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Aim and Scope

The Environmental Technology and Science Journal (ETSJ) is devoted to the publication of papers which advance knowledge of practical and theoretical issues that daily plague our society. The aim of the journal is to provide an avenue for the dissemination of academic research findings from various disciplines of the environment, engineering, pure and applied sciences, arts and social sciences, which have materials that emphasize on environmental issues.

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Jimoh, R.A. & Adama, S.M. (2014). Assessment of preliminaries in relation to the total cost of renovation work in public schools in Abuja, Nigeria. *Proceedings of ICEC 2014-IX World Congress conference, Total Cost Management in Difficult Times*, organised by the Italian Association for Total Cost Management in Milan, 20th-22nd October 1-9

Jimoh, R.A (2014). Contribution of Co-operatives to Housing Provision: The Road Less Travelled in the Last 100 Years. In Y.A Sanusi, A.M Junaid, O.O Morenikeji, S.N. Zubairu, R.A. Jimoh & O.F. Adedayo (Eds.), *100 Years of Urbanisation in Nigeria* (pp. 219 – 236). School of Environmental Technology, Federal University of Technology, Minna

Oyewobi, L.O. (2014). *Modelling performance differentials in large construction organisations in South Africa*. Unpublished PhD thesis, University of Cape Town, Cape Town.

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Editorial

You are welcome to volume 14, number 2, December 2023 edition of Environmental Technology and Science Journal (ETSJ). In this edition, there are 15 articles that cut across the built environment research domain.

The efforts of our Reviewers are commendable! We are grateful to our contributors for considering and using ETSJ as a platform for disseminating their research outputs. Please, keep the manuscripts coming! May all our wishes come through in 2024 and beyond.

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Let us do it again, peace!

R. A. Jimoh
Managing Editor

Contents

Evaluation of Metals in Printed Wiring Boards of Selected Discarded Mobile Phones in Nigeria

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Obsolete mobile phones form a major component of the e-waste stream. The Printed wiring boards (PWBs) of mobile phones are packed with economic and toxic metals. Regulatory bodies such as Restriction of Hazardous Substances (RoHS) directives regulate the amount of these toxic metals in electrical and electronic equipment. This study is aimed at evaluating selected critical metals present in PWBs of three popular brands of discarded mobile phones used in Nigeria to understudy the behaviour of original equipment manufacturers (OEMs) regarding toxicity, economic potentials, and level of compliance with international initiatives by regulatory bodies to reduce the level of toxic metals in electronic equipment. PWBs obtained from 60 discarded mobile phones of 3 popular mobile phone brands used in Nigeria were chopped into smaller particles, extracted according to EPA 3050B method, and analysed using the Inductive Coupled Plasma-Optical Emission Spectrometry technique. It was observed that Mn, Fe, Zn, and Cu, had the highest concentration range across all brands studied. Notable toxic metals such as Pb, Cd, Cr, and As have mean and standard deviation values of 0.43±0.38 mg/kg, 0.62±0.160 mg/kg, 5.16±1.06 mg/kg, and 84.97±13.83 mg/kg respectively. Economic metals: Cu, Ag, and Au had mean and standard deviation values of 80.37±16.89 mg/kg, 2.12±0.43 mg/kg, and 0.95±0.19 mg/kg respectively. Results from the study indicate that PWBs of mobile phones are a perfect secondary source of a large variety of metals vital for the recycling industry. Also, the low levels of toxic metals suggest that some OEMs are already adopting the 'design-for-environment' option. Therefore, PWBs studied seem eco-friendly; however, need to be handled with care as there are still some toxic metals of concern not determined in this study.

Keywords: Restriction of Hazardous Substances Directive, Environmental pollution, Recycling, Toxic metals, Eco-friendly products

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INTRODUCTION

A large percentage of municipal waste generated globally consists of e-waste. This percentage is growing at least three times faster than municipal solid waste (Genus Earth, 2022; Rimantho *et al*., 2022). The rapid growth in e-waste generated has been predicted to continue to rise since most electrical equipment is designed to have a short lifespan (Kasper *et al*., 2011; Omondi *et al*., 2022; Gómez et al., 2023), generating more obsolete products (Patel & Bina, 2016; Terena *et al*., 2017) and the craving for the advancement of communication and technology. Furthermore, the present design of electrical equipment which mixes metals (both toxic and non-toxic), plastic, and ceramic makes the separation of these materials for recycling extremely difficult and unfeasible (Osibanjo *et al*., 2016; Yken *et al*., 2021) thereby ending up in the waste stream. The 2020 Global e-waste monitor reported that 41.8 million tons of e-waste was generated by 2014. This amount of e-waste showed a growth rate of 20% in 2016 generating 44.7 million tons and a 28% rise by 2019 with a whopping sum of 53.6 million tons of e-waste which amounted to an average of 7.3 kg per capita generated globally (Forti *et al*., 2020, Ruiz, 2023). Statista (2023[a]) predicted that these values would increase to 57.4 million tons by 2021, 59.4 million tons by 2022, and 61.3 million tons by 2023. Despite the alarming amount of e-waste reported to be generated globally, only approximately 17% of this waste was reported to be recycled globally (Forti *et al*., 2020; Statista, 2023[a], Ruiz, 2023). Similarly, in 2019 Nigeria generated approximately 461,300 tons of e-waste with only an approximate amount of 0.4% recycled (Kasper *et al*., 2011; UN Environment Program (UNEP), 2019; Olu, 2023). Therefore, this shows that a greater percentage of the e-waste generated was handled in an environmentally unsustainable manner ending up in landfills.

Statista (2023[c]) stated that as at 2021, 1.43 billion mobile phone units were being sold to end users globally. This amount is on an increase due to the short lifespan of these mobile phones which makes them obsolescent (Gómez *et al.,* 2023). Nigeria, in 2012 was reported to be in the 10th position of countries with the highest mobile phone ownership globally of 90.5 million with Germany at the 9th position (107 million), the USA at the 3rd position (over 327.5 million), India at the 2nd position (over 873.6 million), and China (over 951,6 million) topping the rating (Daily Infographics, 2012). Guardian (2021) and Statista (2023[b]) reported that in 2023, Nigeria has an estimated number of 170

million mobile phone users (based on subscription). This population is expected to increase by 60% by 2025. Mobile phones are one of the smallest pieces of electrical equipment. Despite being small, it contains a large concentration of economic metals such as Au, Cu, Ag, Al, Pt, Sn, Co, and Ni. (Terena *et al*., 2017; Gómez *et al*., 2023), and according to Conocimiento (2022), most of these metals are irreplaceable when mined. An average user of a mobile phone switches phones twice a year mostly from older models to newer models thereby more of these metals are consumed on a regular basis during the process of production leading to the depletion of these metals and generating more waste. Bookhagen *et al.* (2020) reported that the PWBs of smart phones contain metal concentrations higher than current metal content in their respective ores. For instance, PWBs contain 98% of Cu, 99% of Pd, 93% of Ta 90% of Au, and 86% of In. Therefore, recycling these metals would help in reducing the depletion of the underground stock of these metals and a perfect secondary source of metals (Gabbatiss, 2019; Conocimiento, 2022).

As reported by Annamalai and Gurumurthy (2020), Kasper *et al*. (2011), and Nnorom and Osibanjo (2011), a whole mobile phone component consists of a keypad (4.05%), battery (5.304%), LCD (5.77%), metallic components (6.55%), connectors (19.5%), casing (25.89%), and PWBs (34.09%) by weight. Nnorom and Osibanjo (2011) also stated that a complete mobile phone PWB comprises 33% semiconductors, 24% capacitors, 23% bare PWB, 12% resistors, and 8% comprising of switches and other materials while the bare PWB consists of 30% ceramics, 30% plastics, and 40% metals.

The Printed Wiring Boards (PWBs) which control the functions of the phone house a large number of elements (Kasper *et al*., 2011; Omole *et al*., 2015; Terena *et al*., 2017). It constitutes about 20-30% of the weight of a mobile phone (Nnorom and Osibanjo, 2011). Studies by Nnorom and Osibanjo (2011), Hahladakis (2013), Maragkos *et al*. (2013), Ghodrat *et al*. (2018), Adie *et al*. (2019), Intrakamhaeng *et al*. (2019), Gorewoda *et al*. (2020), and Liang *et al*. (2023) showed that the metal content of PWBs varies depending on the type of mobile phone and year of manufacture. Some of the metallic components of a typical PWB of a mobile phone include economic metals (Au, Ag, Cu), toxic metals (Pb, As, Hg, Cd, Se, Cr), non-toxic metals (Fe, Pd, Zn, Ni, Ca, Mn), and non-metals such as Brominated flame retardants (Priya & Hait, 2018). Arsenic in PWBs is from Gallium Arsenide while the lead is from the lead solders used in holding the resistors, capacitors, and other components on the PWBs (Nnorom & Osibanjo, 2011; Dervišević *et al.,* 2013). In a related development, Priya and Hait (2018), Adie *et al*. (2019), Gorewoda *et al*. (2020) indicated that the toxicity potential of PWBs of mobile phone housed the largest quantity of toxic substances hence should be properly managed with caution. Improper handling can lead to pollution of the air, water, and soil (Kasper *et al*., 2011; Omole *et al*., 2015; Terena *et al.*, 2017; Liang et al., 2023). Likewise, mobile phones are packed with economic metals as reported by Annamalai & Gurumurthy (2020), a ton of waste mobile phone contains 340g of gold, 140g of palladium, 130kg of copper, and 3.2g of silver. Thus, a promising source of metals for the recycling industry.

There is a rising concern about the health and environmental impact associated with crude e-waste recycling in developing countries where there is either lack of specific e-waste regulations, regulations present in drafts, or not yet in force. Developed economies already have a system in place to curtail the menace associated with e-waste by developing some regulatory bodies like the European Union 2002/96/EC Waste Electrical and Electronic Equipment (EU WEEE) directive (EU WEEE, 2003), European Union 2002/95/EC Restriction on Hazardous Substances (RoHS) directives (RoHS Guide, 2023), United States Toxicity Threshold Limit Concentration (US TTLC) (Nnorom & Osibanjo, 2011; Adie *et al.*, 2019), European Union Waste Electrical Electronic Equipment (EU WEEE) directive 2012/19/EU (EU WEEE, 2018), and many other regulations. Monitoring this concentration of critical metals (toxic and economic metals) in electrical equipment in Nigeria to study the Original Equipment Manufacture's (OEM's) behaviour is very critical as it is perceived that most new products arriving in Nigeria are substandard with a very short life span (Adie *et al*., 2019).

The management of e-waste in Nigeria is still not appropriate and poorly managed as most of them ends up in the municipal waste stream, burnt at open dumps, surface water bodies, and background recycling leading to air pollution, discharge of toxic leachate into the environment contaminating groundwater and soil posing harm to humans, animals, and the environment (Priya & Hait, 2018; Annamalai & Gurumurthy, 2020; Liang *et al*., 2023).

Studies by Nnorom and Osibanjo (2011), Kasper *et al*. (2011), Dervišević *et al*. (2013), Priya and Hait (2018), Adie *et al*. (2019) established that the number of toxic metals such as lead exceeded RoHS Threshold limit. It is believed that the high lead content was due to the Tin-Lead solder used on the PWBs. Although recent studies done by Hahladakis (2013), Intrakamhaeng *et al*. (2019), and Gorewoda *et al*. (2020) on newer mobile phones (phones manufactured from 2006) have shown lower lead and other regulated toxic metal concentrations as related to the RoHS limits. Also, PWBs of mobile phones examined by Maragkos *et al*. (2013) manufactured between 2002-2006 had a Pb concentration of 27000 mg/kg while those manufactured

between 2007-2011 had a much lesser lead concentration of 300 mg/kg indicating a decrease in the trend of lead concentration in PWBs in mobile phones. This low concentration of lead and other toxic metals might be due to the implementation of the RoHS 2006 deadline (Sargiou, 2021). Therefore, leaded solders are being replaced with lead-free solders made from alloys of non-toxic metals such as Sn, Ag, Cu, Zn, and Mn. (Ogunseitan, 2007; Nnorom & Osibanjo, 2011; Dervišević *et al*., 2013)

The main objective of this study is to evaluate the concentration of selected toxic and economic metals present in selected PWBs samples of three popular brands of discarded mobile phones manufactured after 2006 used in Nigeria. This is to understudy the behaviour of Original Equipment Manufacturers' (OEMs) regarding toxicity and economic potentials and comparing their concentration with 2006 RoHS directives.

MATERIALS AND METHODS

Sample Collection and Preparation

A total of 60 PWBs, 20 each from three (3) different models of discarded popular brands mobile phones were obtained from phone repairers' shops in Ibadan, Oyo state and Ikeja, Lagos state, both in Nigeria. The dates of manufacture of all the 60 discarded phones were captured to be from 2011 to 2017. Each discarded mobile phone was sorted according to its OEM and year of manufacture. To analyze only the PWBs, all the other components attached to the PWBs were detached using a fire gun and a screwdriver and subsequently chopped into smaller sizes of < 3 mm using stainless steel scissors according to Kulkarni (2016) and Ammamalai & Gurumurthy (2020). Then ground separately into smaller pieces using a hammer miller. To prevent cross-contamination the container and blades were cleaned with sawdust after every round as used by Adie and Onyebuenyi (2021). The smaller pieces were sorted using a 2 mm sieve as used by Nnorom and Osibanjo (2011). Each reduced PWB was properly labeled and stored in sealable plastic polyethylene bags.

