215	100.00

Source: *Field Work (2021)*

4.4 Income Level

According to the field survey carried out, the table below shows that 11.16% of the population earn below 30,000, 16.28% earned between 30,000 to 60,000 while 32.56% and 40% earn between 61,000 to 100,000 and ab0ve 100,000 respectively. The inference drawn from this is that the area is constituted by mostly high-income and middle-income earners, evident from the fact that a larger percentage (88.84%) earns more than N30,000 the standard minimum wage in the country.

4.5 Occupation

Figure 5 depicts that 44.65% of the total sampled population are self-employed, 33.35% are civil servants; 8.84% and 6.98% are students and unemployed respectively, while 4.19% belong to other categories. It can therefore be inferred that government establishment is not the predominant employer of labour around the shopping mall; even if the area is closer to Government offices (establishments). This also acts contrary to the report of [12] and [13] which says that the major employer of labour in Nigeria is the government (Fig. 6).

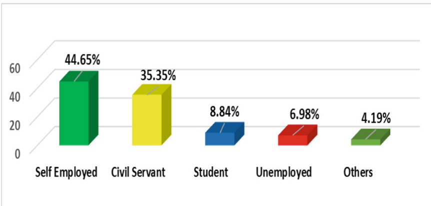

Fig. 5. Occupation of respondents. ***Source:*** *Field Work (2021)*

4.6 Residents Locational Perception of the Shopping Mall

Findings from the field survey show that 26.84% of the respondents agreed that the shopping mall is properly located. Contrary to this, 71.16% of the respondents responded

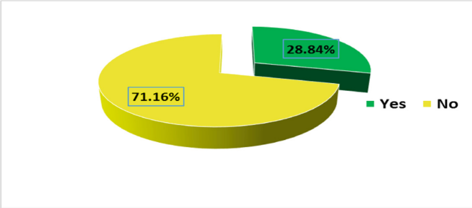

Fig. 6. Locational perception of shopping mall. ***Source:*** *Field Work (2021)*

negatively to the present location of the shopping mall. They categorically stated that the shopping mall is wrongly located. The inference drawn from this is that the area surrounding the mall is largely constituted by high-income earners who are residents of the Alagbaka GRA. But due to the daily influx of people coming to visit the mall, the residents experience congestion in their environment, amongst other negative impacts leading to their inconveniences.

4.7 Environmental Impacts of the Mall on the Connecting Residential Area

Figure 7 shows the impacts of the shopping mall on respondents. Over 40% (41.40%) of the respondents agreed to be positively impacted by the shopping mall, 50.23% are negatively impacted and 8.37% are indifferent.

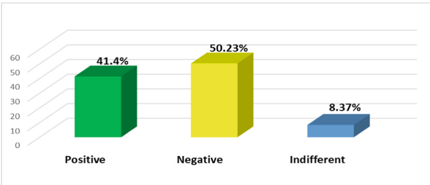

Fig. 7. Perceived impacts of the mall. ***Source:*** *Author's Field Work, 2021*

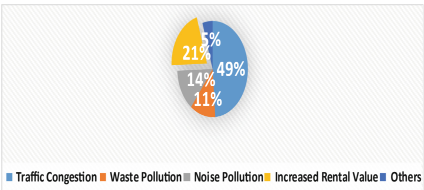

Fig. 8. Negative impacts of the mall. ***Source:*** *Field Work (2021)*

4.8 Planning Implications of the Shopping Mall

As shown in Fig. 8, the largest percentage of the respondents (49%) agreed that the major negative impact of the mall is traffic congestion, followed by increased rental value with

21%, noise pollution with 14% while 11% and 5% of the respondents agreed the major negative impacts are waste pollution and other specified reasons, respectively.

4.9 Negative Impacts of the Mall

It was also discovered that smoke emitted from the generating set is released directly into the atmosphere. This can lead to respiratory problems for people that live and work around the environment. Waste pollution in the environment can be attributed to lack of proper waste management facilities strategically located within the premises of the shopping mall and its environs. Also, the presence of the mall has resulted in the sprouting of small-scale businesses, kiosks, and shops around the area haphazardly (Figs. 9, 10 and 11).

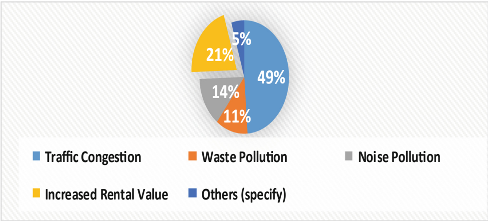

Fig. 9. Negative impacts of the mall. ***Source:*** *Field Work (2021)*

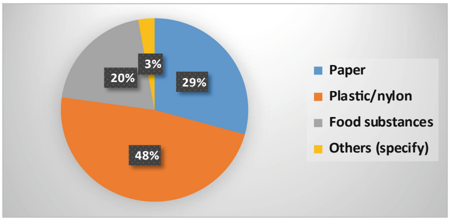

Fig. 10. Poor waste channel and pollution from the mall. ***Source:*** *Field Work (2021)*

Fig. 11: Types of solid wastes generated. ***Source:*** *Field Work (2021)*

4.10 Types of Solid Wastes Generated

Findings show that the most generated type of solid waste is plastic/nylon (48%). This is closely followed by the paper waste (29%). Next to this are food substances and other specified types of solid wastes with 20% and 3% respectively.

4.11 Major Causes of Noise Pollution

From the field survey, 92.09% of the respondents claimed the major cause of noise pollution was generating plant and vehicular horns, while 7.91% agreed it was noise from music in the mall. According to the UN standard, road traffic noise and leisure noise are among the five relevant sources of environmental noise. Noise pollution poses serious harm to human health and interferes with people's daily activities at school, work place, home, and during leisure activities. It disturbs sleep, reduce performance, cause cardiovascular and psychophysiological effects, and changes in social behavior. Little children chronically ill and elderly people are more sensitive to disturbance. In addition, the less affluent who cannot afford to live in quiet residential areas or have adequately insulated homes are likely to suffer disproportionally. This is, however, the opposite in this case as the residential estate close to the mall, devoid of noise and disturbances. Asides from being an eyesore to the environment, the un-tarred road causes dust to cover the natural vegetation in the surroundings, as well as air pollution.

Table 3. Peak periods of negative impacts

Peak periods	Frequency	Percentage (%)
Weekdays	48	22.33
Weekends	67	31.16
Public holidays	100	46.51
Total	215	100.00

Source: Author's Field Work, 2021

Table 4. Major cause of noise pollution

Cause of noise	Frequency	Percentage (%)
Plant/Vehicular horns	198	92.09
Music from mall	17	7.91
Total	215	100.00

Source: Field Work (2021)

4.12 Peak Periods of Negative Impacts

Table 3 depicts, that the peak period of the negative impacts of the mall is during the public holidays and festive periods which constitutes 46.51%, of the respondents. However, 31.16% of the respondents believe the peak period occur during weekdays and weekends respectively. As a result of this, residents who might want to rest and observe a quiet time in their homes during public holidays will not have the opportunity to do so because of the high influx of visitors during these periods. In some other cases, residents may also want to spend their holidays visiting other sites outside the area but could be deterred by traffic congestion within their neighbourhood (Table 4).

5 Summary of Findings and Policy Recommendations

The survey has examined the locational impacts of the Akure shopping mall on the adjoining environment. The ways by which the shopping mall impacts the adjoining areas were evaluated using a structured questionnaire that was administered to residents and workers within the sample population. The study acknowledges that the adjoining areas of the Akure shopping mall have witnessed negative impacts that could lead to degeneration if the area is not properly planned and sustainability measures are not taken. Negative impacts were found to be generated from the shopping mall regularly. The management of these impacts is often poor, with a mixture of potentially hazardous and non-hazardous wastes being found in the surrounding areas of the mall. Although waste generated within the mall is properly disposed of weekly, no attention is paid to the waste generated by visitors outside the mall. In most cases, these wastes block the drains, and also constitute an eyesore in the environment.

Another negative impact posed by the mall is the problem of traffic congestion which occurs as a result of the influx of visitors in the area, thereby causing inconvenience to the residents and workers in the environment. The unruly parking of public motorcycles completely causes an eyesore in the area and also slows down the free movement of vehicles passing through the road. The blaring horns from cars and many public motorcycles, which have become a norm in the area, cause noise pollution and increased risk of traffic congestion and road accidents.

It is also worthy to note, as established by this study, that the location of the shopping mall is not suitable because it is not easily accessible to the low-income earners and brings little or no benefits to them, due to the consideration of transportation costs. If located in the city center or high-density areas, it will be easier for the high-income earners to access, no matter the location, because they can afford the transportation costs.

The study has immensely contributed to the body of knowledge on the subject of mall locational impacts, rate of impacts, and types of impacts. Therefore, it will be unwise to neglect this aspect of environmental management to ensure sustainability, and to avoid the problems that the negative impacts of the mall can have on the adjoining areas.

For the major findings of this study, it has become imperative for the following recommendations to be made:

i. There should be proper planning for small-scale businesses springing up around the mall.
ii. Proper transportation planning should be embarked on in the area. There should be the provision of a terminus for public vehicles and traffic lights in necessary locations.
iii. There should be proper enforcement of traffic regulations in the area.
iv. Road maintenance should be an utmost priority because more pressure will be asserted on the available roads in the area.
v. It is also necessary to provide an adequate amount of waste bins within and outside the premises of the shopping mall.

6 Conclusion

The motive for this study arose from the concern for proper environmental management, due to impacts posed by the Akure shopping mall on adjoining areas. In this study, the various land uses surrounding the shopping mall, and the impacts faced were discussed and applied in the management of impacts. Findings from the expert assessment were reported, using a set of quality indicators derived from the literature. The influx of commercial activities and migration of people from other areas has been a major contributor to the general impacts posed by the location of the shopping mall. An increase in rental value, over-stretching of infrastructural facilities, air, land, and noise pollution are some of the notable negative impacts which the inhabitants of the adjoining areas experience. Necessary environmental management approaches that would provide related solutions are required. These would focus on the improvement of the existing systems and the integration of sustainability principles and practice into the management of the environment.

In conclusion, it is pertinent to state here that the study was not without its challenge. A major limitation to the study is the inaccessibility of the development plan of the area under study. Also the lack of willingness of the development authority to divulge sensitive information as regards the location of the shopping mall.

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Understanding Land Use Planning and Sustainable Development from the Perspective of Smart Groundwater Monitoring

Ange Kalala Kubuya, Rebecca Alowo(✉), and German Nkhonjera

Faculty of Engineering and the Built Environment, University of Johannesburg, Doornfontein Campus, Johannesburg, South Africa
216042670@student.uj.ac.za, {ralowo,germann}@uj.ac.za

Abstract. This conference paper attempts to put into perspective the issues with groundwater over abstraction in DRC in the context of land use and land cover. The mandatory vital data that is needed for successful monitoring of groundwater use is not provided by water customers. This has made it difficult to make decisions and conserve groundwater. Regarding methodology, mixed methods/methodological design and approach was used to achieve the research objectives. Two land cover maps for 2010, 2015 and 2020 were created, comparing the growth or decline of criteria such as vegetation, urban planning, agriculture, and other factors to determine the impact of urbanisation on Kimbanseke. The land cover maps for 2010, 2015 and 2020 were created using Landscapes 2010, 2015 and 2020. Using ArcGIS 10.5 software, the research region in Kimbanseke was retrieved from a Landsat picture and projected in the UTM 33 South zone for further examination, and data classification. In addition, using an android telephone and basic computer, well information, water levels and lithography related information such as soil formation were assembled and mapped out onto the GIS enabled layers/platform named LAAME for better spatial analysis. The findings from the land cover maps are that: increased urbanization in Kimbanseke is leading to increased water demand. From groundwater mapping and analysis, the Kimbanseke catchment has a fluctuating abstraction rate resulting from no clear monitoring mechanism. It is the recommendation of this research that the development appropriate hydrological based monitoring system using of factors such as land use and apps like LAAME be carried out for increased groundwater sustainability in Kimbanseke.

Keywords: Land use · Sustainability · Artificial intelligence · Groundwater · Monitoring system

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1 Introduction

Despite its enormous surface and groundwater resources, the Democratic Republic of Congo has been experiencing a growing shortage of safe drinking water in recent decades [5]. Overcrowding, particularly in metropolitan areas, government's failure to implement water master plans, and a continued low-intensity war in the eastern half of the country with its ramifications on the economy of the country are all factors contributing to this predicament [6]. As a result, the collection of groundwater is a growing business for the National Service of Rural Hydraulics (NSRH), private companies and the Environmental Non-Governmental Organizations (ENGO). The need to provide high-quality drinking water in urban, semi-urban, and rural areas is paramount [7, 8]. This conference paper attempts to put into perspective the issues with groundwater over abstraction in DRC in the context of land use and land cover. It also looks at smart groundwater monitoring using apps with linkages to groundwater lithology and groundwater drought.

2 Literature Review

2.1 Groundwater Abstraction

Groundwater is the world's most abundant freshwater resource providing about half of all drinking water, around 40% of water for irrigated agriculture, and roughly one-third of the water necessary for industry [1]. It helps preserve the ecosystem and the river's baseflow [2]. Groundwater is an important source of storage for climate change adaptation because it reduces land subsidence and ocean intrusion [3]. However, aquifers are frequently misunderstood and inadequately managed due to their invisibility [4].

Groundwater levels, groundwater abstraction rates, spring discharge, and groundwater quality are all measured around the world [9]. However, because of inadequate monitoring and limited access to monitoring data/outcomes, there is insufficient understanding regarding the state and trends of groundwater resources globally [4]. Groundwater level and quality monitoring in an aquifer can operate as an early warning system in preventing infinite groundwater exploitation and contamination, which is becoming increasingly important due to rising concerns about groundwater exploitation and contamination [10]. Most current research focuses on the exchange of surface and groundwater as well as groundwater system models [11]. Since the cost of installing and maintaining a groundwater monitoring network is so high, it is necessary to create an optimal monitoring network, which necessitates the study of effective network design approaches [12].

2.2 Sustainability of Groundwater Resources

The idea of groundwater sustainability is nuanced and intricate [9]. The same holds true for its application in setup and real-world circumstances [4]. The diverse influences and effects of various human-induced activities on groundwater assets and the larger ecosystem must be fully understood and taken advantage of [10]. The World Commission for Economic Development claims that as a result, the idea of groundwater sustainability is currently the subject of intense discussion. The majority of discussions center on how harmful human activity is [4].

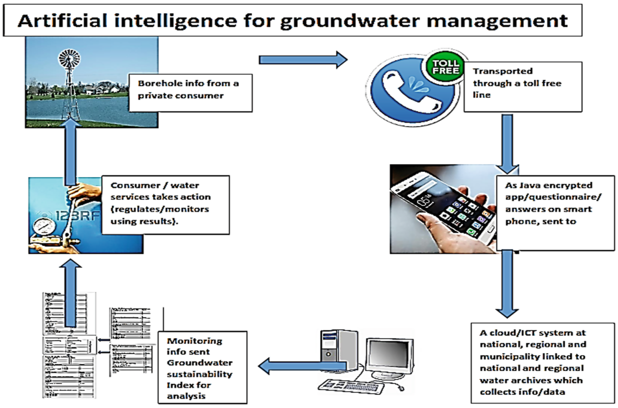

Fig. 1. Proposed app architecture. (Source: Alowo, 2020).

According to one meaning of the phrase "groundwater sustainability," it might mean using and developing groundwater resources in a way that addresses all development concerns and may account for future changes [11]. The term "groundwater sustainability" refers to the idea that groundwater is sustainable in its ideal form. This condition is dependent on time and space and neither constant nor static [4]. These circumstances demand a study or series of studies to track the development of sustainability through time and space. Additionally, it shows that efforts to evaluate performance measures to calculate groundwater sustainability were insufficient. This is true despite the numerous debates that have taken place in the academic, scientific, and water management fields. The reason for this is because sustainability is a multifaceted idea rather than a pure scientific one, even if it frequently supports scientific evaluation and analysis [12].

2.3 Early Warning Systems

Early warning systems (EWS) are defined and described in this section by looking at their structures and roles [13]. This section focuses on risks that aid in clarifying and understanding EWS in the context of groundwater scarcity. These include both dangers that develop quickly and slowly, as drought [14]. Each EWS must be considered as a social process, typically involving technological components that are entrenched in their social context, according to the essential premise [15]. This results in a preference for a "First Mile" approach to designing EWS, which includes communities from the start of constructing an EWS, as opposed to a "Last Mile" approach, which integrates people and communities toward the end of the design process [16]. Instead of being a separate system waiting to be activated only when a danger occurs, an EWS may support daily life and livelihoods by keeping people and communities at its core from the start, enabling broader disaster risk reduction and sustainable development endeavors [15]. However, any EWS has its limits. These constraints must be acknowledged and handled using other strategies, with the possibility of taking into account "middle warning" and "late warning" systems rather than merely early warning systems [16].

The innovative component of technology, its primary output, and its potential commercial value in relation to this paper are that they will contribute to new knowledge in the development of a groundwater sustainability framework that supports an improved groundwater monitoring system using ICT [13]. The sustainability framework employs concrete and arbitrary methods [14]. Variables are simply evaluated by the sustainability index [15]. The answer comes in the shape of a general early warning system (EWS) with four parts: (1) obtaining risk information; (2) monitoring and forecasting the situation; (3) disseminating warning messages; and (4) responding to the warning [16]. The ISDR model was modified, as it did in the ITIKI framework, to combine the various ICTs (artificial intelligence, wireless sensor networks, and mobile phones) in the 3-elements' EWS [17]. Java programming and Android technology support the design elements. The architecture of the application is shown in Figs. 1 and 2 (Fig. 3).

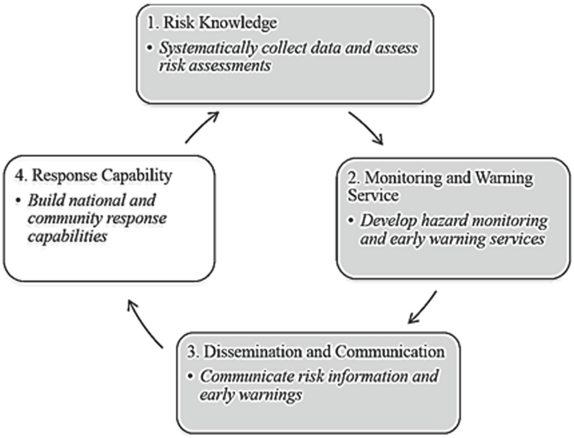

Fig. 2. Elements of an early warning system (adapted from: ISDR 2006).

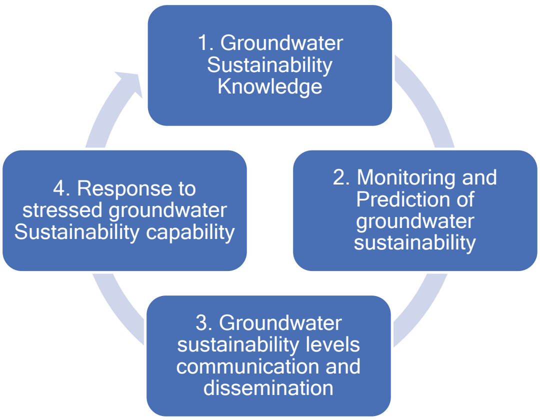

Fig. 3. Groundwater sustainability early warning system. (Source: Authors)

2.4 Mathematical Models for Artificial Neural Network (ANN)

With an ANN technique, groundwater monitoring aims to address problems including prediction estimation as well as typical groundwater yield phenomena [6]. In any event, after a while, attention turned to running errands and causing scientific aberrations [7]. Considering the model in Fig. 4 and Eqs. 1 and 2, lessons were learned from the use of artificial neural networks on a variety of assignments, including personal computer vision, discourse acknowledgment, machine interpretation, informal community separating, playing board and computer games, and conducting medical research.

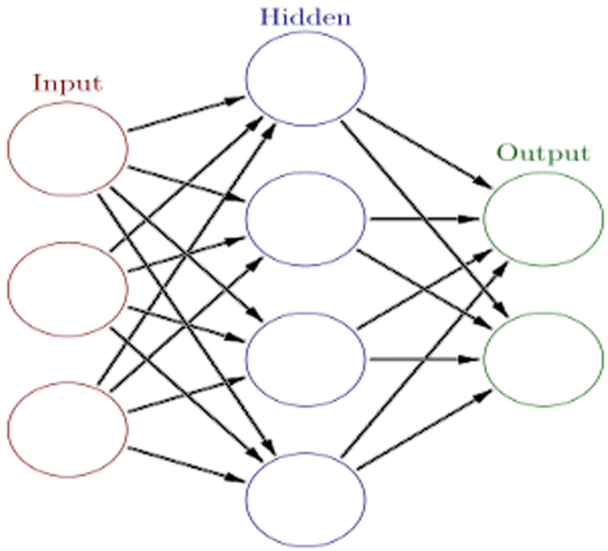

Fig. 4. Model of an artificial neuron network. Source: Antonić et al. (2001)

Using a network of remote servers accessible through the Internet to store, manage, and process data is known as “cloud computing,” as opposed to using a local server or a personal computer [13]. It enthusiastically backs hydrological gauge models that predict outputs from inputs based on historical data on groundwater levels. Although a generic system may be adopted when constructing these AI processes (ANNs), there are no established guidelines for their development [14]. Studies focused on anticipating water releases with the aid of precursor values aim to summarize a relationship of the auxiliary structure or cloud required in Eq. 9:

$$Y = f(X_m) \tag{1}$$

In the formula, Y is the yield variable and X_m is an m-dimensional information vector made up of elements x1… xI x_m.

In release demonstrating, estimates of x i_m may be stream estimations with a variety of time lags, and the estimation Y is typically the stream in the succeeding time frame. Most of the time, the preceding result does not reveal how many precursor esteems are included in the vector X_m.

Equation 2 depicts the relationship between the actuarial labour, information sources, weights, and inclination in a scientific manner [13]:

$$y(k) = f\left(\sum\nolimits_{i=1}^{m} i(\mathrm{k})^{*}Wi(k) + b\right) \tag{2}$$

In the formula above, X_i (k) is the input for a certain period k, and I is a number between zero and infinity.

The value given to a weight in each instance of k where i spans from zero to infinity is known as W_i (k).

B stands for bias value.

F stands for the transfer function.

The output for each iteration of k is indicated by the symbol y(k).

3 Methodology

3.1 Study Area

The Kimbanseke commune is situated between 15° 20″ and 15° 30″ East longitude and 4° 15″ to 4° 30″ South latitude (see Fig. 5) [18]. After the municipality of Mont-Ngafula and by its population, which is close to 1,400,000, the municipality of Kimbanseke, with a land area of 237,80 km^2, is ranked third [19]. It is the municipality with the highest population in Kinshasa, and the majority of its residents are from the Bandundu and Bas-Congo provinces (Paideco, 2) [20].

3.2 Methods and Materials Adapted

In terms of methodology, mixed methods/methodological design and approach was used to achieve the research objectives. This methodology was chosen because of the exploratory nature of the research. To establish an app-based monitoring system for groundwater management status, a variety of sources of material of the study area were required and examined. This included data obtained using GIS-based analytical and numerical modelling techniques to build a groundwater flow model that took into consideration muddled urbanisation of Kimbanseke and their implications on groundwater in Kinshasa Capital Region. The model was also used to anticipate how different development scenarios would affect groundwater supply and management. Due to the era and advancement of the fourth industrial revolution 4IR, the researchers used ANN instead of RF. In addition, ANNs appeared more innovate and easier to adapt compared to other AI algorithms.

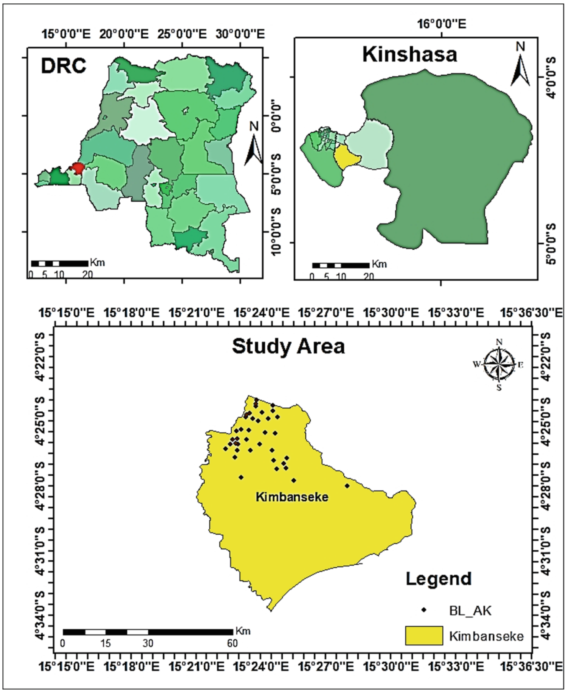

Fig. 5. The study area of Kimbanseke. (Source: GIS based)

3.3 Data Collection

Collection of data relating to the issue under study was the initial step in groundwater research. Data from 39 exploration boreholes was collected from the Regideso company to conduct the study and this includes, among other things, all data relevant to the research area's spatial analysis, environmental geology, pumping system, and stream flows. There are 39 exploration boreholes in Regideso Catchment, for this reason no relevance statistical testing to validate the sample based on the population was necessary.

3.4 Software Used

The following software was utilized to complete this study satisfactorily: A geographic information system (GIS) is a system for creating, managing, analysing, and mapping various types of data. As such, GIS was used to process spatial data to represent geological models of the study area as well as to relate hydrogeological conceptual models.

Rockworks supports a variety of data types, for geological and hydrogeological analysis such as visualization in 3D, interpretation, and presentation, including borehole location, lithology diagram, and stratigraphy diagram which will aid in the creation of the geological and hydrogeological conceptual model. Hence Rockworks 16 software was utilized. Surfer 16 software was used to create representations of terrain surfaces by clearly expressing information about geology, hydrology, the environment and building among other things. AppStudio is a full set of productivity tools that make app development, testing, deployment, and distribution simple and efficient.

3.5 Spatial Analysis Approach Aspect of the Study Objectives

3.5.1 Land Use and Land Cover

To achieve the research objectives, two land cover maps for 2010, 2015 and 2020 were created, comparing the growth or decline of criteria such as vegetation, urban planning, agriculture, and other factors to determine the impact of urbanization on Kimbanseke. The land cover maps for 2010, 2015 and 2020 were created using Landscapes 2010, 2015 and 2020. Using ArcGIS 10.5 software, the research region in Kimbanseke was retrieved from a Landsat picture and projected in the UTM 33 South zone for further examination, and data classification.