Sample Analysis

To transfer elements (metals) into their liquid form, the EPA 3050B digestion protocol (U.S EPA, 1996) was used for the digestion process. EPA 3050B is used in determining the number of metals that could be leached from waste under extreme conditions. EPA 3050B method involves the treatment of waste samples with hydrogen peroxide, hydrochloric acid, and nitric acid (U.S EPA, 1996; Nnorom and Osibanjo, 2011).

One gram of the grounded samples was accurately weighed in a properly labeled digestion vessel and 10 mL of 1:1 HNO_3 was added. The solution was heated on a hot plate to 955ºC ±5ºC for 15 minutes without boiling. The sample was allowed to cool to less than 60ºC, 5 mL of Conc. HNO_3 was added, Covered, and refluxed for 30 minutes at 95ºC±5ºC without boiling. Another 5 mL of Conc. HNO_3 was added repeatedly every 30 minutes for 2 hrs until the brown fumes subsided. After cooling to less than 60ºC 2 mL of water and 3 mL of 30% H_2O_2 was added and heated continuously until effervescence was minimal. Later, 10 mL of Conc. HCl was added, heated, and fluxed at 95ºC±5ºC for 15 minutes without boiling. The digest was allowed to cool, filtered through Whatman No. 41 filter paper, and made to mark with distilled water using a 100 mL volumetric flask. An aliquot of each sample was taken and preserved with 5 drops of Conc. HNO_3. Each digest was analyzed for metals using Inductive Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) using standard calibration techniques.

Quality Control

To ensure the reliability of the results, blank samples (this contained 100 mL of distilled water without adding the sample) were carried through the procedure and analyzed to check impurities in the reagents. Also, to test for precision and accuracy of the analytical process 20% of the samples were selected randomly and were passed through the analytical processes to produce replica values. These data was analyzed to determine the accuracy and precision of the analytical process.

To prevent contamination, all glassware and plastic apparatus/containers used were washed with detergent, rinsed with water, and then soaked in dilute HNO_3 overnight before rinsing with distilled water to remove any possible adsorbed metals to the walls of the containers and dried in a clean environment. Also, all reagents used for the digestion process were of Analytical grade. The analytical balance used was calibrated before use.

RESULTS AND DISCUSSION

Analysis of Metal Concentration in Examined Selected Mobile Phones PWBs

An analytical summary of the mean ± standard deviation and ranges of metal concentrations (mg/kg) in the various categories of mobile phone PWBs examined are presented in Table 1. The metal concentrations of Mn, Fe, Zn, As, and Cu had the highest values in the order Mn > Fe>Zn>As>Cu, while the concentration of Cr, Ag, Co, Au, Al, Cd, Ni, and Pb had relatively lower values. The results of the ICP-OES analysis of replica samples, and metal concentrations of the bulk samples to determine the degree of precision and accuracy of the analytical method were analysed using interclass correlation (F-test). Perfect reliability (Cronbach's Alpha=1.0) was gotten. The comparison test between the mean concentration of metals within each OEM using Tukey HSD and one-way ANOVA at a 95% confidence interval shows no significant difference ($p>0.05$) and normal distribution of 0.977 was

determined which denoted an almost perfect distribution. This implies that these OEMs use a standard template in manufacturing their products which has been maintained over the years. The standard deviation of Mn among examined PWBs of OEM's was high. This high standard deviation values might be due to the disparity of colours among mobile phone brands and manufacturers as it is known that transition metals are inorganic pigments for materials. This property is due to the transfer of electrons from lower d-orbital to a higher energy d-orbital (Adie *et al.,* 2019).

Table 1: Average metal concentrations (mg/kg) in PWBs of all mobile phones

Metal	OEM 1 N=20		OEM 2 N=20		OEM 3 N=20	
(mg/kg)	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Al	1.25±0.18	1.46-2.97	1.32±0.16	1.17-1.64	0.80±0.18	1.23-2.00
Fe	1357.1±256	1887.38-1794.45	1248.70±148.41	1105.68-1550.54	1254.56±201	1243.21-2057.21
Ni	0.49±0.07	0.62-1.26	0.52±0.06	0.46-0.64	0.31±0.07	0.43-0.75
Zn	691.6±82.90	640.89-1295.99	763.09±90.69	675.69-947.56	457.1±34.37	240.98-606.27
Mn	1486±213	532.43-1076.67	1577.30±187.46	1396.65-1958.58	951±217	685.43-1603.41
Co	2.35±0.34	0.18-0.37	2.49±0.30	2.21-3.10	1.50±0.34	0.07-0.17
Cu	89.30±12.80	87.51-170.48	94.73±11.26	83.88-117.63	57.1±13.0	75.20-150.53
Au	1.06±0.15	1.66-3.36	1.12±0.13	1.00-1.40	0.68±0.16	1.74-2.52
Ag	2.36±0.34	12.50-25.27	2.50±0.30	2.22-3.11	1.51±0.35	8.76-10.79
Pb	0.48±0.07	0.47-0.97	0.5±0.06	0.45-0.64	0.31±0.07	0.18-0.45
Cd	0.69±0.10	2.41-4.87	0.73±0.09	0.65-0.91	0.44±0.10	0.91-2.28
Cr	5.73±0.82	5.61-11.36	6.08±0.72	5.39-7.55	3.67±0.84	1.75-4.40
As	99.39±18.81	64.99-131.42	89.20±17.52	0.79-1.10	66.31±3.51	24.44-61.48

Number of total sample=60, Unit= (mg/kg)

Table 2: Summary of toxic and economic metal levels in PWBs

	Mean±StDev mg/kg	Median mg/kg	Range mg/kg	TTLC RoHsGuide.(2023)	RoHS
Cu	80.37±16.89	67.53	75.20-170.48	2500	NA
Au	0.95±0.19	1.83	1.00-3.36	NA	NA
Ag	2.12±0.43	10.65	2.22-25.27	500	NA
Pb	0.43±0.38	0.64	0.18-0.97	1000	1000
Cd	0.62±0.16	2.23	0.65-4.87	100	100
Cr	5.16±1.06	6.46	1.75-11.36	2500	1000
As	84.97±13.83	58.36	0.79-131.42	500	NA

NA= Not available, Number of total sample=60, TTLC= Toxicity Threshold Limit Concentration , RoHS= Restriction on Hazardous Substance

Comparison with RoHs Directive Maximum Limits and Total Threshold Limit Concentration (TTLC)

All the selected toxic metals i.e. As, Pb, Cd, and Cr incidentally had concentration values relatively below the permissive threshold value limits TTLC and RoHS Directive maximum limits as shown in Table 2. This low concentration of toxic metals is a strong indication that the OEMs studied might have considered the option of 'design-for-environment' by possibly reverting to the use of more environmentally friendly solders like Sn/Ag/Cu blend other than Pb/Sn solder which is popularly known to be used as a conductive glue that sticks components on the board (Cadence, 2022). The RoHS Directive mandated the use of lead-free solders with an implementation deadline of 2006 (RoHS Guide, 2018),

and all examined PWBs were manufactured between 2011 and 2017. It is also obvious that Cu is still much in use in the circuitry works as demonstrated by the significant concentration in all the examined samples (75.20-170.48 mg/kg). The presence of metals such as Zn, Al, Fe, Ni, Mn, and Co in high concentration as shown in Table 1 might be an indication that Lead-free solders were used rather than Pb/Sn solders; though, Sn was not measured in this study. Most Lead-free solders are made from an alloy of Sn, Ag, and Cu while some contain a fourth metal such as Zn, or Mn (Ogunseitan, 2007). Posch (2020) also reported that elements such as Al, Ni, Mn, Co, Bi, and Ge are added to Lead-free solder alloys to improve their properties such as thermal reliability, vibration resistance, and electro migration resistance. It is very important to take note that Hg, a toxic metal regulated by RoHS Directive was not within the scope of this study. Therefore, examined selected PWBs of mobile phones should still be classified as hazardous substances and be handled with caution.

Comparison with Literature Data

The comparison data of some previous work done on metal levels of PWBs of end-of-life mobile phones are shown in Table 3. Adie *et al.* (2019) using the EPA 3050B leaching method reported a mean value concentration of Cd of 0.28 mg/kg falling within the range of the concentration of this study. Also, the concentration value of Au reported by Ernst *et al*. (2003); Huisman *et al.* (2007); Hageluken and Buchert (2008), and Kasper and Veit (2018) are similar to the mean concentration value of the present study. The mean concentration of selected toxic metals such as Pb, Cd, As, and Cr are lower than the values reported by Nnorom and Osibanjo (2011); Ghodrat *et al*. (2018); Sahan *et al*. (2019); and Annamalai and Gurumurthy (2020). However, recent studies on PWBs of mobile phones manufactured after 2006 done by Intrakamhaeng *et al*. (2019) and Gorewoda *et al*. (2020) as shown in Table 3, has a mean concentration of Pb comparable to the mean values of this study. Maragkos *et al*. (2013) reported mean concentrations of Pb (300 mg/kg), Cd (4.5 mg/kg), and As (110 mg/kg) for PWBs manufactured between 2007-2011; though higher than mean value concentrations gotten from this study but much lower than the RoHS limit. This relatively low concentration of toxic metals in the examined PWB gives a strong indication that the 2006 RoHS recommendation of toxic metals limits in electrical equipment may have been implemented since all examined PWBs of mobile phones were all manufactured after 2006.

Table 3: Comparison with Literature Data

References	Year of Manufacture	Leaching agent	METALS (mg/kg)						
			Pb	Cd	As	Cr	Cu	Au	Ag
Ernst *et al.,* 2003	-	Aqua Rega	-	-	-	-	-	0.37	3.57
Huisman *et al.,* 2007	-	-	-	-	-	-	-	1.3	5.7
Hageluken & Buchert, 2008	-		-	-	-	-	-	0.98	5.54
Nnorom & Osibanjo, 2011	EPA 3050B		20100	2.1			250000		227
Maragkos *et al.,* 2013	EPA 3052	2002-2006	27000	3.7	74	540	12700		
		2007-2011	300	4.5	110	4400	21900		
Ghodrat *et al.,* 2018	Before 2005	-	11700	-	-	-	395600	600	600
	After 2005		12600	-	-	-	383300	1000	600
Kasper & Veit, 2018	2001-2005	$S_2O_3^{2-}$	-	-	-	-	-	0.49	-
Sahan *et al.,* 2019	-	EPA 3051A	12000	-	-	17000	335000	1400	3600
Intrakamhaeng et al. (2019)	2006-2007	-	0.31	-	-	-	-	-	-
Adie *et al.,* 2019	2000-2015	EPA 3050B	2507	0.28	-	1002	-	-	-
Gorewoda *et al.,* 2020	After 2014		0.75	-	-	-	7645	0.41	3.19
Annamalai & Gurumurthy,2020	-	Aqua rega	118300	-	-	-	431900	3100	100
Present study	**2011-2017**	**EPA 3050B**	**0.18-0.97**	**0.65-4.87**	**0.79-131.42**	**1.75-11.36**	**75.20-170.48**	**1.00-3.36**	**2.22-25.27**

CONCLUSION

Quantities of end-of-life mobile phones are on the increase of which a large percentage ends up in landfills or dumpsites resulting in the loss of valuable resources and creating environmental pollution. This study provides insight into the metal contents (both toxic and economic) of PWBs' of three popular brands of mobile phones in Nigeria and their level of compliance with the RoHS 2003 directives. The concentrations of toxic metals regulated by RoHS Directives were below the permissible level indicating a possible implementation of RoHS Directive by some Original Equipment Manufacturers which had an implementation deadline of 2006. The metal concentration of the examined PWBs was also below the TTLC limits. Though, since Hg a toxic metal regulated by RoHS was not within the scope of this study, it is recommended that mobile phones should be handled with caution.

Results from the study indicate that PWBs of mobile phones are a perfect secondary source of a variety of economic metals such as Cu, Ag, and Au which are vital for the recycling industry thereby reducing the amount of waste that ends up in landfills and incinerators with a huge economic advantage.

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African Traditional Arts and Ornamentation in the Architecture of the Cultural Centre Ibadan

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Art and architecture have been intertwined throughout history. Art in its various forms has played a vital role in the lives of African people as evident in their architecture. The paper reviewed the African visual culture with respect to ornamentation in the built environment as well as the variations of cultural heritage in the anthropogenic sense. The study adopted a qualitative approach using the case study method with the selection of the Cultural Centre Ibadan. The 1977 Second World Black and African Festival of Arts and Culture (FESTAC 77) held in Lagos, Nigeria inspired the architecture of the National Theatre in Lagos, and other cultural centres in other cities in Nigeria including the Cultural Centre, Ibadan which exemplified African arts and ornamentation in its façade and spaces. The Cultural Centre Ibadan is a significant masterpiece adorned with African traditional arts and ornamentation. It embodies a bold fusion of art and architecture evident in the intricate sculptural reliefs that beautify its walls, the wooden and metal ornamentation embellishing its halls and lobbies, the luscious blend of geometrical forms and shapes in its façade, its harmony with the undulating landscape and the concrete anthropomorphic sculptural pieces that welcome guests into the entrance quadrangle. The themes of the arts and ornamentation of the Cultural Centre Ibadan reflect traditional Yoruba cultural festivals, philosophical and religious motifs that has transformed the building into a cultural heritage. Artfully embellished architecture with symbolic meanings like the Cultural Centre Ibadan affords the dividends of cultural emancipation, cultural renaissance and cultural preservation. The interweaving of art and architecture in public buildings should be promoted.
Keywords: Art, culture, heritage, ornamentation, sculpture

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INTRODUCTION

Throughout history, humans have cultivated a deep-seated yearning for beautification and ornamentation. This is visible in various artistic expressions ranging from paintings, markings, and piercings on the body; the use of jewelleries to adorn the body; craftsmanship of objects, artefacts, carvings and sculpture; to the decorations and artistic expressions on buildings, temples and other physical structures. The context of ornamentation is invariably expansive and can be constrained only to the limits of human imagination (Adegoke, 2016). Aside ornamentation, art is one of the most potent tools for the promotion of cultural heritage and the preservation of family values especially in traditional African societies (Okoye & Ukanwa, 2019).