3.6 Using Internet of Things as an Approach to the Study Objectives

3.6.1 Cell Phone Use

Mobile internet is seen as one of the most extensively used methods of connectivity worldwide and for many people, cell phones are the vehicle for mobile internet [21]. This is owing to technological advancements that have allowed mobile phones to take the place of desktop or laptop computers in locations where internet connectivity is still relatively new [22]. Citizen science has grown in popularity because of the emergence of mobile communication devices such as smartphones [23]. Scientists and citizen scientists are merging, with sciences leveraging citizen science's power with newer and better tools [24]. Furthermore, because a smartphone can take a photo and associate a global positioning system (GPS) point and a time stamp with it, it may collect both spatial and temporal data, which is useful in many scientific domains, particularly environmental science [25]. Smartphones today include a variety of integrated sensors that can be used in a variety of applications [26]. Newer Japanese models come with a radiation detention sensor as well [23]. Scientists are constantly working on new ways to harness the power of on-board sensors [24]. Concerns have also been expressed about the use of technology in citizen projects [25]. The researchers will continue to study smartphone and mobile internet adoption, keeping in mind that people who do not have access to mobile internet should not be overlooked [26].

3.6.2 Testing the LAAME App on Major Devices

The following steps are completed to test the app on the smart phone:

- In the gallery, the new app that was named LAAME was situated.
- The app was uploaded to ArcGIS by clicking Upload on the side panel.
- AppStudio Player was installed on a mobile phone.
- ArcGIS was accessed using AppStudio Player.
- The app was installed and ran on the mobile phone.

3.6.3 Licensing App

A developer subscription to ArcGIS is required to use this feature (Builder level and above). In the ArcGIS organization, the user must have an add-on license activated. All ArcGIS AppStudio features are included. The researchers created a standalone, executable for the software, ready for app marketplaces or Mobile Device Management (MDM). Furthermore, ArcGIS app studio allows a free 14-day trial for development, deployment, and distributions [31].

4 Results and Discussion

4.1 Overview

This section captures the elements underpinning the development of the app, where the specific methodology and data acquisition are described, pre-testing/testing is explained. Additionally, outlining Kimbanseke urbanization impact on groundwater into many details and precision meaning of information collected.

4.2 Land Use and Land Cover

From 2010 to 2020, the geographic dynamics of land use/land cover (LU/LC) are depicted in Fig. 6, which shows the percentage of land use/cover according to the supervised classification for the LU/LC 2010, 2015 and 2020.

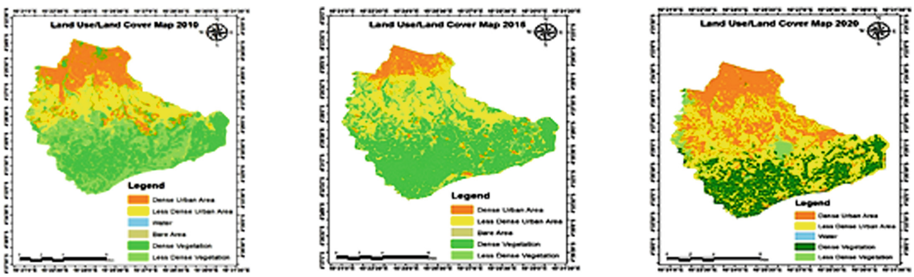

Fig. 6. Land used/cover for (2010, 2015, 2020). (Source: Authors).

Due to population growth, an increase in an urban area was noticed, which increased from 40.7% to 74.4%. However, there was a declined in dense and less dense vegetation, agricultural areas, and aquatic bodies because of driving forces exerting pressure on the environment. These driving forces include uncontrollable drilling and water abstraction, human activity influencing climate change, pollution handled unsustainably, increases in fertilizer and pesticide consumption as well as the quantity of animals and intensification, which have all contributed to an increase in greenhouse gas emissions from agriculture.

4.3 Processes that Influence Groundwater Movement and Storage

Using Rockworks 16, the drilling site in 3D was created using lithological data from 39 drillings, allowing the researchers to gain a deeper understanding of the physical properties of each borehole before correlating them to create block diagrams. This 3D model (Fig. 5) depicts a stratigraphy made-up primarily of three geological units. Firstly, the superficial soft sediments such as river alluvium and Lemba Sands. Secondly, underlying consolidated formations such as Soft Sandstones, and thirdly, Schisto-Sandstone base of the inkisi, which serves as the foundation for all superimposed deposits and groundwater. The 3D stratigraphical model of the research region and the continuity and discontinuity of the geological layers is shown (see also Fig. 7).

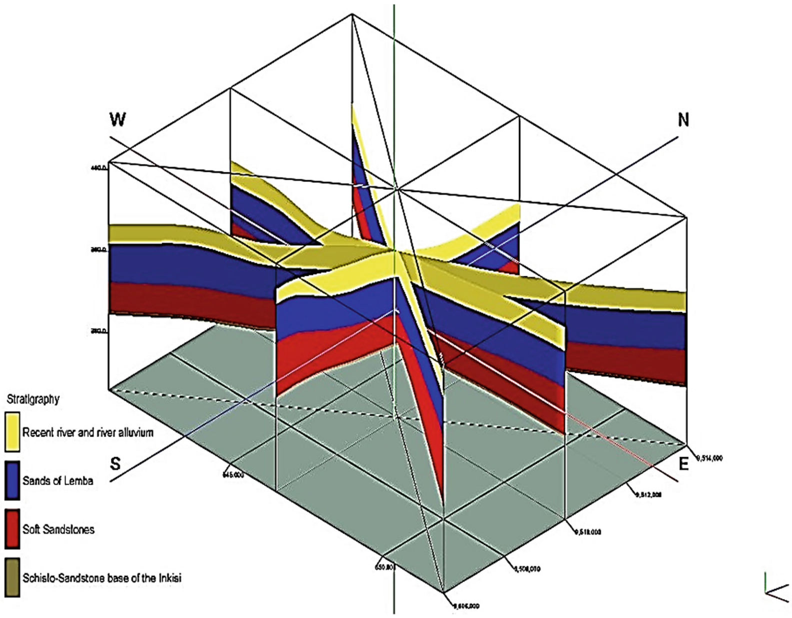

Fig. 7. Stratigraphy fence diagram. (Source: Authors).

This is crucial in groundwater research because each layer has hydraulic conductivity, which is linked to the characteristics that influence groundwater movement because of land use.

4.4 Regarding Volumes Abstracted Per Day in Regideso

Figure 9 shows the monthly output of two boreholes: f3 boreholes in July and f3 boreholes in August. These two boreholes serve as the population's primary supply of water because the Kimbanseke community depends on extensive water extraction from springs via a distribution network. Additionally, most of the groundwater, which is thought to make up

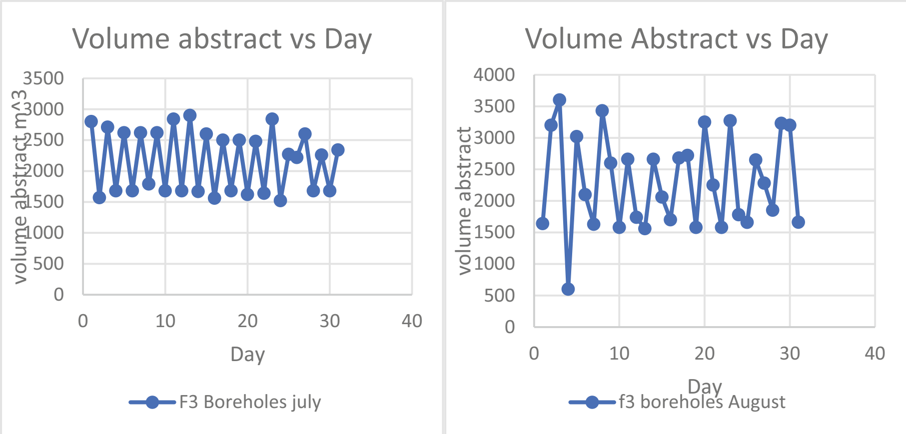

Fig. 8. Volume abstracted daily. (Source: Authors).

around 10% of the supply of drinking water, is extracted using manual and mechanical pumps.

The entire 24 h of water extraction were not possible because of load shedding. As observed in the numbers, the yield for the boreholes varied in both July and August, and the engine's intensity ranged from 48 to 47, which is directly related to the fact that the current voltage must be over 360 kw rather than 400 kw for it to operate as intended. With a volume of 3140 m^3, f1 had the largest abstraction, followed by f3 with a volume of 2900 m^3, and both had volumes of 66501 m^3 and 66850 m^3 for the month of July. In addition, the amount of abstraction for the month of August has increased somewhat from 76596 m^3 for f3 in July to 71425 m^3 for f3 in August. This is because there is no cap on the amount of water that can be extracted each month, and it demonstrates that far more water might be extracted in the future than is now being done.

4.5 Implementation of the App

Figure 10 shows the high-level implementation design of the mobile app that distinguishes between two user types: "general public" and "professionals". The ability to do accurate borehole measurement, analysis, and interpretation is the main difference between these two user categories. Users can see all the data collection fields available. Users who have registered as professionals will be able to capture all fields, but basic public users will only be able to submit data by going through a selection list that must be filled.

With regards to the app interface features, Fig. 8 below shows the running procedure of the app.

The mobile app was tested using Kimbanseke available boreholes data that added up to 39 and analysis were performed, and the map was generated illustrating the location of each borehole. Professionals on the other hand can export the submitted data in preferable

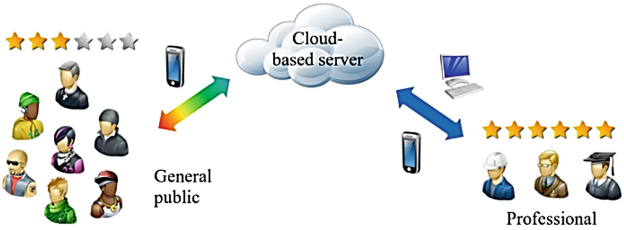

Fig. 9. App Implementation. (Source: Authors).

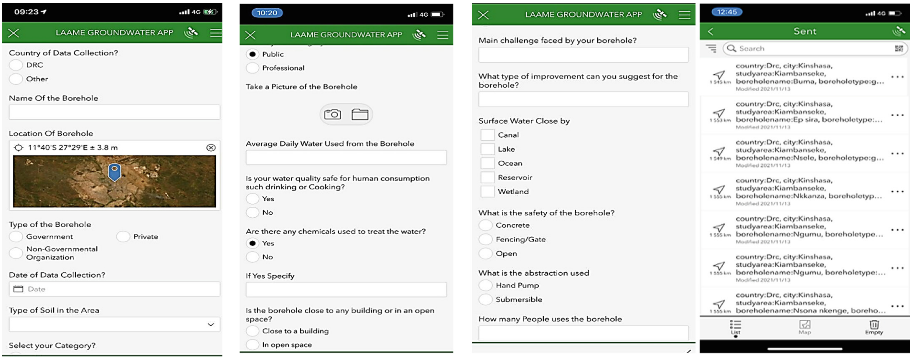

Fig. 10. Running procedure of the developed app on the Smart phone. (Source: Authors).

format such as CSV, Excel, KML, shapefile, and file Geodatabase among others. The exported data from the laptop can be processed to conduct further analysis, store for future research, and investigations. A list of the collected data and the generated map achieved in the app is also shown.

Furthermore, the professional interface also has a statistical feature such as bar chat, pie chart, summarizing the collection process such as which country used the app recently, and questions answered the most etc. The app includes a feature that allows users to verify each other's information. With registrations, each user is given a user rating and a one-star rating. The star rating of a particular user rises because of many verifications.

The difficulty with a borehole is that measurement calls for specialized equipment. But the general public can get the GPS coordinates, snap a picture, and respond to some straightforward inquiries with a checkbox list or a comment. Furthermore, this aligns public awareness framework, engaging population into decision-making, educating them of environmental issues and implementing them into the engineering world. Moreover, this will promote successful citizen science so that together, many can overcome global groundwater challenges by monitoring them regularly, by contributing positively to the future management water resource as well as land management. Finally, such information will empower citizens, allowing them to address local districts and stakeholders, and from there, further analysis/decision might be taken.

4.6 The Social/Theoretical/Practical Contributions of the Paper

The paper's findings supported the well-known difficulties in groundwater monitoring that most water administrative agencies still experience. One of the causes is that many water customers fail to provide the mandatory vital data that is necessary for accurate water use monitoring. This has made it harder to make decisions and conserve groundwater. It also means that water authorities have no restrictions on the number of boreholes that licence holders may drill. The paper explores the possibilities of artificial intelligence in groundwater management to address this from a social, theoretical, and practical standpoint. An artificial intelligence-based groundwater management framework is suggested. By using a monitoring system that provides real-time updates and early warning signals for water management, this framework seeks to increase the likelihood that groundwater management, conservation, and sustainability will be successful. This reinforces good behavioural practices for water abstraction and efficient water use. As a result, municipalities will be able to determine whether a catchment is being over-abstracted and groundwater users will be able to gauge whether they are consuming too much water. Water savings, cost reductions, and improved performance by provinces, municipalities, and water management departments will be the net gains or effects. Additionally, once put into practice, this framework would guarantee automation of the groundwater system sustainability modelling. As a result, a catchment monitoring, allocation, licensing, and characterisation system for a groundwater management system would be effective.