Art and architecture have been intertwined through the various epochs of architectural history as an age long phenomenon transcending beyond the earliest human civilizations to the pre-historic period as evident in the paintings of walls and roofs of the caves that provided shelter to the cave dwellers (Adegoke, 2016). The aesthetic ambience of architecture can be perceived in its artistic expressions and visual forms which transcend beyond the structural envelope and utilitarian reflections. The articulation of artfully embellished architecture with symbolic meanings, and the adornment of cityscapes with monumental structures drive cultural emancipation and promote cultural heritage (Igbaro *et al*., 2010; Antonova *et al*., 2017).

Over the years, the application of art in its various forms in architecture has played a vital role in the lives of African people (Awoniyi, 2015; Okoye & Ukanwa, 2019). It served as a media of communicative expression of religious beliefs and socio-cultural norms. However, its form, presentation and significance vary from one cultural setting to another (Opoko *et al*., 2016). In many cultures, public buildings such as palaces and town halls provide a facade for art and ornamentation (Sogbesan & Awonusi, 2022). In recent times, the traditional town halls have evolved into cultural and civic centres like the Cultural Centre Ibadan which provide a rich canvass for the exhibition of traditional arts and ornamentations.

LITERATURE REVIEW

Culture is a concept that is acknowledged universally, although its phenomenal relevance varies across societies, it can be expressed as a complex whole which includes knowledge, belief, art, moral, law, custom any other capabilities and habits acquired by man as a member of society (Awoniyi, 2015). Culture is dynamic and cultural phenomena are susceptible to transformation and diffusion. An aspect of culture peculiar to buildings and artifacts is material culture. Material culture is an offshoot of culture evident in

artwork, visual arts, sculpture and buildings. The built environment encompassing buildings and spaces represents a microcosm of culture with great amplitude. As buildings provide a shell for daily interactions (person-to-person and often, person-to-deity), and serves as the locus of the dissemination of social norms and values, it is invariably one of the most potent manifestations of cultural heritage (Osasona, 2012).

Heritage is the repository of the values, traditions, and achievements of a people that typically represents a phenomenon within a traditional historical discourse but also encompasses the appearance of peripheral influences (Monteiro *et al*., 2015). Heritage is a compendium of historical facts run through mythology, ideology, nationalism, local pride, romantic ideas or mere plain marketing (Nilson & Thorell, 2018). It lends itself to usage in diverse forms from existential, ideological, and cultural to the egalitarian or utilitarian ideals (Thurley, 2005).

Cultural heritage is the bridge between culture and heritage. The United Nations Educational Scientific and Cultural Organization describes cultural heritage as the legacy of physical artefacts and intangible attributes of a group or society that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations (Nilson & Thorell, 2018). As an inherent construct of human activity cultural heritage produces tangible representations of value systems, beliefs, traditions and lifestyles manifest in art and architecture with visible and tangible traces from antiquity to the most recent past. The cultural heritage credentials of iconic architecture and monuments embellished with traditional arts and ornamentation often transcends beyond the utilitarian considerations of architecture into the sublime aesthetic and symbolic attachments (Anifowose & Olatubosun, 2020).

Ample evidence suggests that the life of the traditional African is intrinsically interwoven with art wherein it played a vital role in the political, social, economic and religious life of the people (Osasona, 2012; Awoniyi, 2015). African art is highly symbolic, and its interpretations have been tenaciously passed on through generations. The media of artistic expression include the human body, textiles, artefacts, buildings and landscapes. As a key medium of expression, arts and ornamentation in buildings is an ancient practice that spreads across the continent from prehistoric times as cave paintings and carvings have revealed. Ornamental arts is manifest in the architecture of the dynastic empires of Nubi, Egypt, Abyssinia, Kush, Mali, Songhai, Carthage, Punt, Aksum, Swahili, Nok, Ashanti, Kanem-Bornu, Songhai, Wolof, Benin, Oyo and others (Adebaike *et al*., 2020). Traditional African architecture erroneously referred to as primitive exudes a lucid inspiration for its aesthetic value hinged upon naturalism distinctive from the modernist and post-modernist ideals pivoted upon geometrical fundamentalism. African art is a craft daintily poised upon sculptural similes with metaphorical ambience and a picturesque fabric emanating rhythms of sensuous symbolic interpretations and unique connotations.

Architecture afforded a rich fabric for African art. Door panels and frames were beautifully carved with great symbolic representations. The walls of buildings provided an elaborate canvass for artistic expressions in the form of paintings, carvings and embellishments with colourful motifs and animated inscriptions (Sogbesan & Awonusi, 2022). Interiors were richly adorned with elaborate artefacts such as brightly colored enamel and ceramic wares, mats, furniture, fabrics, utensils, and cutleries, which asides functional necessity were artfully crafted and decorated in vivid colours (Opoko *et al*., 2016). In some cultures, the exterior of important buildings were decorated with low relief designs and adorned with a myriad of sculptural elements, relics and monuments (Igbaro, 2010; Anifowose & Olatubosun, 2020).

Ornamentation in architecture is the application of ornaments sometimes with iconographic and symbolic roles for the beautification and enhancement of the aesthetic appeal of buildings. Although ornamentation adds beauty to architecture by transforming the ordinary into the sublime through the weaving of interest and complexity into ordinary forms and spaces, it is beyond adding beauty to architecture (Anifowose & Olatubosun, 2020). Ornamentation may be symbolic of wealth, class, hierarchy, and power (Osasona, 2006). In traditional African society, it is reflective of a deeper meta-physical spiritual undertone as several of these arts and ornamentation are replicas of kings, gods, deities and ancestral icons. Typically, African cultures have evolved distinct repertoire of architectural ornaments which materialize in the form of plant or floral motifs, animals and birds, emblems and heraldry, geometric patterns, or human forms as reflected in architectural caryatids. The symbolism attached to these decorations is typically relative to their form and placement and reinforced by their sublime as well as formal qualities.

MATERIALS AND METHODS

This study is a cross-sectional survey adopting the case study approach. The Cultural Centre, Ibadan, Nigeria was purposively selected based on its cultural heritage credentials, its symbolic importance and its standing as one of the monumental structures that dot the urban landscape of the city of Ibadan. This study is purely qualitative and was conducted with the aid of direct physical observation as the major instrument of data collection wherein the traditional arts and ornamentation in the architecture of the Cultural Centre, Ibadan were examined.

Pictorial media played a significant role in the study as pictures of artworks, embellishments, sculptural reliefs, and anthropomorphic structure in different media such as concrete, metal and wood were captured in images and elaborately examined. The arts and ornamentations adorning the Cultural Centre, Ibadan were selectively examined with an analysis of the styles, forms, placement, presentation media and inherent symbolic meanings. The authors of the sculptural and artistic themes were identified in other to provide a detailed backdrop of information adding to the body of knowledge.

RESULTS AND DISCUSSION

Historical Narrative of the Cultural Centre Ibadan

The Second World Black and African Festival of Arts and Culture held in Lagos, Nigeria in 1977 served as the pedestal upon which the Cultural Centre Ibadan metamorphosized (Apter, 2021). The idea behind the Black Arts Festivals was endorsed at the Second Congress of Black Writers and Arts in Rome in 1959, to discuss the resurgence of the Black man's culture (Ojukwu & Enuka, 2020). Consequently, in April 1966, in Dakar, Senegal, the first festival titled the World Festival of Negro Arts (Mondial des Arts Nègres) was held. For the festival, two monumental buildings were constructed in Dakar – the Musée Dynamique (Figure 1) exhibiting African visual and plastic arts, and the National Theatre (Figure 2). The architecture of these buildings were reflective of the vision to promote African arts and culture which is visible in the intricacy of their ornamental arts and spatial forms.

Figure 1: Musée Dynamique
https://www.photos/musee-dynamique

Figure 2: National Theatre, Dakar, Senegal
https://www.photos/national-theatre-in-dakar

The Second World Black and African Festival of Arts and Culture (FESTAC 77) was a rare historic opportunity that significantly marked Africa's cultural renaissance and enhanced the appreciation and projection of African culture and civilization as it fostered global consciousness and visibility of African culture, with renewed interest in African studies, culture, science, history, literature, arts and architecture (Ojukwu & Enuka, 2020; Apter, 2021). FESTAC 77 held in Lagos, Nigeria birthed a cultural renaissance and resurgence of African arts. Architecture was also invariably influenced by the effusive charm of African arts. The National Arts Theatre, Lagos (Figure 3), the Cultural Centre, Benin City (Figure 4), the Cultural Centre, Calabar (Figure 5), the Cultural Centre, Ibadan and several iconic buildings and monuments that dot the Nigerian urban landscape were inspired by the FESTAC 77. These buildings were designed with a fusion of African arts and ornamentation on the façade and interior spaces and were envisioned as the ideal canvass to promote and exhibit the beauty of African arts and ornamentation

Figure 3: National Arts Theatre, Lagos
https://www.photos/national-theatre-in-lagos

Figure 4: Cultural Centre Benin City
https://www.photos/culturalcentre-in-benin

Figure 5: Cultural Centre Calabar
https://www.photos/culturalcentre-calabar

The Cultural Centre Ibadan also referred to as the Oyo State Council for Art and Culture emerged within the ambience of the FESTAC 77 and was built same year. Ibadan is one of the most liberal and strategic cities in Yoruba land and at the beginning of colonial administration, it was made the administrative headquarters of the western region of Nigeria and currently the capital city of Oyo State. It has since metamorphosised into one of the largest urban agglomerations in Africa with immense administrative, economic and cultural significance.

Arts and Ornamentation in the Cultural Centre Ibadan

The Cultural Centre Ibadan is a magnificent piece of architecture designed by Professor Demas Nwoko and constructed by Strabag Construction Company in 1977. The core vision of the design was to attract tourists and artistes to Ibadan to showcase the cultural landscape and heritage of the ancient city. The Cultural Centre Ibadan is a public building currently owned and maintained by the Oyo State Government of Nigeria (Figure 6). It embodies a bold fusion of art and architecture evident in the intricate sculptural designs that adorn its walls, wooden and metal ornamentation adorning its halls and lobbies, the luscious blend of geometrical forms and shapes in its façade, its integration and harmony with the undulating landscape. Indeed, the building is breath-taking presenting a cascade of mesmerizing views from different vantage points.


Figure 6: Approach view of the Cultural Centre Ibadan
https://www.photos/culturalcentre-in-ibadan

Art is interwoven into the Cultural Centre Ibadan from its approach. Two magnificent more than life sculptures produced by Adéyẹmí Victoria Ajéwọlé-Àlàdé and Samson Kẹ́hìndé Adékọ̀yà adorn the entrance quadrangle (Figure 7). These concrete anthropomorphic sculptural pieces strategically located at both sides of the main entrance project a metaphorical ambience of welcoming guests to the building in an apparent reflection of Yoruba traditional culture. *Àyàn Àgalú* holds a traditional Yoruba musical ensemble called *ìyá ìlù*, a traditional drum fabricated from wood and animal skin, while the other plays a Yoruba musical instrument known as *sẹ̀kẹ̀rẹ̀,* fabricated from a calabash and beads held together with small ropes.

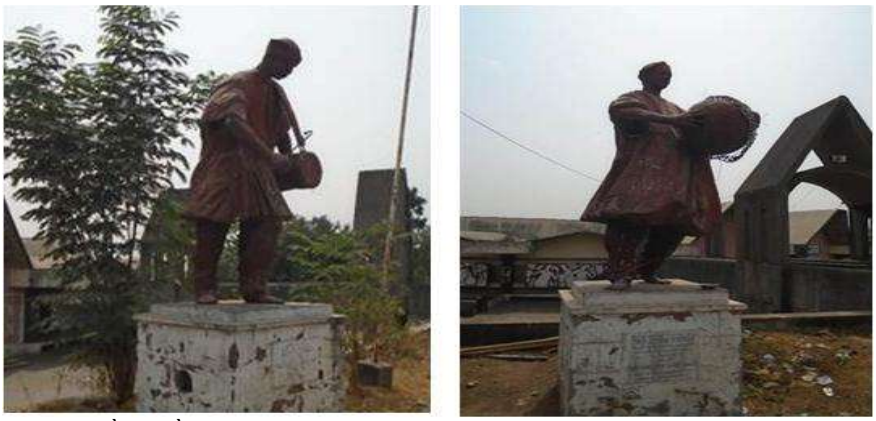

Figure 7: Àyàn Àgalú and Onisẹ̀kẹ̀rẹ̀ Sculptures
Fieldwork, 2022

On the approach view, eight segments of relief sculptures of two distinctive styles credited to Demas Nwoko made in concrete adorn the external walls depicting different themes of Yoruba traditional culture such as entertainment, dance, festival and religion. The first relief sculpture depicts two men with one beating the *ìyá ìlù* and the other playing the *sẹ̀kẹ̀rẹ̀* (Figure 8). The two semi-abstract cubic figures adorn typical Yoruba traditional attire with cap, engulfed in an ambience of celebration. Embellished motifs add lucidity to the whole composition. The relief sculpture, like the others produced in similar style on the building, is painted white with a brown background, creating a sharp contrast against the brightly painted walls. The second relief sculpture (Figure 9) depicts four women dancers holding ceremonial horsetails known as *ìrùkẹ̀rẹ̀,* wearing ecstatic facial expressions seemingly responding to the rhythm of the drummers on the first sculpture. The third relief sculpture is a composition of *sàngó* festival celebrated by the Yoruba people (Figure 10). *Sàngó* is the Yoruba god of thunder and is depicted in his typical attire; a traditional Yoruba male sleeveless top and a skirt known as *làbà*. He holds an axe which is his most important insignia. The composition also includes a drummer and a dancer.

Figure 8: Relief Sculpture I
Fieldwork, 2022

Figure 9: Relief Sculpture II
Fieldwork, 2022

Figure 10: Relief Sculpture III
Fieldwork, 2022

Figure 11: Relief Sculpture IV
Fieldwork, 2022

The fourth relief sculpture comprises three anthropomorphic figures apparently dancing to a melody (Figure 11). The three figures adorn the traditional Yoruba flowing gown *agbádá,* usually worn during important ceremonies and festivals. The fifth two-dimensional sculpture is a composition of three

cubic semi-abstract *bàtá* drummers dressed in Yoruba traditional attires (Figure 12). *Bàtá* is a traditional Yoruba drum ensemble in the membranophone family and is largely used as part of *sàngó* drum ensembles. The sixth relief sculpture (Figure 13) is a replica of the *sàngó* festival depicted in relief sculpture III (Figure 10) in style and thematic composition with little variance in the type of axe held by *sàngó*, and the musical ensemble.

Figure 12: Relief Sculpture V
Fieldwork, 2022

Figure 13: Relief Sculpture VI
Fieldwork, 2022

The seventh and eighth relief sculptures have a different stylistic content from the first six. These two relief sculptures are placed at either side of the entrance into the main hall. The stylized sculptures depict anthropomorphic figures playing different types of traditional musical instruments (Figures 14 and 15). Other figures on the ensemble seemingly dance to the rhythm of the melody. The frames of the sculptural pieces are designed with twisted ropelike motif.

Figure 14: Relief Sculpture VII
Fieldwork, 2022

Figure 15: Relief Sculpture VIII
Fieldwork, 2022

In addition to the relief sculpture on the entrance walls and the magnificent sculptural pieces standing aloft the entrance quadrangle, the two entrance doors into the main hall of the Cultural Centre Ibadan bear ornate ornamentation. The doors were intricately fabricated with a delicate mix of metal and wood (Figure 16). Wooden frames enclose metal panels embellished with plastocast print motifs authored by Bruce Onabrakpeya, a renowned Nigerian contemporary artist. The doors are in two halves each with three panels. The upper and lower panels in each halves have figurative illustrations while the middle panels are non-representational with a blend of geometrical shapes and patterns. The theme is African, ranging from acrobatic displays to drumming and cultural dances. The stylized human figures are heavily decorated with motifs.

Figure 16: Entrance Doors
Fieldwork, 2022

The integration of African arts and ornamentation into the Architecture of the Cultural Centre is in tandem with the objectives of the FESTAC 77 to promote the uptake of African arts and culture in all facets of national life. The Cultural Centre Ibadan represents a significant masterpiece that exhibit and promote African traditional art and architecture.

CONCLUSION

Art is one of the most potent tools for the promotion of cultural heritage and the preservation of traditional customary values as observed in the Yoruba cultural displays and festivals captured in the sculptural relief designs adorning the walls of the Cultural Centre, Ibadan and the monumental sculptures that welcome guests into the entrance quadrangle of the edifice. When the built environment witnesses artistically embellished architecture with symbolic meanings like the Cultural Centre Ibadan, society reaps the dividends of cultural emancipation, cultural renaissance and cultural preservation.

A symbolic building like the Cultural Centre Ibadan that embellishes art and ornamentation in its architecture becomes a cultural heritage asset with enormous present and future economic, social, political and cultural value. This reinforces architecture as a composite of art and science, the artistic leaning espousing aesthetic tenets derivable from beauty, decoration and ornamentation. The Cultural Centre reinforces the complementary relationship between art and architecture. Ornamentation plays a significant role in transforming architecture from a solid structure into a graphical canvass eliciting soft subtle symbolic hues of aesthetic splendour. While architecture emphasizes the functional and rational aspect of the design, artistic expressions on buildings present a canvass to promote African traditional arts and ornamentation.

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Land-use and its implication on physicochemical parameters of groundwater: Evidence from Ikenne Local Government Area, Ogun State

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Groundwater is essentially the major source of fresh water and used widely for drinking purpose. In any given area, groundwater within an aquifer, or groundwater produced by a well, has some vulnerability to contamination from human activities. Therefore, information on human activities that leads to contamination of groundwater is important. Such information can aid in the choice of proper locations for certain activities, so that the adverse effects on groundwater are minimized and protection of groundwater achieved. Against this background, the study examines land-use and its implications on physiochemical properties of groundwater in Ikenne Local Government Area, Ogun State, Nigeria. The study obtains and analyses the existing land-use maps. Water samples were collected for laboratory test to benchmark physicochemical parameters based on World Health Organisation standards. Water Quality Index (WQI) was used to determine groundwater quality. Findings from analyses of land-use map show that residential land-use has highest percentage in Iperu (79.9%) and Ilishan (52.8%) towns, while industrial land-use constitutes the least, representing for 0.6% and 1.9% in Iperu and Ilishan respectively. The study found that WQI for Ilishan I (39.4), II (33.5), III (43.8) and Iperu I (32.9), II (31.4) was of good quality, while Iperu III (19.4) was excellent. ANOVA results of $F = 0.596$ and $p > 0.05$ established that there is no statistical significant variation in the physiochemical properties of groundwater. It can be concluded that absence of land-uses that generate contaminants reduce the likelihood of groundwater contamination. Therefore, strategies for effective implementation of zoning regulations should be put in place by relevant government agency.

Key words: Groundwater, landuse, parameter, physiochemical**,** water quality index (WQI)

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INTRODUCTION

Groundwater is a form of water occupying all voids within a geological stratum (Todd, 1980). It is estimated that groundwater represents about 30.1% of the global fresh water. Thus, it is one of the main sources of fresh water available for man's use. It is widely used for drinking and other domestic purposes. Generally, groundwater reservoirs are exploited to meet an increasing need of water for city dwellers, irrigation and industrial development. Therefore, in order to maintain an adequate supply of healthy and clean drinking water, the 30.1% groundwater resources must be carefully developed and managed (Ocheri *et al*., 2014). Groundwater sources can either be borehole or well. However, borehole is more reliable for human consumption compared to well (Okelola *et al.*, 2010). Groundwater can pose serious danger to public health if contaminated. Effects of contaminated groundwater or lack of access to quality water has been focus of many studies.

Fallahzadeh *et al***.** (2017) observed that contaminants from industrial, domestic, and agricultural wastewater discharge as well as leachate from waste and surface runoff have led to contamination of groundwater resources and have reduced their quality. It is documented that globally water-borne diseases kill more than 25,000 people per day and about 5,000 children die daily due to water related diseases (mainly diarrhoea) and as such, it represents leading cause of death mostly in developing nations (Davis, 2013). Contaminated water not only has the potential to pose immediate threat to human, but also affect an individual productive rate (Mpenyana-Monyatsi & Momba, 2012). Over 66 million Nigerians in the cities and rural areas lack access to drinking water of good quality. This has resulted to an increase in consumption of contaminated or polluted water (WHO, 2012; Ologbushere *et al*., 2016; Beshiru *et al*., 2018) with potential detrimental to public health effects. Studies investigating the spatial and seasonal variability of water quality have reported that water quality issues, such as eutrophication, are highly dependent on land-use pattern (Bridget & Reedy, 2005). Other studies have also identified the pollution sources and anthropogenic activities on spatio-temporal variations in water quality (Gambhir *et al.*, 2012).

Previous studies (Bello-Osagie & Omoruyi, 2012; Kwadzah & Iorhemen, 2015; Alabi, *et al.*, 2016; Alabi, *et al.*, 2017) have observed that indiscriminate location of land-uses that are potential sources of contamination to groundwater. The land-uses include abattoir, industry, agriculture and cemetery. It has also been established that effluents from industries such as pharmaceutical

(Bakare *et al.*, 2011); hospital (Iyekhoetin *et al.*, 2011), tobacco (Alabi *et al.*, 2016) and automobile (Alabi *et al.*, 2016) contained heavy metals and other chemical constituents in high concentrations that can contaminate groundwater, with harmful effects on public health. Against this backdrop, the study examines existing land-uses and its implications on the physiochemical properties of groundwater in the study area.

LITERATURE REVIEW

Water is an important environmental component which is an essential ingredient for sustainability and survival of living creatures on earth. Webster dictionary (2016) defines water as a transparent, tasteless, odourless, and nearly colourless chemical substance, which are the main constituent of earth's hydrosphere and the fluids of most living organisms. Its chemical formula is H_2O meaning that each of its molecules contains one oxygen and two hydrogen atoms. Water covers about 70 per cent of the earth's surface and in nature exists in liquid, solid and gaseous states. Water can be used for recreation, drinking, fisheries, agriculture or industry.

There are two major categories of water which are surface water and groundwater. On the one hand, surface water is water that is located on top of the earth's surface, the vast of which is produced by precipitation and run-off from high areas. This includes lakes, streams, rivers, creeks and reservoirs which are used for irrigation, livestock, hydropower, industrial uses and recreation. Moreover, there are three major types of surface water: permanent surface water (e.g. lakes, rivers and wetlands); semi-permanent- present at certain times of the year (for examples; lagoons, creeks and waterholes) and man-made surface water (for examples; canal, damned artificial lakes and ponds). On the other hand, groundwater is fresh water that soaks into the soil and is stored in tiny pores (spaces) between rocks and particles of soil. It comes to the surface as springs or be pumped from a well and could be found in two zones: saturated zones and unsaturated zones – this is where pores and rock fractures are filled with water and the top of this zone is called the water table.

While Hill (2004) stated that more than one quarter of the world population depends on groundwater for drinking and other basic needs, Henry and Heinke (2005) corroborated that groundwater is naturally replenished by surface water from precipitation, streams and rivers and generally not as susceptible to pollution as surface water; but once polluted it is difficult to restore back to its pristine state. Groundwater is generally abstracted as well water (open surface drilling) or as borehole (drilling with pipe). It provides a reasonably constant supply for domestic use, livestock and irrigation, which is not likely to dry up under natural conditions thereby buffering the effects of rainfall variability across seasons (Calow *et al.*, 2011; David, 2011). Consequently, it is considered as one of the purest forms of water available in nature as it meets the overall demand for people (Tyagi *et al.*, 2013).

It is documented in literature that there is association between land-use and physicochemical properties of groundwater. Tu (2011) noted that impact of land uses on water quality involves association of land use and water quality indicators. Researchers have shown that there are significant correlations between land use and water quality parameters (Buck *et al*., 2004; Li *et al*., 2008). Razali *et al*. (2018) reviewed case studies of land use change in highland areas and its impact on river water quality, and their study was limited to the river system network in the Cameron Highlands in Malaysia. However, current study examined the impact of land-uses on groundwater quality.

Chemicals are among the major groundwater contaminants affecting its quality. This is possible through vertical migration of chemical contaminants to the aquifer and extending to the borehole, or by horizontal migration through permeable soils to water supplies that are poorly constructed (Calow *et al*, 2011). Examples of heavy metals and organics which are major chemical contaminants of drinking water sources and potential threat to public health include polyaromatic hydrocarbon (PAH), polychlorinated biphenyls (PCB), polybrominated diphenyl ethers (PBDE) and among others. In Nigeria, abattoirs are located indiscriminately and usually near water sources since the process require a lot of water and for ease of disposal of wastes (Omoruyi, *et al.*, 2011). The impact of the abattoir effluents has been reported to markedly increase the amounts of nitrogen, phosphorus and total solids in contiguous water bodies (Bello-Osagie & Omoruyi, 2012). The high biochemical oxygen demand (BOD), nutrients and pathogen content in abattoir waste poses pollution risk to water bodies (Keskes *et al.*, 2012).

Effluents from the industries mostly contain heavy metals, hydrocarbons, and atmospheric deposition (Alam *et al.*, 2007). Findings established that industrial effluents when loaded with heavy metals and harmful microbes can be hazardous when it gets into the food chain through the soil and water bodies and can affect plants, animals and humans adversely (Deshmukh *et al.*, 2011; Bai *et al.*, 2012). Interestingly, many of these industrial effluents are not treated before being discharged into water bodies. This action consequently contaminates the receiving ground waters.

Wastewaters from most industries in Nigeria are disposed into water bodies (Kwadzah & Iorhemen, 2015). The following reports have shown that effluents from pharmaceutical industry (Bakare *et al.*, 2009; Bakare *et al.*, 2011), hospitals (Iyekhoetin *et al.*, 2011), universities (Alabi *et al.*, 2012), tobacco industry (Alabi *et al.*, 2016), automobile workshops (Alabi, *et al*, 2016) and cocoa industry (Alabi *et al.*, 2017) contained heavy

metals and other chemical constituents in high concentrations capable of contaminating drinking water sources and lead to public health detrimental effects.