5 Conclusion

This conference paper has attempted to put into perspective the issues with groundwater over abstraction in DRC in the context of land use and land cover. It also looks at smart groundwater monitoring using apps with linkages to groundwater lithology and groundwater drought. As such, the GIS tool and a java enabled phone was used to compile spatial analysis by producing maps such as LU/LC Map, description of the Kimbanseke area, which then aids in the development of a conceptual geological model. Additionally, Rockworks 16 was used in terms of the processes that influence groundwater movement and storage. It is worth noting that the design of this 3D aquifer model allowed the researchers to determine the extension and geometry of each sedimentary unit, indicating that the aquifer system of the Kimbanseke is made-up of a system of multi-layered aquifers subdivided into separate aquifer units by aquitards of sandy clay or clay sand as well as polymorphic sandstone (silicified). The National.

As a limitation, the testing was done in a quaternary sub catchment not a tertiary or primary hence lager catchment. in future further study and these levels should be conducted to deepen and widen the study in DRC.

Water Supply Company, REGIDESO has failed to anticipate and prepare for the increased demand of water in Kimbanseke. This might have been due to inadequate monitoring of resources such as groundwater. Groundwater is perceived as a potential solution to this water shortage. However, unmanaged groundwater exploitation causes aquifer depletion, while climate change may exacerbate the situation. Thus, this paper recommends that a monitoring app like LAAME groundwater app be designed to assist with monitoring groundwater in DRC and globally.

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Pollution in the Urban Environment: A Research on Contaminated Groundwater in the Aquifers Beneath the Qoboza Klaaste (QK) Building at University of Johannesburg in South Africa

Davhana Patience, Nkhonjera German, Mahachi Jeffrey, and Rebecca Alowo(✉)

Faculty of Engineering and the Built Environment, University of Johannesburg, Doornfontein Campus, Johannesburg, South Africa
{patienced,germann,jmahachi,ralowo}@uj.ac.za

Abstract. Through water quality surveillance research and testing, the paper seeks to establish whether groundwater at the Qoboza Klaaste (QK) building, in the University of Johannesburg, Doornfontein Campus (UJ DFC) is fit for consumption. Waste generated in Johannesburg causes contamination to groundwater resources, affecting its quality, and thus making groundwater unsafe for consumption if not treated. In the assessment of groundwater at QK building collection of samples of groundwater to conduct laboratory tests was carried out; checking quality for the water for human consumption and for any chemical and physical elements that may be the cause of contamination to the water. During the research it was found that there are dolomites in the southern parts of Johannesburg as well as high yield of groundwater occurrence because of the nature of the rocks in those areas. The results were also bench marked against the South African National Standards 241:015 (SANS 241:2015), the finding was that the water in not compliant with drinking water requirements, in addition only two national physical parameters which are the pH and EC were satisfactory. Therefore, this means the groundwater at UJ DFC is not affected by Acid Mine Drainage generated from mining activities in the Witwatersrand. The major source of contamination to groundwater at UJ DFC is mainly faecal pollution, which probably enters the aquifers through leakages of sewers. The research concludes that the groundwater is unsafe and not suitable for Human consumption. The value of the study to other intuitions and UJ DFC is that the university can use the groundwater for purposes such as watering gardens, and for flushing toilets in all the buildings within the university premises.

Keywords: Dolomite · Faults · Lithological · Permeability · Weathering

1 Introduction

The University of Johannesburg is situated in Gauteng Province within Johannesburg Central Business district (CBD) [3]. The campus is in Jukskei River Catchment of the Crocodile River, where is it underlined by few a fractured aquifer rocks which are

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Basaltic Lava, agglomerate and tuff from the Kliprivierberg Subgroup and the south by the Breccia, conglomerate, and shale of the Platberg Subgroup. The influence of faults, weathering and lithological permeability have not been investigated due to lack of hydraulic data for these zones. In this case, the campus is at north of the subcontinent surface water divide between the Vaal River basin south and Limpopo River basin to the north (Taylor et al., 2005). The study area has a combination or networks of aquifers and spring water system/network. The building was erected on top of a spring water network. In addition, the groundwater from the aquifer compromises the structural integrity of the QK building and poses a risk on human life [4]. Hence, the water needs to be channelled away from the QK building and several possible alternatives uses of this water found.

2 Literature Review

Groundwater in South Africa plays an important role in making provision for drinking water, sanitation, and hygiene. It also supports the agricultural irrigation schemes and industrial uses and maintain aquatic and terrestrial ecosystems (Sharma and Kaushik, 2021). The groundwater chemistry reveals important information on the geological history of the aquifers and the suitability of groundwater for domestic, industrial, and agricultural purposes (Rajmohan et al., 2021). This necessitates groundwater quality surveillance and emphasize its importance in South Africa (Barilari et al., 2021).

Groundwater is an immediate alternative source of water for many waters scarce communities of South Africa, hence contamination to groundwater sources pose a major threat to human health, especially because people consume the water without any form of prior purification processes [8]. Due to human and industrial activities, groundwater resources in Johannesburg are contaminated [6]. Lack of adequate sanitation is one of the most common problems that pose a threat of water borne diseases such as cholera, amoebiasis, typhoid and fever [1]. More people from rural areas are migrating to the cities in search of opportunities, yet this is resulting in increased water demands subsequently overwhelms the city's capacity (Molle and Berkoff, 2009).

Contaminated groundwater is poor in quality and is a major problem for many groundwater dependent communities surrounding UJ DFC. There is a lack of information regarding the level of contamination and the associated problems of groundwater resources at the DFC. Although there is information for the larger aquifer types, there is no information available on the boreholes on UJ premises and the yield capacity of groundwater aquifers underlying the Q/K building at DFC. This research seeks to address these highlighted problems.

3 Methodology

Using new trends in water quality surveillance methodology such as Eutech waterproof TN 100 turbidity meter, the HI 98129 combo pH and EC waterproof meter, the research investigated the groundwater storage potential at the university premises (Mpho, 2020). The research included collection of samples of groundwater to conduct laboratory tests, checking quality of the water for human consumption and for some chemical and physical elements that may be the cause of contamination to the water. The samples informed some of the potential uses of groundwater, that the university can employ to make ensure that groundwater resources are not always wasted, but also put to good beneficial use. Approval/permission was taken from the UJ/institution for this research. The research methodology composed of two-phase analysis, which were:

- Phase 1 - the Sampling and Field analysis phase. This phase evaluated the physical characteristics (temperature, electrical conductivity, pH and turbidity) of groundwater. This included daily collection of water samples to investigate the sources of contamination of the groundwater found at the University of Johannesburg Q/K.
- Phase 2 - the Laboratory Analysis. In this phase, the presence of biological constituents (Total Coliforms and E. coli bacteria) in the collected samples were analysed.

3.1 Limitation of the Study

Due to time constraints, this research was unable to provide quantification of the actual amount of groundwater that is pumped out and wasted into storm water drains from the basement of the Q/K building of the UJ DFC. Also, due to limitation of resources, only few water quality parameters were analysed to meet the objectives of this research. Therefore, there is a need for future research that will quantify the amount of groundwater that is wasted from pumping out at UJ DFC and for investigation of all the water quality parameters to determine other groundwater-associated problems.

4 Study Area

The University of Johannesburg is situated in Gauteng Province within the Johannesburg CBD (see Fig. 1). The campus is in Jukskei River Catchment of the Crocodile River, where is it underlined by a few fractured aquifer rocks including Basaltic Lava, agglomerate and tuff from the Kliprivierberg Subgroup and the south by the Breccia, conglomerate, and shale of the Platberg Subgroup. The influence of faults, weathering and lithological permeability have not been investigated due to lack of hydraulic data for these zones. In this case, the campus is at north of the sub-continent surface water divide between the Vaal River basin south and Limpopo River basin to the north. The QK building as shown in Fig. 1, was built on top of spring water, meaning that the rising of water to the surface is continual (Leketa et al., 2019).

5 Discussion and Results

5.1 Overview

Waste generated in Johannesburg causes contamination to groundwater resources, affecting its quality, and thus making the groundwater unsafe to be used if not treated. While large quantities of contaminated groundwater are pumped out of the building's basements daily and discharged into stormwater drains for protection of public health and infrastructure from flooding incidents. On the other hand, the City of Johannesburg is encountering challenges of increased water demands, mainly due urbanization and rapid population increases.

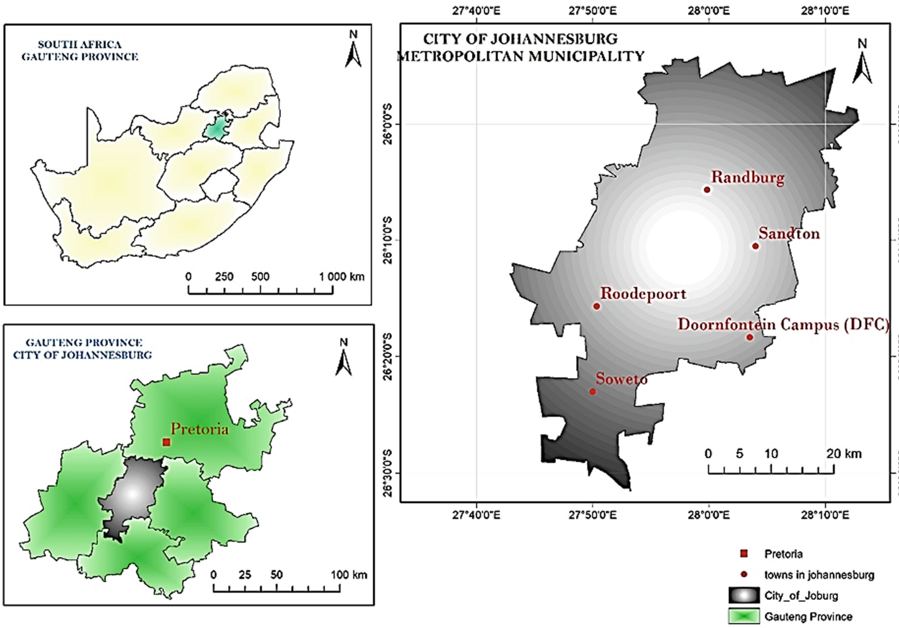

Fig. 1. Focus area of Doornfontein Q/K Building. (Source: Kapata et al., 2021).

5.2 Water Quality in South Africa

South Africa is classified as one of the dry and drought susceptible countries in Africa, with relatively low rainfall of 500mm compared to 860mm world mean average [2]. The country encounters shortage of water mostly due to climate change, infrequency of terrain to supply the country with sufficient water (Raleigh et al., 2007). Drinking water quality is strictly regulated by national standards, which prescribes parameters to be analysed as well as sampled frequently [5]. Figure 2 is a South African Map Showing Water Risks in Different Provinces.

5.3 The South African National Policy and Standards 241:015 (SANS 241:2015)

The South African National Standard (SANS) is a drinking water specification that states the minimum requirements of portable water to be considered safe for human consumption (Vinlab.com). The physical, microbiological, and chemical properties in the water must be balanced and meeting the drinkable/consumption standards. The limits and associated risks for domestic water as determined by South African National Standards (SANS) 241:2015 are as follows:

- Health risks: parameters falling outside the SANS limits may cause acute or chronic health problems in individuals.
- Aesthetic risks: parameters falling outside the SANS limits indicate that water is visually, aromatically, or palatably unacceptable.

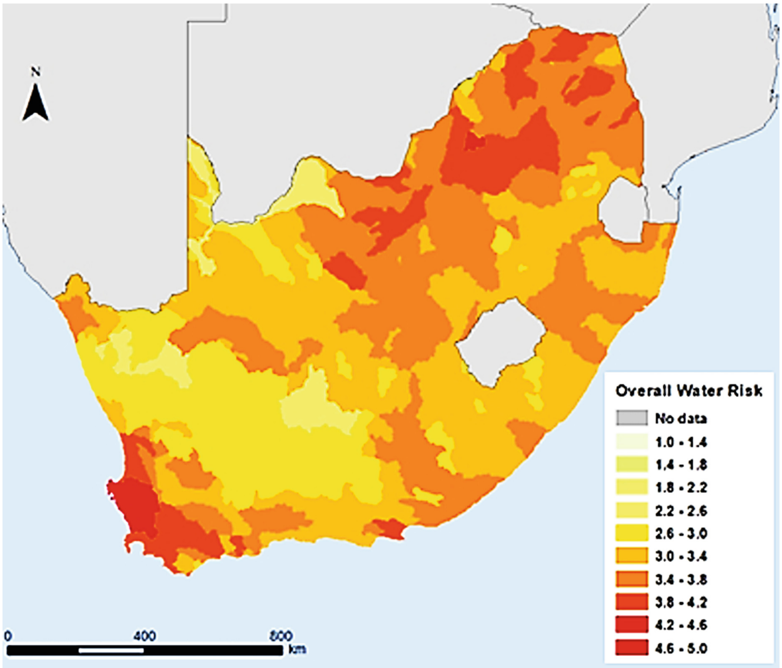

Fig. 2. South Africa map showing water risks in different provinces. (Source: geoscience.org.za).

- Operational risks: parameters falling outside the SANS limits indicate that operational procedures to ensure quality standards are met may have failed.

State of drinking water (see Fig. 3) where, < 95 (red colour coded, represent water of bad quality), 95–97 (yellow colour coded, water of poor quality), 97–99 (green colour coded, water of good quality) and > 99 (blue colour coded, water of excellent quality).

The South African Bureau of Standards (SABS) is a South African regulatory body established in terms of the Standards Act, 1945 (Act No. 24 of 1945). It continues to operate in terms of the newest edition of the Standards Act, 2008 (Act No. 29 of 2008) as the national institution for the promotion and maintenance of standardization and quality in connection with commodities and the rendering of services (Interview with Adrian Carter).

The gaps in the SAN 241

Department of Water Affairs (DWA) proposed and is now implementing the Blue Drop Certification which is intended to monitor the drinking water quality supplied to consumers country wide. Both water quality and administrative aspects are combined in this certification with emphasis being on the administrative aspects instead of water quality. The success of the Blue Drop Certification is dependent on stringency of the water standard to which the water supplied to consumers is compared. SANS 241 is used for this task. Regrettably, SANS 241 of 2006 does not adequately address removal

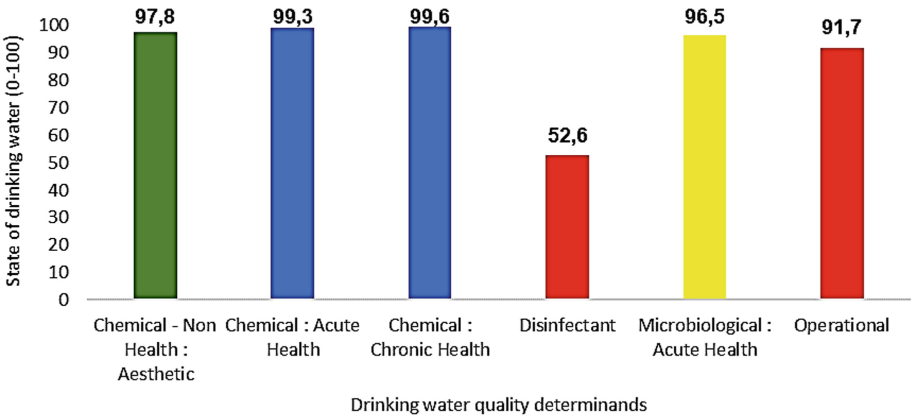

Fig. 3. State of drinking water. (Source: SAN241)

of NOM which is the major and the most important pollutant. The permissible DOC = 10 mg/l, which is higher than that in most surface waters in South Arica does not ensure a supply of wholesome quality water to consumers. In view of that, SANS 241 of 2006 cannot be considered a suitable standard for drinking water quality in general and the Blue Drop Certification in particular. If not linked to a stringent standard the Blue Drop Certification will become a dangerous tool that will provide a comfort zone instead of highlighting the problems associated with the quality of water supplied to consumers. It will certify that our drinking water is of excellent quality whilst this water will continue to make people sick.

The Framework in Place at UJ For the Aspects Covered in The Research

A question remains as to what university of Johannesburg health and safety framework arrangement for this type of water under research. The research done by the centre deals with the relationship between water and human health. No other advancement in the field of medicine and health have attributed more to increased lifespan and improved general health than access to safe water and improved domestic hygiene and sanitation. Access to and availability of good quality water are the key aspects of safe water, and supported by sanitation and domestic hygiene, forms a cornerstone of improved public health. It is therefore vital to understand this relationship. The Water and Health Research Unit researches the environmental health impact of inadequate or improved services related to Water, Sanitation and Hygiene in Southern Africa.

This approach supports the national priority of significantly reducing the impact of water-borne disease in the region. Target constituencies for research by the Unit therefore include government agents and service providers as well as members of communities – especially the rural and the poor (Interview with Dr TG Barnard).

The current UJ university policy tries its best to ensure the monitoring the quality of water in the University is always in place, this is to avoid/ensure that water is up to South African National Water Standards. UJ has people in the microbiology lab that are working effortlessly day to day testing water for microbiological components such as.

5.4 Discussion of Lab Experiment Results

After assessing water quality parameters and comparing the obtained results against the SANS 241:2015 for drinking compliance, the research found that the groundwater complies with only 2 physical parameters which are the pH and EC (see Table 1). This indicates that there may be a possibility that the groundwater at UJ DFC is not affected by AMD generated mining activities in the Witwatersrand mining area. However, the research found that the major source of contamination to groundwater at UJ DFC is mainly faecal pollution, which probably enters the aquifers through leakages of sewers. Thus, this makes faecal pollution from wastewater a major source of groundwater pollution at UJ DFC (see Tables 2 and 3). As such, the groundwater is unsafe and not suitable for drinking. Since the research found that the groundwater is not portable for drinking, the university can use the groundwater for purposes such as watering gardens, and for flushing toilets in all buildings at the university premises.

6 Policy Recommendations

Based on the authors analysis and reflections, this research has nine policy recommendations

1) Expedite water safety planning at the various spheres of South African Government and UJ.
2) Effectively, UJ can support the alignment of gaps in the SAN 241, through evidence and action lead/ based research.
3) Updating the SAN 241 for water quality of (rainwater harvested, stormwater reclaimed, Sustainable Urban Drainages, greywater recycled use etc.) is highly recommended. UJ can lead or support on this aspect.
4) Wide and massive testing of water on quality basis in surrounding areas of QK building.
5) Development of university level guidelines, protocols, frameworks, and critical requirements for reclaimed water from sustainable urban drainages harvested runoff.
6) At least ensure that 80% of the water is recycled for non-human consumptive use such as gardens, cleaning etc. at UJ.
7) Partnerships with Green building council, DWA, WSA and Universities for community education on water contamination, treatment, and conversation.
8) UJ should Lobby/advocate for increased 50% investment in household level water treatment units and water harvesting systems nationally.
9) Bye laws for mandatory water conservation and water quality protection at community level.
10) UJ should revisit and support the enforcement of household level best practice homestead lay outs, so that minimum distances at household level between sanitation facilities/faeces and structures in a homestead don't contaminate household drinking water and food, i.e. (South African standard stat that there should be a minimum of 7 m from toilets to the main house and a minimum of 30 m from the water sources). This can be done in the areas surrounding QK at UJ.

Table 1. Summary groundwater physical parameters 1.

		Groundwater			
Sampling date (Oct-Nov)	Number of days	Temperature (°C)	pH	Electrical conductivity (mS/m)	Turbidity (NTU)
14-Oct	1	17.9	6.88	33.8	0.15
15-Oct	2	19.3	7.04	35.8	0.62
16-Oct	3	18.6	7.25	26.5	2.25
17-Oct	4	19.7	7.15	31.1	1.86
21-Oct	5	25.4	4.13	34.7	0.42
22-Oct	6	23.5	7.11	29.8	0.83
24-Oct	7	21.9	7.58	31.6	0.66
28-Oct	8	20.6	6.55	42.1	6.26
29-Oct	9	20	7.01	46.3	3.46
30-Oct	10	20.2	7.59	51	2.61
31-Oct	11	19.8	7.4	48.9	2.37
04-Nov	12	20.1	7.43	39.2	5.55
05-Nov	13	20.4	6.89	45	0.47
06-Nov	14	20.5	7.05	45.5	1.69
07-Nov	15	20.2	6.88	45	0.9
South African National Standards (SANS) 241:2015					
Drinking water quality limits					
Quality limits			≥ 5 to ≤ 9.7	≤ 170	≤ 1
			OK	OK	NOT OK

(Source: Author, 20019)

Table 2. Summary of groundwater physical parameters 2.

Sample appearance after incubation	Results
Yellow equal/greater than the control when incubated for 18 h at 35 °C	Positive for total coliform
Yellow and fluorescence equal/greater than the control when incubated for 18 h at 35 °C	Positive for E-coli

(Source: Authors)

Table 3. Groundwater microbiological parameters analysed.

		Groundwater		
Sampling date (Oct-Nov)	Number of days	Temperature	Total coliforms (MPN per 100 mL)	E-coli (MPN per 100 mL)
14-Oct	1	17.9	231	< 1
15-Oct	2	19.3	613	1
16-Oct	3	18.6	817	< 1
17-Oct	4	19.7	260	2
21-Oct	5	25.4	58	< 1
22-Oct	6	23.5	1120	3
24-Oct	7	21.9	99	< 1
28-Oct	8	20.6	24,196	162
29-Oct	9	20	345	9
30-Oct	10	20.2	1553	4
31-Oct	11	19.8	326	< 1
04-Nov	12	20.1	86	4
05-Nov	13	20.4	9804	< 1
06-Nov	14	20.5	1733	< 1
07-Nov	15	20.2	1733	< 1
South African National Standards 241:2015				
Drinking water quality limits				
Quality limits			≤ 10	No-detect (0)
			NOT OK	NOT OK

(Source: Authors)

7 Conclusion

This research found that all the prominent aquifers underlying the Johannesburg region have extensive dolomite. These dolomitic aquifers have been identified as the most productive in the Johannesburg/Gauteng region. It also found that the abstraction of groundwater through deep boreholes and wells in the dolomitic aquifers plays an important role in providing water for irrigation and agricultural purposes in Johannesburg. Furthermore, the dolomites in the southern parts of Johannesburg have a high yield of groundwater occurrence. Dolomite rock can easily be dissolved by slight acidic water. Underground caverns can develop in regions where dolomite or limestone is common because water erodes the rock.

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Nexus Between Urban Landuses and Water Pollution

Chidozie Charles Nnaji[1,2](✉) and Chibueze Chekwubechukwu Victory[1]

[1] Department of Civil Engineering, University of Nigeria, Nsukka, Nigeria
{chidozie.nnaji,Chekwubechukwu.chibueze}@unn.edu.ng

[2] Faculty of Engineering and Built Environment, University of Johannesburg, Johannesburg, South Africa

Abstract. Urbanization has been severely implicated in the pollution of freshwater resources through the impairment of urban runoff. Studies have linked specific pollutants to certain kinds of urban landuse and land cover. This study combines conceptual and experimental approaches to explore the impact of landuse and land cover on the physico-chemical characteristics of urban runoff in Nsukka, Southeastern Nigeria. Landuse and landcover classification of the area was undertaken using geographical information system and the location of specific landuses that contribute to runoff pollution such as waste dumps, farmlands, mechanic workshops and industrial sources were identified and digitized using global positioning system (GPS). Then runoff water samples were collected and analysed for physico-chemical parameters. Specific contaminants expected in the runoff were predicted based on the pollutants usually associated with these landuse types. The conceptual predictions were augmented with the results of the physico-chemical analyses. Results showed that the landuses were in this decreasing order: bare land (21.8%), residential built-up (19.2%), Commercial built-up (18.6%), Cropland (16.1%), natural vegetation (10.6%), roads/pathways (10.2%) and institutional landuse (3.6%). The major pollutants specific to these landuses are heavy metals, total phosphorus, total nitrogen, turbidity, hydrocarbons and pathogens. According to the laboratory results, Cr, Fe, Hg, Ni, Pb, Cu and As were the key pollutants with concentrations ranging from 0–0.7, 11.74–47.44, 0–10.0, 1.44–2.67, 0–0.50, 0–1.94 and 0.45–2.26.

Keywords: Water · Landuses · Pollution · Land cover · Rainfall

1 Introduction

Stormwater /Rainwater harvesting, reuse and management (RWHM) is receiving heightened attention globally as an optional source of water supply and has become a practical solution to the water demands in many countries [1–3]. According to [4] there are two major ways of harvesting rainwater namely surface runoff harvesting and roof top rainwater harvesting. The later being the commonest and mostly adopted means is the use of roof to collect rain water while the later uses land surfaces, steep slopes, road surfaces or rock catchments as a means for collecting rainwater. Besides, rainwater harvesting

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as a measure against seasonal water scarcity and decreasing drinking water use, it can become a veritable tool for urban water cycle management. It can cut down nation's external water demand, decrease non-point source pollution, control or avert flooding and help to assuage climate change. Studies revealed that RWH results in a reduction of stormwater runoff volume between 20 to 50% [5]. However, the there is a general apathy towards stormwater reuse because of wide range of contaminants associated with it.

Various studies have shown that in the past, stormwater runoff was considered clean but recently it has been included as a key source of freshwater pollution. It has been reported that 22% to 40% of the total pollutants loading rate of the four major rivers of Korea is as a result of non point pollutant sources [6]. Generally, there is a correlation between types and concentrations of pollutants in stormwater on the one hand, and landuse types on the other [7–9]. Hoffman [10] revealed from his study that over 50% of the annual total pollutant load of PAHs, solids, Pb and Zn in Pawtuxet River are from highway within the city of Cranston, Rhode Island. In developing countries like Nigeria, stormwater has been recognized as a potential source of water quality impairment if uncontrolled.

Stormwater runoff can be a threatening source of pollution which can harm the environment if not carefully handled. The impairment of water quality is because, after most rainfall events, the runoff washes off various pollutants such as dusts, litters, debris etc. off streets, parking lots, construction sites, storage yards, paved roads and dumpsites into the storm sewer system or directly into water bodies untreated. Stormwater carries suspended particles that increase the turbidity of water bodies therefore preventing appropriate amount of sunlight from reaching the aquatic plants to grow, afterwards disrupting the self purification process of the water body concerned. In addition, excess nutrients carried by stormwater into water bodies can lead to algal bloom and its attendant environmental consequences. Besides, bacteria and other pathogens washed into swimming areas poses serious health hazards to swimmers. Urban stormwater also pollutes drinking water sources like stream therefore, making the water unhealthy for drinking or causes health problems when consumed [11].