Moreover, analysing quality of water requires some form of calculations. Also, there are different methods of achieving this objective. However, weighted arithmetic water quality index will be adopted in this study. This method is adopted when most common quality variables are measured. The parameters or variables were analysed in the laboratory as per the standard procedures of American Public Health Association (1995). In order to calculate water quality index, the following equation were used:

First step: This is to calculate quality rating (Qn):

$$\text{Quality rating (Qn)} = 100 \times \frac{(Vn - Vi)}{(Vs - Vi)}$$

Where,

Vn = actual value of particular parameter in water sample

Vi = ideal value of parameter (0 for all parameters except pH 7 Milligram per liter)

VS= standard value for the parameter

Second step: This is to find unit weight (Wn) of each parameter: Wn=K/ Vs

$$\text{Where} = \frac{1}{1/vs\ 1 + 1/vs\ 2 + \ldots 1/vsn}$$

Step3: To calculate water quality index (WQI):

$$WQI = \frac{\Sigma\ QnWn}{\Sigma\ Wn}$$

Where Qn is quality rating

Wn is relative weight

Table 1: Water quality index and Status of water quality

Water Quality Index Range	Water Quality status	Classification
0 – 25	Excellent quality	A
26 – 50	Good quality	B
51 – 75	Poor quality	C
76 – 100	Very poor quality	D
>100	Unsuitable for drinking	E

Source: International Journal of Engineering Research and Technology (Abhijeet, 2022)

MATERIALS AND METHODS

Ikenne is geographically located on Latitude $6^0$51'57''N or 6.8658^0 and Latitude $3^0$42'55''E or 3.7152^0 (Fig. 1, 2, 3). Ikenne Local Government Area (LGA) has its headquarter seated in Ikenne with about 144 square kilometre in size.

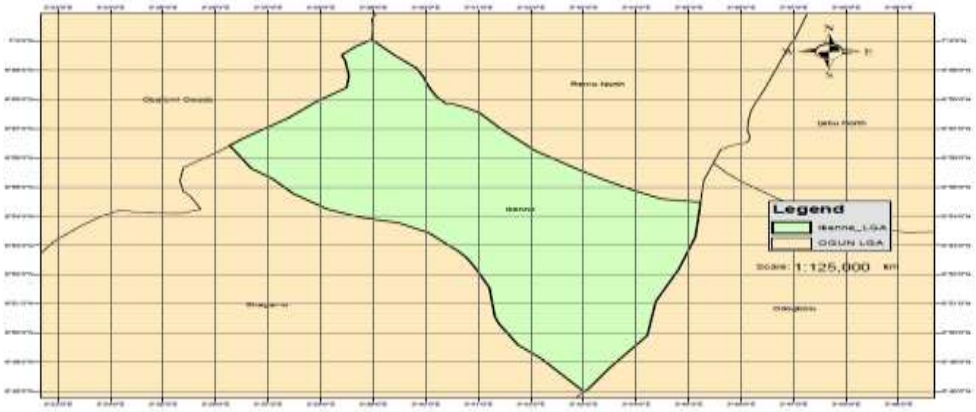

Figure 1: Map of Ikenne Local Government Area
Source: Department of Surveying and Geo-informatics, 2022

It is bounded in the west by Obafemi-Owode LGA, on the south by Sagamu LGA, while on the east and north by Odogbolu LGA. Being sub-urban, it comprises of four (4) major towns which are Iperu, Ilishan/Irolu, Ogere, and Ikenne. The local government is located along the transitional forest zone of southern Nigeria and Guinea savannah.

Primary data such as land-use and physiochemical parameters of groundwater were obtained for the study. Information on land-use was collected through land-use map of the area, while data on physicochemical properties were obtained through water sample from groundwater. Out of four major towns, two (Iperu and Illishan) were purposively selected. This is because of their size and proximity to each other that gives room for logical comparison. The two towns selected consist of three wards each, making six wards altogether. Land-use map of the two towns were used to analyse different

uses to which land is put. Six water samples were collected from each of the ward, with priority on groundwater at the centre. This is based on the assumption that centrally located groundwater shares properties of surrounding groundwater. Groundwater samples collected were analysed through laboratory test, while water quality index (WQI) was arrived at by summation of relative weight, multiply by water quality rating and divided by relative weight.

RESULTS AND DISCUSSION

Under this section, findings on analysis of land-uses and physiochemical properties of groundwater through the use of Water Quality Index (WQI) are discussed.

Land-use Analysis

The analysis of land-uses in the study area becomes imperative, if objective conclusion pertaining to groundwater quality of the area under study will be made. This is because, studies have established that types of land-use within an area do have impact on the quality of groundwater in such community (Keskes, *et al*., 2012; Alabi, *et al.*, 2016; Alabi, *et al.*, 2017). The analysis was done based on the two communities that were selected from the study area; namely Iperu and Ilishan towns.

As shown in Figure 2, findings on land-use analysis of Iperu town show that residential constitute highest percentage. Residential land-use alone covers 692.24 hectares, representing 78.87% of the total land area in the town. In order of magnitude, open spaces ranked second. It has a total area of 56.04 hectares (7.50%). This consists of both organised and un-organised spaces. Public land-use is the third in position in terms of size after open spaces.

It covers a total area of 44.42 hectares, accounting for 5.13%. Public land-use comprises churches, mosques, cemetery, civic centres, water corporation office, police training centre, theological seminary and motor parks. Circulation land-use ranked fourth. The total space for different categories of road in the area summed up to 35.96 hectares, representing 4.14%. The total land area for institutional land-use is 19.87 hectares (2.29%). Land-use categories under the institutional land-use are schools, including nursery, primary, secondary and/or higher institution. Other land-uses with significant percentage are industrial and commercial. The respective hectares of each of these land-uses are 5.00 and 4.14, with percentage contributions of 0.58 and 0.48.

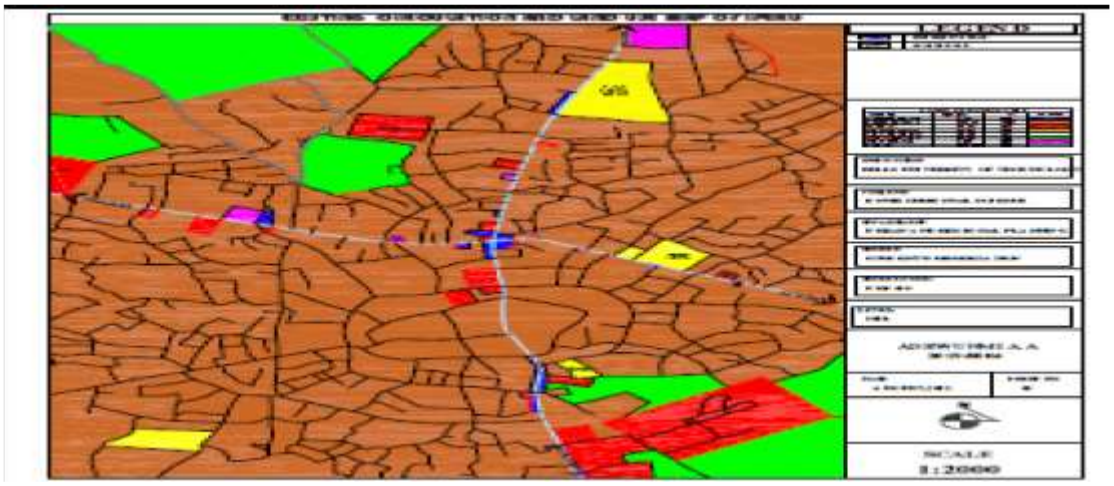

Figure 2: Land-use Map of Iperu Town

Figure 3 represents the findings on land-use analysis of Ilishan town. As shown in the figure the major land-use is residential (1,053.16 hectares), constituting 52.82% of the total land area. area. Open spaces ranked second. It covers an area of 666.96 hectares, representing 33.45%. Institutional land-use covers the total area of 214.22 hectares. It accounts for 10.74%. The next in rank is circulation land-use. It has a total land area of 38.23 hectares, constituting 1.92%. The town also has a number of public land-use. It covers a total of 10.22 hectares. This accounts for 0.51%. Commercial use occupies a space of 9.33 hectares, with proportion of 0.42%, which makes it second to the last in terms of total land area. The least land-use is industrial occupying an area of 1.93 hectares. It has a percentage of 0.10% of the total land area. The analyses of land-uses from the two towns do not show much variation in terms of land-uses. Residential land-use was predominant in the two towns. This might have significant impact on the quantity of contaminants generate and quality of groundwater in the area.

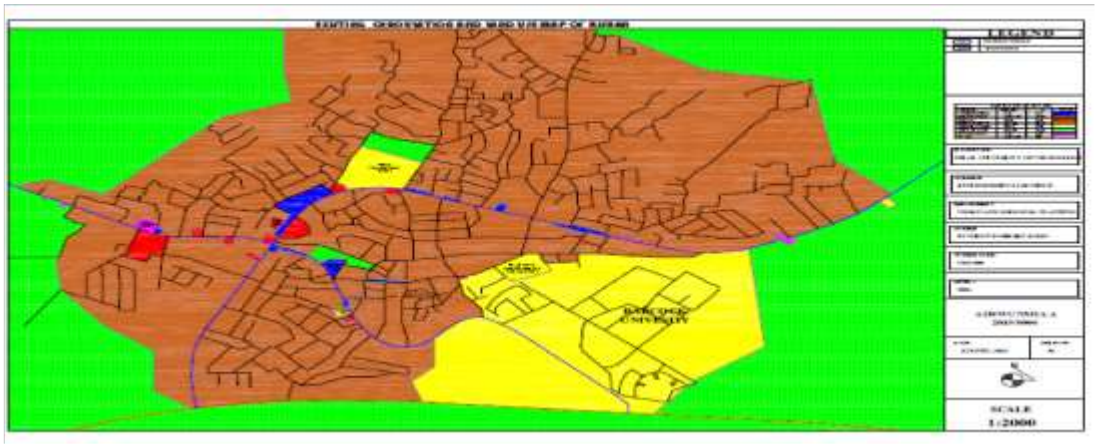

Figure 3: Land-use Map of Ilishan Town, 2022

Analysis of Physiochemical Parameters of Groundwater

Both physical and chemical parameters of water samples collected were subjected to laboratory test as depicted in Table 2. Important physical parameters that were tested included Total dissolved solids (TDS), temperature, turbidity, Electrical conductivity (EC), and pH of water. While important chemical parameters which were tested included Dissolved Oxygen (DO), chloride, sulphate, magnesium, calcium, hardness, Biochemical Oxygen Demand (BOD), Feacal coli form, Total Suspended Solids (TSS) and nitrate. The results were then harmonized and discussed with World Health Organization standards. It was found that groundwater pH in the study area ranges from 5.0 – 6.5. According to WHO standards pH should be between 6.5 and 8.5. The groundwater pH in Iperu ward I, II and III are 5.32, 5.3 and 5.0 respectively. In Illishan ward I, II and III the respective pH was 6.0, 5.62 and 6.5.

Turbidity is the measure of relative clarity of a liquid Though WHO gave no guideline for turbidity of drinking water quality however, maximum permitted according to Standard Organization of Nigeria (SON) (NSDWQ, 2007) is 5 NTU. Hence, water samples in Iperu wards and Ilisan wards are all within permissible limit. WHO standards the permissible range of magnesium in water should be 150 mg/l. In study area, magnesium values in Iperu wards range from 1.08 – 3.89mg/l and it ranged from 1.19 – 5.48mg/l in Ilisan wards. The values of it still fall within the prescribed standard limit. The quantity is significantly low in all the six wards. The values show a low concentration which could affect health of residents as it is essential for human body. The WHO (2017) allows maximum permissible limit of nitrate in drinking water is 50 mg/l. The results of the water samples in Iperu and Ilisan wards are 2.98, 5.01, 4.98, 3.06, 4.32 and 2.46mg/l. These outcomes indicate that the quantity of nitrate in study locations is acceptable.

The results of dissolved oxygen (OD) are in the range 6.2 – 7.6mg/l as shown in Table 2. This showed that the values obtained from the study areas exceeded the WHO standard limit of 5mg/l. This can be due to the infiltration of oxygen demanding waste. The value of biological oxygen demand (BOD) obtained shows that Iperu and Ilisan wards range from 2.28-3.17mg/l and 2.55-3.5mg/l respectively. According to WHO (2017) standards, its allowable range of calcium in drinking water is 150 mg/l. In study areas, results show that the concentration of calcium in Iperu wards range from 9.37- 19.03 mg/l whereas in Ilisan wards, the range is between 9.55 – 25.25mg/l. Hence, all values are within the acceptable standard limit. The values for total suspended solids (TSS) ranged from 6.66 – 15.55mg/l in Iperu and 7.15 – 12.79mg/l in Ilisan wards. The WHO (2017) maximum allowable limit of total solids in drinking water is 500 mg/l. The results indicated that the values are below the WHO recommended values which means that the sampled groundwater are free from suspended solids.

The temperatures of the sampled water vary from 25.2 to 25.7 Celsius. The temperature range falls within the recommended standard of WHO (2017). According to WHO standards concentration of chloride should not exceed 250 mg/l. In Iperu, chloride value ranges from 18.99-39.72 mg/l, while in Ilisan, the value ranges from 20.11 – 35.13mg/l. Thus, all the samples have lower concentration of chloride. The WHO has established 250 mg/l as the highest desirable limit of sulphate in drinking water. In study areas, values of sulphate in Iperu range from 44.29 – 56.33mg/l and Ilisan range from 44.89 – 60.78mg/l. The results show that concentration of sulphate in the study localities are below the maximum standard limit which makes the water suitable for domestic uses. With reference to World Health Organization (WHO, 2017) hardness of water should be 300 mg/l. The hardness values obtained in the study areas range between 11.89 – 38.45mg/l. It means the

areas had lower values of total hardness within the permissible limit by WHO standards. It is not harmful and does not require treatment with chlorine to remove hardness of water.