However, urban runoff pollution characteristic is highly variable (temporally and spatially) due to the randomness of natural rainfall and complexity of urban catchments [12]. Although, the type and extent of impairment differs from place to place, when compared with other causes of pollution and environmental degradation it cannot be underestimated. The objective of this study was to ascertain the extent of degradation of urban runoff due to anthropogenic activities, represented as landuse types.

2 Methodology

Identification of Possible Sources of Stormwater Pollution

A reconnaissance survey showed that the major source of point source stormwater-pollution in this study is waste dumps. Based on this fact, the locations and numbers of dumpsites in the study area were obtained from the State Waste and Management Agency (ESWAMA), as well as through direct observation, asking people questions and diligent search carried out by the authors. The coordinate of these dumpsites were collected using Google map application on a good android phone (techno Y3; SONY and techno WX3). Furthermore, a landuse/landcover classification of the study area was undertaken in order to provide a reference framework for conceptual identification of possible stormwater pollutants in the study area (Fig. 1). The satellite imagery used for landuse/landcover classification was obtained from the USGS database and processed in GIS. This is because certain pollutants are commonly associated with specific landuses.

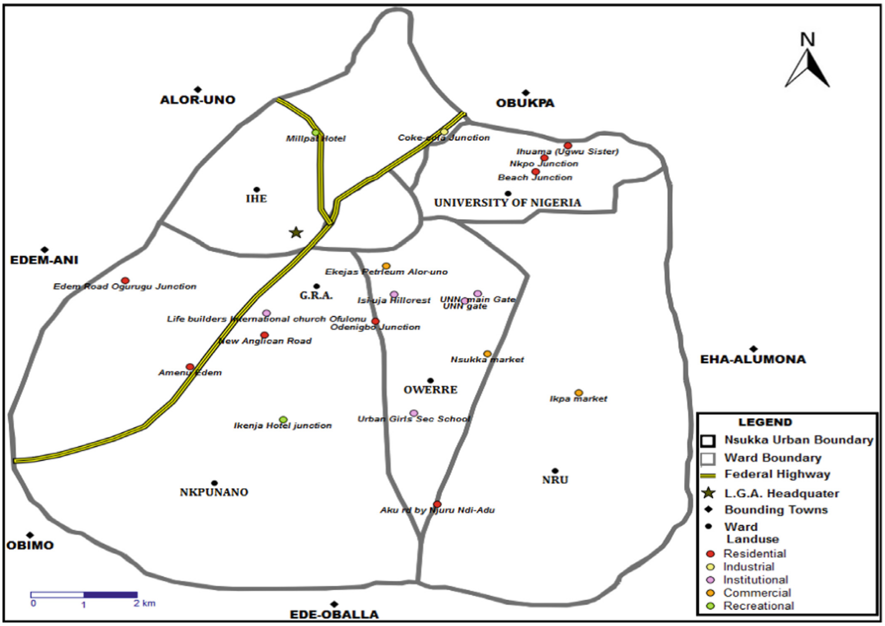

Fig. 1. Topographic maps of the study area, Nsukka Urban

Impact Assessment of Pollution Sources in the Study Area

The approach used in undertaking a predictive and conceptual characterization of stormwater in the study area based on identified sources of pollution (the types of pollutant generated from such source were predicted) and land use classification. Furthermore, stormwater samples were collected and characterized for determination of actual pollutants present. The stormwater runoff was collected during the rainy season from the drain located at the intersection of the University road and the University Market Road. This location was strategically chosen because it serves as a runoff outlet for a greater portion of the study area, which includes the major commercial, residential part of the study area and therefore can serve as a true representative of the storm water runoff (Fig. 2). The samples were collected with clean plastic cans and transported to the University laboratory. The stormwater samples were analyzed for the folloing physico-chemical parameters: turbidity, ph, TDS, EC, and heavy metals. The ph, TDS, EC, were tested in-situ at collection point while the other parameters were tested in the laboratory. All pysico-chemical parameters were determined using standard methods.

Fig. 2. Sample collection from stormwater flow after rainfall

3 Results and Discussion

Landuse/Landcover Classification

The potential point sources of pollution and their respective coordinates within the study area were identified. Figure 3 represents the distribution of these pollution sources within Nsukka urban. It can be observed that the dumps are clustered in areas of high population density. Generally, the waste dumps represent a source of a complex mixture of pollutants which are contained in the leachates produced through biochemical processes. These contaminants are readily dissolved in stormwater and subsequently dispersed into the environment. The dumps are concentrated along major roads of within the urban area.

Based on the landuse classifications (Fig. 4), the largest percentage is the bare land covering approximately 22% of the entire study area (Table 1). The implication of this, is that the larger proportion of the pollutant in the storm water will be silt, sediment and sand particle washed off the bare land therefore, contributing majorly to the total solids (TS) which includes suspended solids and dissolved solids (TSS and TDS) and hence increased turbidity level in the stormwater runoff (Table 2). This explains why most stormwater runoff are reddish brown in colour bearing in mind the type and colour of soil in Nsukka urban environ. This prediction is in agreement with [13] who studied runoff from 15 construction sites and reported that there is an increase in the TSS concentrate and turbidity of the stormwater runoff generated on the construction site due to disturbances on the soil.

The next area with the largest landuse area is the residential built up area. A larger percentage of people spend most of their time in their houses. The volume of pollutants generated is very enormous and diverse due to a high degree of imperviousness associated with rooftops and paved compounds.

The papers, rotten foods and vegetables washed off during storm event account for the organic load and nutrients in the runoff in other words BOD/COD and TN and TP of runoff increases. These discharge of sewage into the environment accounts for a major sources of organic compound and nutrients (such as total nitrogen (TN), total phosphorous (TP) from detergents and soap. Moreover, leakages from sanitary sewers, septic sewers and leaking pipes, coupled with the fact that open defecation has not been

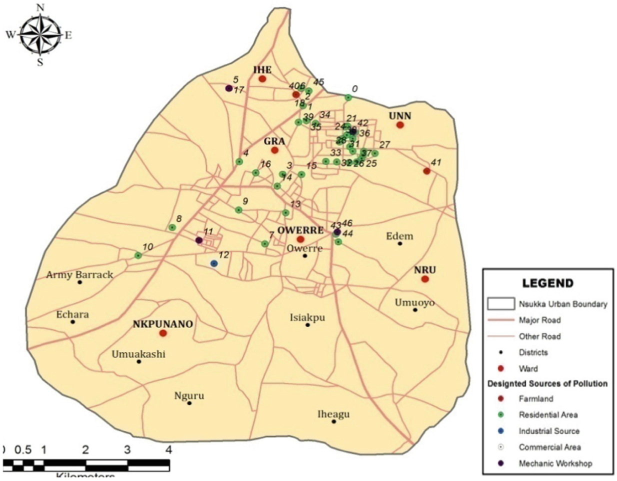

Fig. 3. Map showing point sources of stormwater pollution in Nsukka [21]

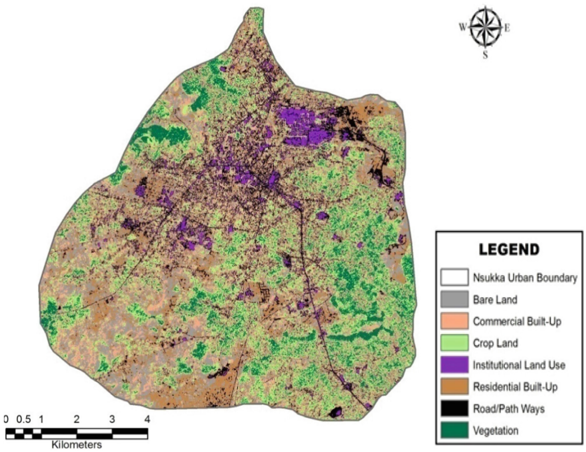

Fig. 4. Landuse classification map of Nsukka Urban using GIS [21]

totally eliminated are major sources of pathogens which will introduce bacteria such as E-coli into the stormwater runoff generated in this area (Table 2). Although institutional area has the least land use cover, the high population density results in generation of large quantities of solid water which usually constitutes between 30 to 50% of biodegradable matter. For instance, there are twenty two (22) identified solid waste dumps located within the premises of the Unibersity of Nigeria, Nsukka.

The next highest landuse class was commercial areas. In commercial areas like Ogige Market, both buyers and sellers dispose dirt such as water sachets, nylons from snacks, plastics and paper indiscriminately on the ground. Spent water sachet waste is a common sight in Nsukka environ and the result of the study revealed the environmental

Table 1. Landuse classification of Nsukka Urban [21]

Land use	Descriptions	Colour indicators	% Cover	Area (km^2)
Vegetation	Undisturbed area where there are bushes, shrubs forest	Green	10.56	9.01
Crop land	Disturbed area i.e. tilled area where crops are grown	Lemon	16.06	13.69
Commercial built-up		Peach	18.61	15.86
Bare land	Sand plains, unpaved areas/, excavation site and construction sites	Gray	21.75	18.55
Residential built-up	Areas where people reside	Brown	19.15	16.33
Road/Path ways	Paved roads and pathways	Black	10.22	8.71
Institutional land use	Schools, university, college	Purple	3.65	3.11

threats posed by this act which ranges from blocking of the drainage systems, blockage of ruminant tracts, soil infertility, pollution of ponds, littering of the environment to air pollution. The commercial areas are source of nutrient like nitrogen, organic matters from wasted food items/spoilt vegetables and rotten fruit all these will also increase the BOD and COD concentration of storm water runoff. Motor parks, filling stations and mechanic workshops are also included in the commercial area and are also potential sources of hydrocarbons in storm water runoff (Table 2).

Cropland area is the 4th largest landuse which covers about 16.06% of Nsukka urban. These are areas that have been disturbed through tilling and farming activities and are thus a major source of solids. Croplands are also pollution source of nutrient like potassium, nitrogen, phosphorus which is due to fertilizer application. Besides, heavy metals such as cadmium, arsenic, nickel, cobalt and toxic chemical can also be present in runoff due to application of pesticides, fumigants and various chemicals applied on the cropland. Dried leaves get rotten and are carried away by storm water runoff during the rainy season and then becomes a source of organic matter. These also increases the BOD, COD and TN concentration in the storm water. Huang et al. [14] found that COD and total phosphorus (TP) were the major pollutants with event mean concentrations of 56.09 mgL^{-1} and 0.44 mgL^{-1} in urban runoff from Xiamen City of China. It is worthy of note that there will be a substantial amount of some of heavy metals from the roof present in the stormwater runoff, which is a product of the material the roof is made of, particularly Zinc from every built up areas that are roofed whether it be commercial, residential or institutional areas [15].

Table 2. Conceptual characteristics of stormwater runoff generated in Nsukka Urban [21]

Land use classification (activities that generates pollutants or sources of pollutants in such landuse)	Types of pollutants generated											
	Total solids (TS) (TDS)(TSS)	Turbidity	Nutrients		Pathogens	Heavy Metals					Organic BOD/CODs	Hydrocarbons, PAH, oil & grease
			TP	TN		Cu	Zn	Pb 90	As	Hg		
Residential area (19%) And Institutional area (3%)												
Food wastes				M							M	
Leakages from septic tank and open defecation	M	M	M	M	M						M	
Grey water from kitchen, bathroom and laundry	M	M	M	M	M						M	
Litters from papers											M	
Leachate from dumpsites	M	M	M	M	M				M		M	
Roofs							m	m	M			
Commercial area e.g. markets, shopping mall (19%)												

(*continued*)

Table 2. *(continued)*

Land use classification (activities that generates pollutants or sources of pollutants in such landuse)	Types of pollutants generated											
	Total solids (TS) (TDS)(TSS)	Turbidity	Nutrients		Pathogens	Heavy Metals					Organic BOD/CODs	Hydrocarbons, PAH, oil & grease
			TP	TN		Cu	Zn	Pb 90	As	Hg		
Dirt and debris	M	M										
Rotten food item and vegetables				M							M	
Waste from animals rearing/wastes and abattoirs				M	M						M	
Parks, filling stations, mechanic workshops	M	M					M	M	m	m		M
Leachates from dumpsites	M	M	m	M	M				m	m		
Roofs							m	m				
Bare land (22%)												
Soil erosion in unpaved areas	M	M	m									
Construction sites	M	M										
Crop land (16%)												

(continued)

Table 2. *(continued)*

Land use classification (activities that generates pollutants or sources of pollutants in such landuse)	Types of pollutants generated											
	Total solids (TS) (TDS)(TSS)	Turbidity	Nutrients		Pathogens	Heavy Metals					Organic BOD/CODs	Hydrocarbons, PAH, oil & grease
			TP	TN		Cu	Zn	Pb 90	As	Hg		
Cultivated areas where fertilizers are applied.	M	M	M	M					M			
Debris from fallen dry leaves	m	M	m	M					M			
Vegetations (11%)												
Trees, shrubs green areas												
Debris from fallen dry leaves.	m	M	m	M					M			
Roads (10%)												
Wears and tears from tires and brakes						M	M	M				
Wash off from vehicle bodies						M	M					
Road abrasions	m											m

M = major pollutants, m = minor pollutants

Table 3 reveals that the concentrations of pH, TDS, Cu and Mn in the stormwater samples examined fall within the WHO standard for drinking water, while the rest of the parameters violated their respective guideline values as specified by the WHO. The high level of turbidity can be attributed to bare soil which the highest proportion (21%) of the total landuse/land cover. Soil particles detached from bares soil and transported by stormwater is responsible for the brownish colour of the water samples. This is due to the dissolution of oxides of iron (Fe) which abound in the lateritic formation of the study area. Cropland which makes up 16.06% of the land cover also contributes to turbidity due to detachment and transport of loose soil particles. There was a clear discrepancy between samples 1 and 2, despite having been collected from the same spot. These differences can be attributed to the characteristics of the two rainfall events that produced the runoff. [16] affirmed that rainfall characteristics remain a critical influential factor to be considered when determining the stormwater quality because it influences the pollutant wash off process. Rainfall characteristics can be described in term of rainfall duration, rainfall intensity and runoff volume [17]. Among these terms, the rainfall intensity was the major factor responsible for the disparity in results. [18] explains that kinetic energy of the rainfall and the turbulence caused in surface flow are the driving force responsible for the pollutant carrying capacity of any rainfall. Therefore, the rainfall of high intensity tends to transport coarser particles owing to high turbulence created in the surface flow which will then result in runoff having a higher pollutant load (high turbidity and high total suspended solid load) and larger particle sizes. The turbidity of sample 2 was higher than that of sample 2 by several orders of magnitude because the rainfall that produces sample 2 was more intense. Furthermore, [19] reported that the first 10% of the washoff process has a close link with the runoff volume which is related to rainfall duration and rainfall depth. The runoff volume for the rainfall event1 is lesser than the rainfall event 2. It is obvious that there is a correlation between the turbidity levels of water or total suspended solids and concentration of heavy metal present in it. [13] observed that correlation values more than 0.5 existed between the runoff concentrations of total suspended solid and the particulate runoff concentrations of some heavy metals.