From the results in Table 2, total dissolved solids (TDS) of water sampled in Iperu ranges from 20.3 – 90.1mg/l and that of Ilisan ranges from 14.4 – 72.6mg/l. Hence, the TDS values were far negligible compared to the maximum standard level of 500mg/l and concentration of TDS is not harmful. WHO standards limit, established that electrical conductivity (EC) value should not exceeded 300 μS/cm. EC values in Iperu ward I II and III were 31.3, 135.4 and 92.8 μS/cm, respectively. While in Ilisan wards I, II and III the respective EC values were 22.2, 109.9 99.8 μS/cm. Hence, the values obtained were lower than the standard limit. The microbiological analyses of the water indicate that faecal coliform microbial loads were not found in all the groundwater sampled. This indicates minimal level of microbial load in all the groundwater which makes the water suitable for drinking purpose.

Table 2: Laboratory Analysis of Physio-chemical Parameters of Groundwater

Wards	pH 6.5-8.5	Temp.0C 24-30	Turb. NTU 5	Conductivity 300 μS/cm	Chloride 250 mg/L	Total hardness 300 mg/L	SO_4 250 mg/L	NO3 50 mg/L	TDS 500 mg/L	E.Coli cfu/ML	Mg^{2+} 150 Mg/L	Ca 150 Mg/L	TSS 500 mg/L	DO 5	BOD - 50
Iperu ward I	5.32	25.5	2.78	31.3	18.99	11.89	56.33	2.98	20.3	0	1.08	9.37	8.59	6.7	3.17
Iperu ward II	5.3	25.2	4.63	135.4	45.24	20.01	44.29	5.01	90.1	0	3.89	13.83	15.55	7.0	2.94
Iperu ward III	5.0	25.3	2.41	92.8	39.72	25.32	55.79	4.98	60.5	0	3.44	19.03	6.66	7.6	2.28
Ilishan ward I	6	25.5	2.04	22.2	35.13	12.22	60.78	3.06	14.4	0	1.19	9.55	7.15	6.4	3.25
Ilishan ward II	5.62	25.4	2.78	109.9	29.22	38.45	44.89	4.32	72.6	0	5.48	27.73	8.65	7.2	2.55
Ilishan ward III	6.5	25.7	3.15	99.8	20.11	34.95	51.55	2.46	64.6	0	3.86	25.25	12.79	6.2	3.5

Information from Table 3 indicates Water Quality Index (WQI) for each of the ward sampled. The WQI for Iperu I, II and III are 32.9, 33.5 and 19.4 respectively. Furthermore, the respective WQI for Illishan I, II and III are 39.4, 31.4 and 43.8. as recommended by American Public Health Association (1995) as shown in Table 1, the WQI of sample of groundwater from Iperu I, II and; Illishan I, II and III was found to be of good quality (Category B). It was only in Iperu III where WQI was found to be excellent (Category A). This is in agreement with the finding of Okelola, *et al*., (2010), in which they established that water from borehole is more reliable. The results of ANOVA of $F = 0.596$ and $p > 0.05$ established that there is no statistical significant variation in the physiochemical properties of groundwater in the surveyed wards. The findings might be attributed to two major factors. One is the fact that most of the residents' source of groundwater is borehole, which is deep enough to be contaminated by human activities. The other is that most of land-uses in the studied towns might not have by-products that will have significant negative impact on land that might lead to contamination of groundwater. It is clear from the study that groundwater; especially borehole might not be easily contaminated by anthropogenic activities of man, unlike surface water. Previous studies (Kwadzah & Iorhemen, 2015, Alabi *et al*., 2017) corroborate this assertion.

Table 3: Estimation of Water Quality Index (WQI)

Parameter	Iperu ward I	Iperu ward II	Iperu ward III	Ilisan ward I	Ilisan ward II	Ilisan-Irolu ward III	Relative weight (Wn)
pH	-24	-24.3	-28.6	-12.5	-19.2	-7.2	0.1429
Temperature	2.78	2.74	2.75	2.78	2.76	2.80	0.0333
Turbidity	11.12	18.52	9.64	8.16	11.12	12.6	0.2000
Conductivity	0.034	0.149	0.102	0.024	0.121	0.110	0.0033
Chloride	0.030	0.072	0.064	0.056	0.047	0.032	0.0040
Total Hardness	0.013	0.022	0.028	0.013	0.042	0.039	0.0033
Sulphate	0.090	0.071	0.089	0.097	0.072	0.083	0.0040
Nitrate	0.119	0.200	0.199	0.122	0.173	0.098	0.0200
TDS	8.12	0.036	0.024	5.76	0.029	0.026	0.0020
Magnesium	0.005	0.017	0.015	0.005	0.025	0.017	0.0067
Calcium	0.042	0.062	0.085	0.043	0.124	0.113	0.0067
TSS	0.003	0.006	0.003	0.003	0.004	0.005	0.0020
DO	26.0	28.0	30.4	25.6	28.8	24.8	0.2000
BOD	0.127	0.118	0.091	0.13	0.102	0.14	0.2000
$\sum WnQn$	25.28	25.8	14.9	30.3	24.2	33.7	
$\sum Wn$	0.7688	0.7688	0.7688	0.7688	0.7688	0.7688	
$WQI=\frac{\sum WnQn}{\sum Wn}$	32.9	33.5	19.4	39.4	31.4	43.8	

CONCLUSION

The study has examined land-use and its impacts on physiochemical properties of groundwater in the two major towns in Ikenne LGA. It was found that land-uses in the area do not contribute to contamination of groundwater, especially boreholes. It was also established that there is no significant variation in the physiochemical parameters of groundwater in the sampled wards.

It is therefore, recommended that land-use zoning should be promoted in Nigerian settlements. This will not only enhance considerable improvement in health of the community, but also see to sustainable land-use. It will guide use of land and/or buildings and of the height and density of buildings in specific areas, with the aim of securing convenience, health, safety and general welfare of a community. Since boreholes are less contaminated by human activities, priority should be given to sinking of boreholes by individuals, private and corporate organisations and governments in communities where groundwater is lacking or not adequate.

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Socioeconomic Predictors of Users' Satisfaction with Neighbourhood Facilities in Public Residential Estates in Akure, Nigeria

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The state of neighbourhood facilities in public housing estates play important roles in determining how the residents perceive such facilities. However, when socioeconomic characteristics of users of housing environments are not considered in the planning, it could lead to dissatisfaction with such facilities. Thus, this study aims at evaluating the effects of socioeconomic characteristics on satisfaction with neighbourhood facilities. It adopts a cross-sectional survey of three-hundred and one (301) housing units using structured questionnaire and direct observations in three public housing estates in Akure namely: Ijapo, Alagbaka and Oba-Ile Housing Estates. Data obtained were analyzed using single-factor descriptive analysis, Mean Satisfaction Scoring and Categorical Regression Analysis to examine the effects of socioeconomic factors on users' satisfaction with neighborhood facilities. The findings showed that religious centres had the highest rating in all aspects of the study in the study estates, while fire service station was rated the least. Three of the independent variables significantly explained satisfaction while the model generally predicted satisfaction with neighbourhood facilities in this context. The model explained 34.9% of the variance in the level of satisfaction with Multiple R^2 of 0.349. The study recommended that developers, policy makers, architects and government agencies that manage the housing estates should ensure that, in planning public residential estates, the residents' socioeconomic characteristics should be considered because it can enhance satisfaction particularly as it pertains to neighbourhood facilities.

Keywords: Facilities, Neighbourhood, Public Housing Estates, Satisfaction, Socioeconomic characteristics

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INTRODUCTION

Neighbourhood environments has become an important domain because residents spend a large proportion of their time in neighbourhoods for social interaction, and physical activities (Ma *et al.*, 2018). Thus, neighbourhoods support the lives of residents and enables them to meet their aspirations within the housing environment. Housing has always been of great necessity to man, as it is one of his most important needs (Olotuah & Taiwo, 2013). An integral part of neighbourhoods are the facilities within the neighbourhood, which along with other infrastructure, supports the activities of individuals and the community living within such housing environments. Therefore, due to its potential to enhance liveability in neighbourhood environment, the importance of neighbourhood facilities cannot be disputed. Ma and Haarhoff (2015) asserted that public facilities are critical aspects of neighbourhoods that need to be considered when internationally evaluating cities for liveability. More so, rapid urbanization has put significant pressure on local and state governments on providing urban infrastructural facilities that are intended to improve the quality of urban life (Mohit & Ali, 2016).

Over the years, the urbanized environment of big cities has become the main focus of urban planners, policy makers and numerous researchers have devoted to evaluating housing environment satisfaction as an indicator of citizen's quality of life (Novianto *et al*., 2016). Therefore, it has become imperative to clarify the present residential environment situation especially in terms of the neighbourhood facilities (Novianto *et al.,* 2016). Fakere and Duke-Henshaw (2020) posited that neighbourhood satisfaction is largely the lens through which the residents perceive their neighbourhood environments relative to their individual needs, while satisfaction with neighbourhood facilities refers to the way that residents perceive the facilities within their neighbourhoods. These two are interlinked because, the facilities are essentially an integral part of the neighbourhood and cannot be separated from it (Fakere & Duke-Henshaw, 2020).

Residents make their judgments about housing conditions based on their personal needs and aspirations (Hezzrin *et al.,* 2017). This includes how they assess their residential environment especially as it relates to neighbourhood facilities. Neighbourhoods should be provided with such facilities as schools, healthcare centres, police stations, and recreational facilities, fire service stations, religious centres, events centres and shopping centres because they also constitute important neighbourhood facilities in public housing estates (Asiyanbola *et al.,* 2012). A very important factor that affects the quality of life is the residents' satisfaction with their neighbourhood's facilities and services (Iyanda & Mohit, 2016). Thus, satisfaction is generally an indicator of the quality of life (Mohit & Ali, 2016). Housing and residential quality and the satisfaction one derives from them are particularly important (Dimuna & Olotuah, 2019). However, people's behaviours are complicated with various influencing factors such as of social, economic, psychological and natural conditions (Novianto *et al.,* 2016).

The extent to which socioeconomic variables of residents influence the level of satisfaction with

neighbourhood facilities in public housing estates is not well elucidated in literature. Novianto *et al.* (2016) evaluated neighbourhood environments in terms of neighbourhood facilities and urban planning in Japan. Residents' behaviours and preferences were subjectively evaluated using questionnaire survey of 3000 households of younger families located in Kitakyushu City in Northern Kyushu Island, Japan. The study revealed that the residents were largely dissatisfied with safety, while more than 60% of the households achieved their comprehensive wish on living conditions. It contributed some strategies on efficient planning and development of the neighbourhood environment. Furthermore, Lim *et al.* (2017) investigated the relationship between satisfaction with neighbourhood facilities and social trust in urban villages in Kuala Lumpur, Malaysia. The study stems from identifiable neglect of urban villages in the drive to achieve social cohesion and the goals of Vision 2020 in Malaysia. It includes data from a survey of 334 respondents. The study found that satisfaction with neighbourhood facilities was a significant predictor of social trust and that there was a need to improve perception and satisfaction of users towards these facilities, especially the commercial and educational ones.

In addition, Dimuna and Olotuah (2019) assessed residents' satisfaction with planning and neighbourhood facilities of six public residential estates in Benin City, Nigeria. The study surveyed 1000 housing units. Findings showed that relative satisfaction index scores for all the estates were fair within the region of 2.1 to 3.0, implying that residents were satisfied with the estate planning conditions. Results showed no significant difference in the relative satisfaction index among the estates, while it found significant relationship between estate planning and residential satisfaction. The study recommends the need for improved government policy to encourage a decent and liveable environment in terms of planning of estates. These studies have been able to provide some information on certain aspects of neighbourhoods and satisfaction; they however did not provide information that contributes towards understanding the intricacies that exist between socioeconomic profile of residents and satisfaction with neighbourhood facilities in public housing estates.

However, few studies that exists on this subject relates socioeconomic variables with other aspects of satisfaction. Li (2012) found that income and education determines neighbourhood satisfaction. Likewise, Mohit and Ali (2016) determined that socioeconomic variables significantly influence neighbourhood satisfaction. According to Sungur and Cagdas (2003), individual and household characteristics including age, and characteristics of location of resident were significant predictors of neighbourhood satisfaction. Similarly, Amestoy and Toscano (2007) found that gender is a significant but weak predictor of housing satisfaction. Conversely, Li and Song (2009) in a study conducted in Shanghai between displaced residents and other residents of the city averred that socioeconomic and demographic characteristics do not significantly predictors of residential satisfaction. Likewise, Housing Authority Council (HAC, 2000) observed that income did not influence satisfaction, however age of the respondents was. It then becomes pertinent to discover how socioeconomic variables relate with users' satisfaction with neighbourhood facilities, which is scanty in literature.