The relative concentration of the heavy metals followed the order of Fe > K > Hg > Ca > Na > Ni > Cu > Mg > Cr > Pb > As in sample 1 and Fe > Na > K > As > Zn > Cr > Mn > Cu > Cd > Pb > Hg in sample 2. The result shows that the concentration of Fe is the most abundant in the raw water samples. The higher concentration of Fe in the runoff can be attributed to the lateritic nature of the soil in the study area, and lateritic soils are known to be very rich in Fe. The concentration of Fe is closely linked to the proportion of bare land and cropland exposed to the erosive power of flowing water. The least concentration of metal common to both samples is Pb. However, some of the concentrations of these metals are within the range of values obtained by some authors. [20] obtained a range of 0.007–0.422 mg/L for Pb for runoff from residential catchment in Miri Sawark, Malaysia during two storm events. The presence and concentration of other metals like As, Zn, Cr, Cu and Ni in runoff can be attributed to the emissions from vehicle emissions, depositions of metals from wears and tears of automobile tyres on the road surface which is eventually conveyed by the runoff.

Table 3. Characterization results of runoff from two different rainfall event

Parameters (Unit)	Sample 1	Sample 2	WHO Guideline	Remark
pH	7.74	8.31	6.5–8.8	Acceptable
EC(μS/cm)	230	105	No established standard	Not too significant
TDS(mg/l)	156.67	70	< 600 mg/l	Acceptable
Turbidity (NTU)	152	1457	Not exceeding 0.5	Not acceptable
Ca(mg/l)	9.3340	28.8	No established standard	Not too significant
As(mg/l)	0.4516	2.258	0.01(A,T)	Not acceptable
Cu(mg/l)	1.9400	Na	2	Acceptable
Fe(mg/l)	11.7380	47.441	No established standard	
Hg(mg/l)	10	0	0.006	Not acceptable
K(mg/l)	10.2100	4.6408	No established standard	Not too significant
Na(mg/l)	6.6146	5.4078	No established standard	Not too significant
Ni(mg/l)	2.6666	1.4358	0.07	Not acceptable
Pb(mg/l)	0.5	0	0.01(A,T)	Not acceptable
Mg(mg/l)	Na	27.2	No established standard	
Mn(mg/l)	0.0000	Na	Not exceeding 0.05	Acceptable
Cr(mg/l)	0.7000	Na	0.05 (P)	Not acceptable

A, provisional guideline value because calculated guideline value is below the achievable quantification level; T, provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source protection, etc.

4 Conclusion

The study area comprises of various landuses such as: bare land, cropland, built up area, vegetation, roads and commercial/institutional areas which determine the type of pollutants present in stormwater. A high proportion of bare land is responsible for the high degree of turbidity and the intense reddish-brown colour of stormwater is due to the dissolution of Fe from the lateritic soil make-up. Apart from, pH, TDS, Mn and Ca, all the other physico-chemical parameters were in violation of WHO drinking water standards. As a result, urban runoff cannot contribute meaningfully to the amelioration of urban water stress in the study area, without treatment.

Hence, treatment would be required to render stormwater in the study area suitable for domestic application. Simple and low-cost treatment methods such as sedimentation, slow sand filtration and adsorption can be used to reduce the degree of urban runoff contamination. It is further recommended that proper waste management strategies be adopted by the municipal authorities in order to significantly reduce the transfer of pollutants from the physical environment into urban runoff.

The major limitation of the work is that it could not cover all the wide arrays of possible contaminants found in the urban environment. A more extensive and elaborate work would be required to do that, with the attendant cost implications. Hence, it is recommended that future works should increase the number of water quality parameters, number of samples and duration of study.

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Barriers to the Exploration of Land Resources for Construction Works in Osun State, Nigeria

Sunday Odediran[1,2](✉), Clinton Aigbavboa[2], and Seun Olubolade[1]

[1] Department of Quantity Surveying, Obafemi Awolowo University, Km 5 Ibadan Road, Ile-Ife 220282, Nigeria
sjodediran@oauife.edu.ng

[2] Faculty of Engineering and the Built Environment, University of Johannesburg, 37 Nind St, Doornfontein, Johannesburg 2094, South Africa
clinton.aigbavboa@uj.ac.za

Abstract. Natural environment has suffered decay for ages through various human activities including the exploration of land resources that are required for construction sector towards the provision of human needs such as housing and other basic infrastructures. There is a dearth of research works that document activities in the exploration of land resources for construction works, hence this study. This paper examines the barriers to the exploration of land resources for construction works with a view to achieving a sustainable environment. A quantitative research approach was employed using questionnaire to purposively collect data from 10 quarry operators, 16 sand miners and 30 sawn mailers in Osun state, Nigeria. Data collected were analyzed using frequency distribution, mean score and analysis of variance. Although the views of the key players in the exploration of land resources for construction works were examined, their overall responses ranked insecurity (M = 4.21), poor road network (M = 4.10), occupational hazards (M = 4.04), work related deaths (M = 3.95), financier barrier (M = 3.84) and energy cost (M = 3.71) as barriers faced in the exploration of land resources for construction works. The study concludes that failure in public systems and poor provision of basic infrastructure are inhibiting the exploration of land resources for construction works.

Keywords: Barriers · Construction works · Exploration · Land resources · Nigeria

1 Introduction

Having identified that so many developmental activities including construction projects threaten environment, the United Nation General Assembly in 2015 adopted the 2030 Agenda for sustainable development, which include 17 sustainable development Goals (SDGs). Goal 15 focuses on "Life on Land" and it aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. There is a global concern on how to address continuous environmental degradation usually caused

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by exploration activities including mining of land and land resources [2]. According to [4], the impact of environmental degradation can only be measured based on the threat it poses to human health and the environment, as well as the devastating alterations in nature. Environmental protection is essential for long-term development, yet it is believed that if we do not safeguard the natural environment and its resources, human development and expansion will be short-lived [4].

According to [15] and [16], land and land resources as earth's terrestrial encompasses biosphere that is above or below earth including the near-surface climate, soil and terrain forms, surface hydrology, near-surface sedimentary layers and accompanying groundwater and geo-hydrological reserve, plant and animal populations, and human populations. Earth's terrestrial also includes settlement patterns and physical impacts of previous and existing human activities (terracing, water storage or drainage infrastructure, roads, buildings, etc.) [15, 16]. Similarly, mineral is a chemical compound that is crystalline in nature and generated by geological processes [13], which could be in the form of aggregates often referred to as rocks [14]. Minerals can be categorized into metallic minerals (e.g. iron and gold.); industrial minerals (limestone and baryte); construction minerals (gravel sand and rock aggregates); gemstones (Emerald and topaz); and mineral fuels (coal and hydrocarbons). These minerals are explored (mined) and used in one way or the other for human purposes including construction [5] and the process could be expensive with associated uncertainties [6].

Exploring and mining of these land resources for immediate human uses are not without the involvement of some players that are mostly dominated by the less-privileged groups in the society including local business owners, women, skilled exploration workmen and local exploration workmen. These are involved in the exploration of land resources, process raw materials exploited into goods fit for sale for profit making, make use of plants and equipment for mostly large scale exploration and make use of simple tools for carrying out artisanal and small scale exploration [6]. The processes of exploration produce a great deal of noise due to use of heavy trucks, equipment and machineries including people screaming and radio turned up excessively and loudly. The excessive noise generated during exploration process is not only irritating and distracting, but it can also cause hearing impairment, high blood pressure, sleep disturbances and high levels of stress [7].

In many countries, the extraction of mineral resources is the heartbeat of the economy. However, the consequences of these exploitation activities, such as abandoned mine sites, biodiversity loss, and the usage of chemicals that pose health concerns to mining workers and communities, should be given immediate consideration [1]. This is because, for example, construction operations utilize over half of all nonrenewable resources consumed by humans, making it one of the least sustainable industries on the planet. Humans now live in houses, travel on roads, and work and socialize in a variety of structures. Due to continuous existence and increase in the structure of modern society, humans depend on construction of buildings for shelters and other associated structures; however, the current level of consumption of these resources cannot be sustained by the planet [12].

It was further claimed that the method of acquiring construction materials is damaging environment at an increasing rate due to increase in human population because of high demand for construction materials. Rising population is also putting pressure on scarce land, forests and wetlands leading to damages at quicker rate [12]. According to [9], construction must support a world of continued population increase and economic progress while also taking into account popular social concerns about environmental preservation, a goal that has yet to be met. Situation report in United Kingdom (UK) by [12] reveals that stone and primary aggregates, such as sand and gravel, account for the majority of resources used in the UK construction industry. Extraction of these resources resulted into loss of habitat and ecosystem, landscape damage, potential subsidence issues, and methane release. The extraction of most of these materials go through a number of manufacturing procedures, each of which consumes energy and requires transportation. These processes contribute to the depletion of natural resources, the generation of waste that must be disposed of, and the emission of greenhouse gases into the atmosphere. The extraction activities also contributed to local pollutions like noise and dust [12]. [3] reports that mining in Jos, Plateau State in Nigeria has resulted in the devastation of pastoral land and several people have died due to increase in the magnitude of mine ponds and release of radioactive materials (waste) damaging the environment.

Certain factors according to [9] contribute to increase in extraction activities. Key on the list are the prevailing problem of unemployment and poverty in developing countries, which provides limited option for individuals when seeking their means of livelihood. The increasing demand for land resources for construction activities is equally increasing extraction activities. However, certain factors also inhibit the mining of natural resources in both the developed and developing economies. Limited studies examined the activities in the exploration of land resources for construction works. In lieu of this, the paper examines barriers to the exploration of land resources for construction works in Osun State, Nigeria.

2 Barriers to the Exploration of Land Resources for Construction Works

Barriers are described as what hinders or constrains the activities/processes in the exploration of land resources. Examples of such barriers include occupational hazards, work-related deaths and occupational diseases, fatalities and accidents. On occupational hazards and work-related deaths, the International Labour Organization (ILO) described an occupational hazard as a condition that has the potential to cause an accident, resulting in harm, damage, or both. Occupational hazards have negative impacts on employees' health, resulting in a decrease in organizational production and efficiency, as well as negative impacts on the organization's image and overall status [10]. Hazards in the workplace have the potential to harm individuals [17]. Injuries, disabilities and fatalities at workplaces continue to be an area of concern across the globe [11].

[8] claimed that work-related deaths are usually caused by occupational diseases, fatalities and accidents. In 2010, occupational fatalities is estimated at 2.34 million and 321,000 of these fatalities are originated through work-related accidents while 2.02 million deaths emanated from work-related diseases. This gives average deaths of 5,500 on daily basis. The cause of most health hazard outside office settings is prolonged activities, which is associated with lung diseases. However, mines explorations cannot

be done over prolonged periods due to the strain it places on the body because of its physical demands.

Other significant barrier to the exploration of land resources is registration and licensing policies. The process of registration and obtaining licenses by the private sector companies who are the key players in the mining sector is governed by the government (public institutions) and this constitutes a significant entry barrier to the mining or exploration of land resources [19]. These policies, which are intended to ensure free and fair competition, as well as decent and productive labor for all parties involved, most times hinder the process. Additionally, most of the policies that govern the private sector operations and activities are outdated and do not encourage innovation and entrepreneurship. Some important administrative procedures are obsolete and have become barriers in achieving the desired goals [19, 20].

Use of technology is changing the business world and has made innovation possible in global sectors. However, little adoption of technology creates setback in some sectors due to complexity and fragmentation issues. Technology adoption is in stages and it is possible to upgrade from one stage to another as business success is achieved in a stage. However, upgrading in technology is beyond the scope of small and medium enterprise (SMEs) and this continues to be a barrier in the mining industry especially where major players are SMEs [23]. There is a rising global concern that the economic benefits of participation in global value chains may not always convert into decent jobs or steady employment. Although it is becoming essential to upgrade in order to participate in the value chain. [23] further claimed that economic upgrading is associated with significant degradation in labor conditions and other forms of social degrading.

Tax system is another key barrier to the mining and exploration of land resources. Taxes continue to acts as a trade barrier in most countries of the world. However and due to the fluctuating nature of taxation, tax structure does not sufficiently serve the demands of SMEs who are essential players in mining and exploration sector, which has also put heavier burden on taxpayers and ultimately harming the final consumers [22]. Most of the tax laws are unfriendly to SMEs' growth and productivity. Competition is also a significant barrier and [18] claimed that the size of a company is a barrier to entry and participation in mining industry and exploration activities. Most times, operation requirement in term of size of investment for high value operations are beyond the capability of SMEs in North America [23]. However, opportunities for learning, partnerships, and upgrading throughout the value chain exist to bridge this gap [24].

Mining and exploration industry is an artisanal-driven sector where most activities rely heavily on one skill or the other. However, global report shows that miners' skills are poorly managed [26]. Miners are also unable to improve and preserve in-house technology, which serves as a barrier of entry into mining activities [21]. The list of these barriers to the exploration of land resources is presented in Table 1.

3 Research Methodology

An extant review of literature was carried out to establish the research variables that were used in this paper, which include the barriers to the exploration of land resources for construction works. The study employed a quantitative research approach in the collection and analysis of data presented and discussed in this paper. The study was conducted on the key players in the exploration of land resources for construction works in Osun state, Nigeria, which include quarry operators, sand miners and saw mailers. The operations of these players are less regulated and mostly informal in the study area. These categories of players were selected for this study because they produce materials that are mostly used for construction works.

Table 1. Barriers to the exploration of land resources for construction works

No	Barriers	Authors/Sources
1	Work related accidents, diseases & deaths	ILO, 2010; Harrison 2002; Murray, 2011
2	Physical exhaustion	Harrison (2002); Murray, Davies and Rees, (2011)
3	Occupational hazards	ILO, 2010; Smallwood, 1995; NSSA, 2012; Walker and Collins, 2003
4	Registration and licensing policies	Kanbur and Venables, 2005; Kaplinsky, 2010; Mitchell et al., 2009; Tijaja, 2013
5	Technological barriers	Gereffi, 2013; OECD, 2007b; Quinn et al., 2012; SELA, 2002
6	Taxation/tax system	Mnewa and Maliti, 2008; UNIDO, 2009
7	Competition, size of company and operation requirements	Caspari, 2003; Gereffi, 2000
8	Skills and competency	OECD-APEC, 2006;
9	Insecurity	Pilot study
10	Poor road networks	Pilot study
11	Energy cost	Pilot study
12	Financial barriers	Pilot study
13	Registration fees	Pilot study
14	Ethical standards	Pilot study

Since the activities in the mining and exploration industry are less regulated in Nigeria, it is difficult to determine the study population or sampling frame for the study. However, a pilot study was conducted in major towns in the study area including Ede, Ile-Ife and Osogbo (state capital) with each representing the three senatorial districts in Osun State of Nigeria, to determine the sampling frame from which the sample size was determined. A purposive sampling technique was adopted to select 80 players (including quarry operators, sand miners and saw mailers) on whom copies of questionnaire were administered. However, 56 players including 10 quarry operators, 16 sand miners and 30 saw mailers responded to the questionnaire survey. This gives a response rate of 70% of sampling frame.

Data were collected through the administration of a well-structured questionnaire, which was structured into two sections. Section A explored the general background of the responding players and the information collected include sex, age group, marital status and number of children. Others include work association, name of association, operational location, highest academic qualification, designation of the respondents and mining industry experience. Section B examined the barriers to the exploration of land resources for construction works. Copies of questionnaire were administered through the face-to-face contact with the players by visiting their sites, parks and mills for quarry operators, sand miners and saw mailers respectively.

Data obtained through questionnaire survey were analyzed using statistical packages for social scientists (SPSS) version 16. Both the descriptive and inferential statistical tools were employed in quantitative data analysis, which include frequency distribution (percentage), mean score and analysis of variance (ANOVA). Frequency distribution measures the percentage of respondents who responded to a particular variable while mean score measures the rate of perceptions of respondents to certain number of variables. ANOVA measures whether there is a significance difference on how more than two groups of respondents perceived certain number of variables.

4 Results and Discussion of Findings

This section presents results of analysis of data collected from the respondents to this study. The data collected and analyzed include background profile of the respondents and barriers to the exploration of land resources for construction works. More details on the results are presented in the relevant subsequent sections.

4.1 Background Profile of the Firms and the Respondents

This section presents information on the background profile of those who responded to the questions raised in this study. The information requested from and provided by the respondents cover their sex, age group, marital status, number of wives, number of children, work associations and name of the association. Other information provided are the respondents' operational location, resources explored/mined, highest academic qualification, designation and mining industry's experience. The results on these are discussed in the subsequent paragraphs.

The results on the sex of the respondents show that 53(94.6%) and 3(5.4%) are male and female respectively. This shows that the exploration or mining industry in the study area is dominated by male gender. The results on the respondents' age group reveal that 11(19.6%) are in 20–30 years age group while 24(42.9%) and 21(37.5%) are in 31–40 years and above 40 years age groups respectively. This shows that majority of the respondents are adults, older than 30 years. On marital status, 13(23.3%) and 43(76.8%) are single and married respectively. This shows that the majority of the respondents are married. However, 39(69.6%) have one wife each while 6(10.7%) have two wives. However, 11(19.6%) do not have wives. This reveals that majority of the respondents married one wife.

In term of the number of children that they have, 4(7.1%), 12(21.4%), 19(33.9%), 6(10.7%) and 15(26.7%) of the respondents have 1, 2, 3, 4 and above 4 child/children respectively. Majority of the respondents have more than one children. Considering the results on number of wives with the results on number of children, it shows that some respondents that they do not have wife have children. On type of work of the respondents, 10(17.9%) are working in quarries while 30(53.6%) and 16(28.6%) work in sawmill and sand mining sub-sectors respectively. However, they belong to relevant associations such as Miners Association of Nigeria (17.9%), Association of Sawn Timber Dealers (53.6%) and Sawmill Owners and Association of Tippers and Quarry Owners of Nigeria (28.6%).

Moreover, the operational location of the respondents within the study was examined and the results reveal that 27(48.2%) have their works located in Osogbo (the state capital) while 15(26.8%) and 14(25.0%) work in Ede and Ile-Ife respectively representing the three senatorial districts in the state. Majority of the respondents are working in Osogbo. Results on types of resources that they are mining for construction works show that 30(53.6%), 16(28.6%) and 10(17.9%) are mining woods/timbers, sand and granite respectively. The highest academic qualifications of the respondents were examined and the results reveal that 1(1.8%) is a holder of primary education while 3(5.4%) and 40(71.4%) hold junior secondary and senior secondary educations respectively. Others, who are 12(21.4%) hold higher educational qualifications such as national diploma (ND) and higher national diploma (HND).

Results on the designations of the respondents show that 7(12.5%) are each owners and engineers while 12(21.4%), 14(25.0%) and 16(28.6%) are operators, drivers and gang leaders respectively. Their work experiences in mining industry were examined and the results show that 5(8.9%), 19(33.9%) and 12(21.45) have 0–5 years, 6–10 years and 11–15 years' work experiences respectively. Moreover, 10(17.95) each have 16–20 years and above 20 years respectively. This shows that majority of the respondents have more than 10 years work experience in mining industry.

4.2 Barriers to the Exploration of Land Resources for Construction Works

In this section, barriers to exploration of land resources for construction works are discussed. Five Likert scale rating (0–5) was used in data collection to determine the opinions of the respondents in the study area. The results are as presented in Table 2 and the views of the quarry operators show that the high ranked barriers include occupational hazards (M = 4.00), work related deaths (M = 3.90), insecurity (M = 3.90) and poor road networks (M = 3.70). The least ranked barriers by quarry operators are registration fees (M = 2.80), physical exhaustions (M = 2.90), technological barriers (M = 2.90) and competition (M = 3.00).

The results on the views of sawn mailers reveal financial barriers (M = 4.33) as the top high ranked barrier. This is followed by insecurity (M = 4.27), poor road networks (M = 4.23), work related deaths (M = 4.20), occupational hazards (M = 4.13) and energy cost (M = 4.07). The least ranked barriers by sawn mailers are competition (M = 3.53), competency and skill (M = 3.53), taxation (M = 3.60), ethical standards (M = 3.63) and technological barriers (3.63).

From the views of the sand miners, insecurity (M = 4.31) was the top high ranked barrier. This was followed by other high ranked barriers that include poor road networks

($M = 4.06$), occupational hazards ($M = 3.88$), competency and skill ($M = 3.81$), physical exhaustions ($M = 3.75$) and technological barriers ($M = 3.56$). The least ranked barriers by sand miners include competition ($M = 3.13$), ethical standards ($M = 3.19$), registration fees ($M = 3.31$), taxation ($M = 3.31$) and financial barriers ($M = 3.31$). Similarly, the overall responses of the respondents ranked insecurity ($M = 4.21$) high as a barrier. Other high ranked barriers include poor road networks ($M = 4.09$), occupational hazards (4.04), work related deaths ($M = 3.95$), financial barrier ($M = 3.84$) and energy cost ($M = 3.71$). From the overall views, the least ranked barriers to exploration of land resources for construction works are competition ($M = 3.32$), ethical standards ($M = 3.41$) and taxation ($M = 3.43$).

In order to test the level of agreement in the overall opinions of the respondents on their ranking of barriers to the exploration of land resources for construction works, ANOVA was used to determine if there is a significance difference in the way they perceived the list of barriers and 1% ($P \leq 0.01$) and 5% ($P \leq 0.05$) level of significances were used. The results of ANOVA on Table 2 reveal that there is a significance difference in the way all categories of respondents perceived work related deaths ($P \leq 0.01$), physical exhaustions ($P \leq 0.01$), energy cost ($P \leq 0.01$), registration fees ($P \leq 0.01$), technological barriers ($P \leq 0.05$) and financial barriers ($P \leq 0.01$) as barriers to exploration of land resources for construction works. This implies that the respondents perceived these drivers differently.

5 Conclusion

This paper examines the barriers to the exploration of land resources for construction works. From the results obtained, the paper concludes that mining industry and most especially the exploration of land resources for construction work is a male dominated sector. Majority are adults, married to one wife and gave birth to more than a child. The types of resources being mined for construction works include woods or timbers, sand and granite. A more than one decade experience justify appropriateness of investigating the activities in the exploration of land resources for construction works.

Moreover, based on the central aim of this paper, which is to examine the barriers to the exploration of land resources for construction works, the paper further concludes that the significant constraints (barriers) encountered in the exploration of land resources for construction works include insecurity, poor road networks, occupational hazards, work related deaths, financial barrier and energy cost. The respondents agreed that there is no significant difference in their perceptions of these important barriers except work related deaths, physical exhaustions, energy cost, registration fees, technological barriers and financial barriers.

In lieu, this paper concludes that there are barriers (factors) inhibiting the exploration of land resources for construction works in Osun state, Nigeria. However, the results reported in this paper are limited to information obtained from respondents that were reached in the selected towns in Osun State, Nigeria. To generate these results to the entire state or country, a large-scale research will be required where a large number of respondents (audience/players) could be reached to validate the findings of this paper. The construction materials considered in the study were limited to wood/timber, sand

Table 2. Barriers to the exploration of land resources for construction works

Barriers	Type of players									
	Quarry operators		Sawn mailers		Sand miners		Overall		ANOVA	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	F	Sig.
Work related accidents, diseases and deaths	3.90	2	4.20	4	3.50	7	3.95	4	5.299	**0.008**
Physical exhaustions	2.90	12	3.90	7	3.75	5	3.68	7	7.055	**0.002**
Occupational hazards	4.00	1	4.13	5	3.88	3	4.04	3	0.536	0.588
Insecurity	3.90	2	4.27	2	4.31	1	4.21	1	1.341	0.270
Poor road networks	3.70	4	4.23	3	4.06	2	4.09	2	2.157	0.126
Energy cost	3.10	8	4.07	6	3.44	8	3.71	6	8.054	**0.001**
Registration fees	2.80	14	3.87	8	3.31	10	3.52	9	7.727	**0.001**
Ethical standards	3.10	8	3.63	10	3.19	13	3.41	13	2.510	0.091
Registration and licensing policies	3.20	5	3.67	9	3.44	8	3.52	9	1.671	0.198
Technological barriers	2.90	12	3.63	10	3.56	6	3.48	11	4.291	**0.019**
Taxation/tax system	3.10	8	3.60	12	3.31	10	3.43	12	1.537	0.225
Competition, size of company and operation requirements	3.00	11	3.53	13	3.13	14	3.32	14	2.026	0.142
Skills and competency	3.20	5	3.53	13	3.81	4	3.55	8	1.847	0.168
Financial Barrier	3.20	5	4.33	1	3.31	10	3.84	5	11.764	**0.000**

and granite, other materials could be considered to obtain a more accurate information on exploration of land resources for construction works in the study area.

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