This study therefore aims to extend the literature by exploring how socioeconomic factors influence users' satisfaction with neighbourhood facilities in developing countries especially as it relates to public housing estates. In other words, the goal of this study is to examine the influence of socioeconomic variables of residents on their level of satisfaction with the neighbourhood facilities in selected public housing estates in Akure, Ondo State, Nigeria. It analysed the socioeconomic characteristics of the respondents, assessed their level of satisfaction with neighbourhood facilities and explored how the former predicts the latter in the study area. This should provide information that could be used to improve housing policy for the purpose of planning and developing satisfactory public housing estate facilities for residents. The paper continues by introducing the conceptual framework as well as the methodology section. Section 5 provides the results of data analysis, kicking off with description of the socioeconomic characteristics of the respondents, followed by s description of the satisfaction level with neighbourhood facilities, and then Categorical Regression Analysis of the relationship between the two. The paper later concludes by discussing the results obtained, offering recommendations and implications of the findings, thus adding to the body of knowledge on the subject.

CONCEPTUAL FRAMEWORK

Several socioeconomic variables have been tested against different aspects of satisfaction (Li, 2012; Mohit & Ali, 2016; Sungur & Cagdas, 2003; Amestoy & Toscano, 2007; Li & Song, 2009). It is therefore important to show how they influence satisfaction with neighbourhood facilities. Figure 1 shows the conceptual framework for this study. The study conceptualized that socioeconomic characteristics of respondents influence their level of satisfaction with neighbourhood facilities. The socioeconomic characteristics include gender, age, marital status, employment status, tenure status, income, household size, length of stay, and level of education. Satisfaction with neighbourhood facilities in the study area was construed as the dependent variable while these socioeconomic variables were the independent (predictor) variables. It hypothesized that the several socioeconomic variables influence their levels of satisfaction with neighbourhood facilities.

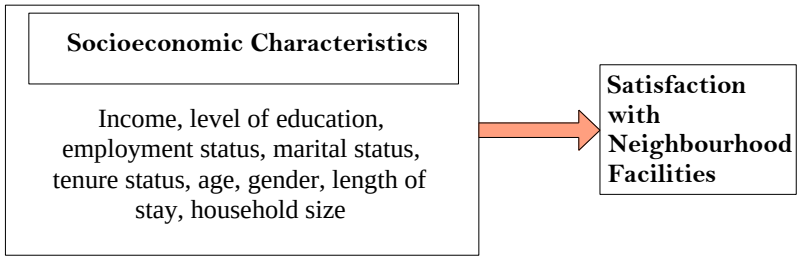

Figure 1: Conceptual Framework for the study

RESEARCH METHODOLOGY

This study used primary data collected through structured questionnaire. The instrument was structured according to the study themes in order to make the questions easy to follow and read by the respondents. The themes of the study are socioeconomic characteristics and satisfaction with estate facilities. The estate facilities were namely: recreational open spaces, religious centres, schools, police stations/posts, shopping centres, health centres/clinics, fire service stations, and event centres. The socioeconomic variables examined were gender, age, marital status, education, employment status, monthly income, tenure status, household size and length of occupation. The levels of satisfaction with estate facilities were defined as very dissatisfied, dissatisfied, neutral, satisfied, and very satisfied. The respondents were asked to select their preferred options from the ones presented. The questionnaire was administered physically in three public housing estates namely: Alagbaka (AHE), Ijapo (IHE), and Oba-Ile Housing Estates (OIHE) by trained assistants. The number of housing units in IHE is 600, while for AHE and OIHE are 508 and 721 respectively. This brings the target population for the study area to 1,829 housing units. Three hundred and eighteen (318) is the sample size for the study, which was generated using Sample Size Table by Bartlett *et al* (2001). The number of copies of the questionnaire administered in each of the estates was determined according to the proportion of their contribution to the total population size. Stratified random sampling technique was used in each of the housing estates to select the samples. An additional 10% of the questionnaire was administered for the study to ensure that the percentage return was as close as possible to the sample size; and this made the total copies of the questionnaire to be 350. Three-hundred and one (301) copies were retrieved, representing 94.6 percentage return. Single Factor Descriptive Statistics, Mean Scoring and Categorical Regression were used in the analysis for this research and Statistical Package for the Social Sciences Version 20 was used for the analysis. Categorical Regression Analysis was used because the dependent variable was in categorical scale (International Business Machine Corporation, 2021). Hence, categorical regression was carried out with optimal scaling method with the criteria for convergence set at 0.00001. A Confidence level of 95% was used for analysis in this study.

RESULTS AND DISCUSSION

Socioeconomic Characteristics of Respondents

Table 1 shows that most of the respondents are not high-income earners since 42.2% of them earn less than N50,000, while only 22.9% of them earn between N50,000 and N99,999 monthly. Over half of the respondents (56.1%) were single, while majority of them were well educated with over 75% of them being educated up to the tertiary level. Majority of the respondents (69.8%) were employed or retired from an employment, while over half (54.8%) of them are renters in the study area. Over four-fifths of them are either forty years of age and below, over seventy-percent of them have a household size of between 3 to 6 persons, and over 66% of them have lived in the study area for over ten years.

Table 1: Socioeconomic characteristics of respondents in the study area

Factors	Frequency (n=301)	Percentage (%)
Income		
Below N50,000	127	42.2
N50,000- N99,999	69	22.9
N100,000- N149,999	18	6.0
N150,000- N199,999	27	9.0
N200,000 – N249,000	18	6.0
N250,000 and above	9	3.0
No response	33	11.0
Level of Education		
No Formal Education	3	1.0
Primary	0	0.0
Secondary	66	22.0
Tertiary	226	75.1
No response	6	2.0
Employment Status		
Unemployed	91	30.2
Civil Servant	66	21.9
Self Employed	93	30.9
Retired	6	2.0
Private Sector Employed	36	12.0
Marital Status		
Single	169	56.1
Married	126	41.9
Widowed	0	0.0
Separated	6	2.0
Tenure Status		
Privately Rented	165	54.8
Owner Occupied	66	21.9
Free Occupation	3	1.0
Family House	45	15.0
Employer's Quarters	6	2.0
No response	16	5.3
Age of Respondents		
Below 30 Years	145	48.2
31-40 Years	108	35.9
41-50 Years	27	9.0
51-60 Years	15	5.0
61-70 Years	6	2.0
70 Years and above	0	0.0
Household Size		
1-2	45	15.0
3-4	138	45.8
5-6	81	26.9
7-8	22	7.3
9-10	3	1.0
Above 10	3	1.0
No Response	9	3.0
Length of Occupation		
1-10 years	198	66.4
11 – 20 years	82	27.2
21 – 30 years	9	3.0
31 – 40 years	9	3.0
No response	3	1.0
Gender		
Male	163	54.2
Female	138	45.8

Levels of Satisfaction with Neighbourhood Facilities in the Study Area

Table 2 shows the level of satisfaction with neighbourhood facilities in the study area. They were ranked according to their positions as determined by Mean Satisfaction Scoring (MSS). The total MSS for satisfaction with neighbourhood facilities was 3.41, suggesting that the respondents were generally satisfied with estate facilities in the study area. The highest ranked neighbourhood facility in terms of satisfaction is religious centres with MSS of 3.96, 88.1 % of the respondents rated it as satisfactory while 11.9% rated it as dissatisfactory. The lowest ranked neighbourhood facility in terms satisfaction in the study area is fire service station with a MSS of 2.37 and 68.8% of the respondents rated it as dissatisfactory while 31.2% rated it as satisfactory. Other selected neighbourhood satisfaction variables according to their ranking were schools (MSS = 3.68, D = 28.9%, S = 71.1%), shopping centres/ shops (MSS = 3.68, D = 13.2%, S = 86.8%), event centres (MSS = 3.60, D = 15.9%, S = 84.1%), health centres/clinics (MSS = 3.34, D = 21.1%, S =78.9%). In addition, recreational open spaces were (MSS = 3.33, D = 23.9%, S = 76.1%), and police station/post (MSS = 3.31, D = 23.9%, S = 76.1%). This implies that there is generally high level of satisfaction with neighbourhood facilities in the study area.

In the study area, it is clear that there is generally a neutral level of neighbourhood satisfaction; except for fire service station within the estate, which was low. This means that though fire safety was important to the residents, they were generally disappointed that they were not adequately provided. This also means that, should there be a fire outbreak within the estates, the residents were concerned that the response rate to handle the outbreak would not likely be swift. If people's current experiences are lower to their aspirations, the usual response is dissatisfaction with that experience. This is a very common phenomenon in Nigeria, where there is huge safety infrastructure deficit (Ndubuisi, 2018; Ayansola & Abiru, 2020).

Table 2: Satisfaction with Neighbourhood Facilities and MSS in the study area

Neighbourhood Satisfaction Variables	D	%	S	%	T	%	MSS N=301	Position
Recreational open spaces	72	23.9	229	76.1	301	100	3.33	6
Schools	87	28.9	214	71.1	301	100	3.68	2
Police Station/Post	72	23.9	229	76.1	301	100	3.31	7
Religious centres	36	11.9	265	88.1	301	100	3.96	1
Shopping centres/shops	39	13.2	262	86.8	295	100	3.68	2
Health centres/Clinic	63	21.1	238	78.9	298	100	3.34	5
Fire service station	207	68.8	94	31.2	301	100	2.37	8
Events Centre	48	15.9	253	84.1	301	100	3.60	4
Grand Mean							**3.41**	

D = Dissatisfied; S = Satisfied; T = Total

Socioeconomic Predictors of Satisfaction with neighbourhood facilities

The research investigated the socioeconomic predictors of the level of satisfaction with neighbourhood facilities in the study area using Categorical Regression Analysis. For this analysis, the level of satisfaction with neighbourhood facilities was the dependent variable, while monthly income, marital status, level of education, employment status, tenure status, age, gender, household size and length of occupation were the independent (predictor) variables. The result in Table 3 shows that not much of the variance in the dependent variable is explained by the regression model with Multiple R = 0.591, and coefficient of determination (R^2) = 0.349. This implies that the regression model explains 34.9% of the residual variation in the level of satisfaction with neighbourhood facilities in the study area. The remaining percentage could be explained by other factors, which are beyond the scope of this study. In addition, Table 3 shows (p = 0.000), which also implies that the regression model is statistically significant at $p<0.05$ and that a significant relationship exists between residents' socioeconomic characteristics and their satisfaction with neighbourhood facilities in the study area. This finding is supported by Li (2012), Mohit and Ali (2016), Sungur and Cagdas (2003) and Amestoy and Toscano (2007), which found that socioeconomic characteristics of users influence their level of satisfaction; while being contrary to the findings of Li and Song (2009), which found that here is no significant relationship between satisfaction and socioeconomic characteristics. This suggests that improvement in the socioeconomic profile of residents should improve their level of satisfaction with the facilities.

It is clear in the Table that only three of the variables investigated were significant predictors of the level of satisfaction with neighbourhood facilities. The order of the importance of the variables are level of educational attainment ($\beta = 0.597$, $p = 0.029$), tenure status ($\beta = 0.193$, $p = 0.041$), and length of occupation ($\beta = 0.184$, $p = 0.001$). The strongest significant predictor was respondents' level of education, which indicates that it contributed the most in predicting satisfaction with neighbourhood facilities. The weakest one was length of occupation, which indicates that it contributed the least. However, gender, marital status, age, employment status, income level and household size were not significant predictors in the model.

This finding is partially consistent with the findings of several researchers, which found that several

socioeconomic variables have positive relationship with satisfaction. Li (2012) found that income significantly influenced neighbourhood satisfaction; whereas HAC (2000) found that it did not do so within the context of their study. Li (2012), HAC (2000), and Sungur and Cagdas (2003) determined that level of educational attainment and age significantly predicted neighbourhood satisfaction. Similarly, Amestoy and Toscano (2007) found that gender significantly predicted housing satisfaction; this is contrary to the findings of this study. This suggests that these findings could be partially applicable to the context of this study.

Table 3: Socioeconomic predictors of Residents' Satisfaction with neighbourhood facilities

Socio-economic Characteristics of Respondents	Standardized Coefficients		*df*	*F*	*Sig*
	Beta	Std. Error			
Gender	0.074	0.068	1	1.174	0.280
Marital status	0.072	0.080	2	0.811	0.446
Age of respondents	0.201	0.105	1	3.680	0.056
Level of educational attainment	0.597	0.315	2	3.593	0.029*
Employment Status	0. 193	0.118	2	2.671	0.071
Income Level	0.033	0.162	1	0.042	0.838
Tenure status	0.193	0.107	2	3.240	0.041*
Household Size	0.053	0.070	1	0.568	0.452
Length of Stay	0.184	0.077	3	5.792	0.001**
Multiple R	**R^2**		***df***	***F***	***Sig***
0.591	0.349		251	8.431	0.000

Dependent variable: Level of satisfaction with neighbourhood facilities;
**Significant predictors (P<0.01); * Significant predictors (P<0.05)

CONCLUSION

This paper examined satisfaction with neighbourhood facilities in selected public housing estates in Akure, Nigeria as well as the socioeconomic variables that influence it. The study found that three out of the nine socioeconomic variables examined in this study singularly predicted satisfaction in the model. However, the nine variables jointly had significant influence on satisfaction with neighbourhood facilities in the study area. Individually, level of educational attainment contributed the most, while length of occupation contributed the least to the model. Tenure status also contributed significantly to the model. The variables that were not significant contributors to the model were, gender, marital status, age of respondents, employment status, income level, and household size. The study also showed that socioeconomic factors significantly predict the level of neighbourhood satisfaction in the study area, with p = 0.0000. The predictive power of the model was 0.349, meaning that only 34.9% of the variance in satisfaction with neighbourhood facilities is explained by the socioeconomic variables in this context. Since, the results could be different for another context, further studies are required. This study was carried out in public housing estates in the urban setting. However, the study cannot be used to generalize for other types of housing environments like private housing estates/ layouts, or even rural housing. For generalization, further studies in these other types of housing are required. Policy makers, developers, architects and government agencies that manage public housing estates should ensure that planning of future and existing public residential estates should consider the residents' socioeconomic characteristics because this has the potential to enhance satisfaction particularly as it pertains to neighbourhood facilities. This study has contributed to the existing body of knowledge by showing which socioeconomic variables predict satisfaction with neighbourhood facilities; this should enhance the process of developing strategies to improve satisfaction with public housing estate facilities.

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Diurnal Assessment of Air Quality at Zuba Motor Park, Abuja of Nigeria

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Exposure to air pollutants is increasing respiratory and cardiovascular morbidity and mortality with developing countries still experiencing the worst air pollution. This stimulates this study on diurnal assessment of air quality at Zuba Motor Park, Abuja of Nigeria. Air pollutants data (CO, SO_2, NO_2, PM, VOCs and NO), were collected at the centre of Zuba Motor Park. Measurement of the air pollutants was carried out three times (morning, afternoon and evening) in a day for a duration of 7 days in December 2022 with the intention to get a comparative result that would show the intensity at various times of the day and how they contribute in air pollution. Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) Version (22.0). AQI was calculated using US.EPA equation. Results shows that the concentration of CO, SO_2, $PM_{2.5}$ and PM_{10} are more in the morning and evening (6a.m. - 7a.m. and 6p.m. - 7p.m.) when traffic volumes were high within the Motor Park. The ambient concentration of CO and SO_2 at the motor park in the morning exceeds the NESREA permissible limit creating threat to human health same goes to $PM_{2.5}$ at the motor park in the morning and evening for only the working days that was above the NESREA permissible limit while PM_{10} for all time of the day and all days of the week were within the NESREA permissible limit. The study also concludes that there is potential hazards during the morning and evening period in the study area for SO_2, CO and $PM_{2.5}$ with the pollutants of health risk to hawkers, road users and transport workers. Based on the findings of this study, there is a need for promoting and sensitizing the vulnerable and sensitive groups on the dangers of air pollution and there is for consistent vehicle inspection with vehicle emission testers to determine the emission status of vehicles patronizing Zuba Motor Park.

Keywords: Diurnal, Air Quality, Zuba Motor Park, Ambient

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INTRODUCTION

Transport is a vital part of modern life whereby there is opportunity to travel short and long distances for personal development and professional activities, more importantly, the economic development of entire regions depends on the easy access to people, goods and services assured by contemporary transport (Oderinde *et al.,* 2016). Motor parks are usually associated with transportation that involves the use of commercial vehicles by offering a place for commuters to come and board vehicles to their places of destination (Salami *et al.,* 2020). Motor parks are widespread and common public spaces in urban areas in Nigeria because many people use public transport systems, however, they differ in design, nature and services (Godson & Olusola, 2015).

The two main sources of air pollutants in urban areas are transportation (predominantly automobiles) and fuel combustion in stationary sources including residential, commercial, industrial heating and cooling and coal-burning power plants (USEPA, 2016b). Motor vehicles produce high levels of carbon monoxide (CO) and a major source of nitrogen oxides (NOx). Whereas fuel combustion in stationary sources is the dominant source of sulphur dioxide (SO_2). Currently, fossil fuels supply about 86% of the global primary energy consumption for transportation, industrial, commercial and residential uses. Due to the combustion of fossil fuels, large quantities of pollutants are emitted into the air, which have serious impact on the local, regional and global air quality (USEPA, 2016a).

Clean air is a vital resource needed for good health and the well-being of humans, animals, and plants (Murat, 2017). Sadly, our atmosphere is being continuously polluted thereby jeopardizing the air quality. Many cities around the world, particularly in developing countries like Nigeria, are experiencing rapid growth (UNICEF & UN Habitat, 2020). Yet, in the absence of adequate environmental policy and action, this growth occurs at a considerable, and often increasing, economic and social cost. Human activities have had a detrimental effect on the makeup of air (Ioannis & Elivaset, 2020). Use of automobiles, burning of coal, oil and other fossil fuels, and open or agricultural burning have changed the composition of air by introducing many pollutants.

Exposure to air pollutants is increasing respiratory and cardiovascular morbidity and mortality with developing countries still experiencing the worst air pollution (WHO, 2016). The World Health Organization (WHO) and other International Agencies have long identified urban air pollution as a critical public health problem (World Health Organization, 2021). Air pollution is the 4th largest health threat worldwide and the topmost environmental risk to human health (WHO, 2016). Outdoor air pollution contributes about 4.2 million premature deaths annually, with particulate matter noted as the major contributor to air pollution and having the greatest health risk among the air pollutants (WHO, 2020). Globally, nine out of ten people breathe unsafe polluted air; resulting to approximately 7 million deaths annually, as more than 90% of people

live in settlements with unhealthy air quality (WHO, 2018 & 2021).

About 91% of the world's population lives in places where the air quality is above the WHO limits for Particulate Matter ($PM_{2.5}$ and PM_{10}), Ozone (O_3), Nitrogen dioxide (NO_2) and Sulfur dioxide (SO_2) as leading pollutants with the greatest health concern (WHO, 2018). Cohen *et. al.* (2017) reported that, of the 4.2 million reported premature deaths caused yearly are as a result of ambient air pollution, ambient $PM_{2.5}$ (particulate matter less than 2.5 micrometres in diameter) was responsible for up to 16.5% with an estimate of 1.7 million lung cancer death worldwide. Polluted air was responsible in 2015 for 6.4 million deaths worldwide - 2.8 million from household air pollution and 4.2 million from ambient air pollution (Prüss-Üstunet *et al.,* 2016). In the absence of aggressive control, ambient air pollution is projected by 2060 to cause between 6 million and 9 million deaths per year (Organisation for Economic Cooperation and Development, 2016).

Urban air quality is noted to be improving in cities of developed countries as against those of low- and middle-income countries such as Abuja in Nigeria (WHO, 2016). Nigeria is said to have the highest burden of mortalities from poor air quality in Africa and 4th globally (Health Effects Institute, 2018). The country was ranked 150th out of 180 countries for poor environmental performance index on air quality (Yale Center for Environmental law and Policy, 2018). Some cities across Nigeria have been noted to have poor air quality and with continuous increase in population, urbanization, anthropogenic activities and climate change, concern on the state of air quality in Abuja and other cities across the world, such remains an important discuss (Akinfolarin *et al.,* 2017).

The goal of establishing of motor parks is to provide satisfaction to its users and commuters. Motor parks play a crucial role in the management of traffic and congestion in cities. However, the activities of a motor park could pollute the air especially from exhaust pipes of vehicles coupled with the use of fossil fuel through incomplete combustion by the engine causing air pollution in the forms of smokes, dusts and so on. This is resulting from poorly managed vehicles, general use of the two stroke engine automobiles (mainly motorcycles and tricycles) for shuttling commuters and traffic congestions which generate high levels of localized air pollution that can affect population health (Oluwole *et. al.,* 2017; Salami *et. al.,* 2020). Traders in motor parks spend about 6 - 8 hours daily in those motor parks, hence they are at risk of possible exposure to carbon monoxide arising from vehicles and other emission sources in motor parks (Olusola *et. al.,* 2018).

In Nigeria, an empirical study was carried out to assess air quality in major motor parks at Kwara State (Salami *et. al.,* 2020). Though several other studies have been carried out with regards to air quality in urban areas and even under several land uses in the FCT in particular (Ishaya *et al.,* 2017; Harrison, 2020; Magaji and Hassan, 2015), yet, diurnal studies on air quality within motor parks are limited in FCT, Nigeria. It is in view of this that this study is propelled to fill in the gap by generating novel air quality/air pollution assessment data of Zuba Motor Park at different time of the day. It will also identify likely impacts on those that engage in activities in the motor park.

STUDY AREA

Zuba Motor Park is located in Zuba town. Zuba town is a ward under Gwagwalada Area Council of the Federal Capital Territory (FCT) in Nigeria. The Zuba Park is located at Latitude 9°5'47" N and Longitude 7°12'46" E on elevation of 432 meters above sea level and sharing boundary with Madalla in Niger State. Zuba town experiences a warm, humid rainy season and a blistering dry season. In between the two, there is a brief interlude of harmattan occasioned by the northeast trade wind, with the main feature of dust haze, intensified coldness and dryness. The rainy season begins from April and ends in October, with a daytime temperature reaching 28^{o}C to 30^{o}C and night time lows around 22^{o}C to 23^{o}C. In the dry season, daytime temperatures can soar as high as 40^{o}C and night time temperatures could dip to 12^{o}C. Rainfall in Zuba town reflects the territory's location on the windward side of the Jos Plateau and the zone of rising air masses. Due to the hilly and mountainous nature of town, orographic activities bring heavy and frequent rainfall of about 1,650mm per annum. Beginning in March to November, the rainy season peaks in September, during which abundant rainfall is received in the form of heavy downpours. The town falls within the northern boundary of the Guinea Savannah having vegetation slightly different comprising shrub savanna vegetation types (Adakayi, 2000).

MATERIALS AND METHODS

Data Used

Air pollutants data (CO, SO_2, NO_2, PM, VOCs and NO), were collected at the centre of Zuba Motor Park. Measurement of the air pollutants was carried out three times (morning, afternoon and evening) in a day for a duration of 7 days in December 2022 with the intention to get a comparative result that would show the intensity at various times of the day and how they contribute to air pollution.

Equipment and software used

i. Testo 350 Flu Gas Analyzer which gave an instantaneous reading and results recorded in real time of O_2, CO_2, ambient CO, draft and pressure, temperature and combustion efficiency;
ii. Minivol Portable Air Sampler is an ambient air sampler for particulate matters;
iii. Crowcon Gas Detector Meter a portable multi-gas monitor for field detection and recordings of concentration levels of air pollutants (CO, NO_2, NO, O_3, H_2S, SO_2) and ambient temperature;
iv. Handheld digital Global Positioning System (GPS) Garmin Dakota 20 device**;** and
v. All hand-held devices used were pre-calibrated before usage for effectiveness and quality assurance purposes

vi. Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) Version (22.0).

Methods of data analysis

Descriptive statistical tools such as averages, percentages, and tables were used to present the data for easy understanding of the pattern and variability of air quality. Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) Version (22.0).

The hypothesis postulated state:

I. Ho_1: There is no significant difference in the daily concentration of pollutants in Zuba Motor Park.

II. Ho_1: There is no significant difference in the daily and diurnal concentration of pollutants from the NESREA limit.

The result of the mean values of the observed air quality parameters was compared with the permissible limits in the National Environmental (Air Quality Control) Regulations, 2014 with the view of finding the deviation from the recommended limits and to determine if the activities carried out within park have significant effect on the air quality within the park.

The Air Quality Index (AQI) establishes daily air quality, to examine the health implication relating to air pollution. This AQI is divided into six categories indicating increasing levels of health concern. The results from the AQI computation were subjected to the air quality rating table to determine the condition of the air as presented in Table 1. The pollutant's index concentration is expressed as a percentage of the relevant air quality standard. In the present study, AQI was calculated by the equation given by the US. EPA (2017) as follows:

$$Index = \frac{Polution\ concentration}{Pollution\ standard\ level} \text{ x } 100 \qquad eq1$$

Table 1: Air Quality Rating Table

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Source: USEPA, 2014.

RESULT AND DISCUSSION

Air Quality Status in the Study Area

The concentration of ambient pollutants (CO, SO_2, $PM_{2.5}$ and PM_{10}) in the study area were presented to determine the trend of air pollution related to motor park activities in during the days of the week (Monday-Sunday). The results were assessed on a daily and diurnal trend of morning, noon and evening hours (6a.m – 7a.m, 12p.m. – 1p.m, and 6p.m. – 7p.m.) to determine the transit hours associated with air pollution. The average concentrations of the ambient pollutants were also compared with the NESREA permissible limit for hourly outdoor concentration.

Ambient concentration of CO and comparison with NESREA limit

The concentration of ambient CO measured in Zuba Motor Park varied substantially during the days of the week as shown in Figure 1. In the morning, the highest (12.7ppm) concentration of CO was recorded on Tuesday while the lowest (8.4ppm) was recorded on Sunday. In the afternoon, the highest (8.6ppm) CO was recorded on Thursday. It is glaring that the CO concentration is more in the evenings with the highest concentration (21.4ppm) recorded on Wednesday while the lowest (10.1ppm) concentration of CO was recorded in the evening on Thursday. Morning and evening are recognized as period of vehicular movement at Zuba Motor Park with many people going and returning from work leading to increasing emissions of vehicular emissions of CO. This result is in agreement with the findings of Ogunleye *et al.* (2018) where they established that motor parks around Ibadan Metropolis tend to have high concentration of CO during peak period of vehicular movement.

The ambient concentration of CO at the motor park showed deviation from the NESREA permissible limit (Figure 1). In the morning, CO concentration on Monday was 10.8ppm, 12.3ppm on Tuesday, 10.7ppm on Wednesday, and 10.4ppm on Saturday were above the permissible limit (10ppm) of NESREA. In the afternoon the concentration of CO was within the permissible limit of NESREA while in the evening, the concentration of CO for all the days of the weeks were above permissible limit of NESREA. The implication of this result is that park traders, transport workers and passengers will invariably be exposed to CO on a long run. The findings of this study is in line with the work of Ogunseye *et al.* (2018) which reported high CO concentration within motor parks in Ilorin with its associated effects on park works, users and traders.

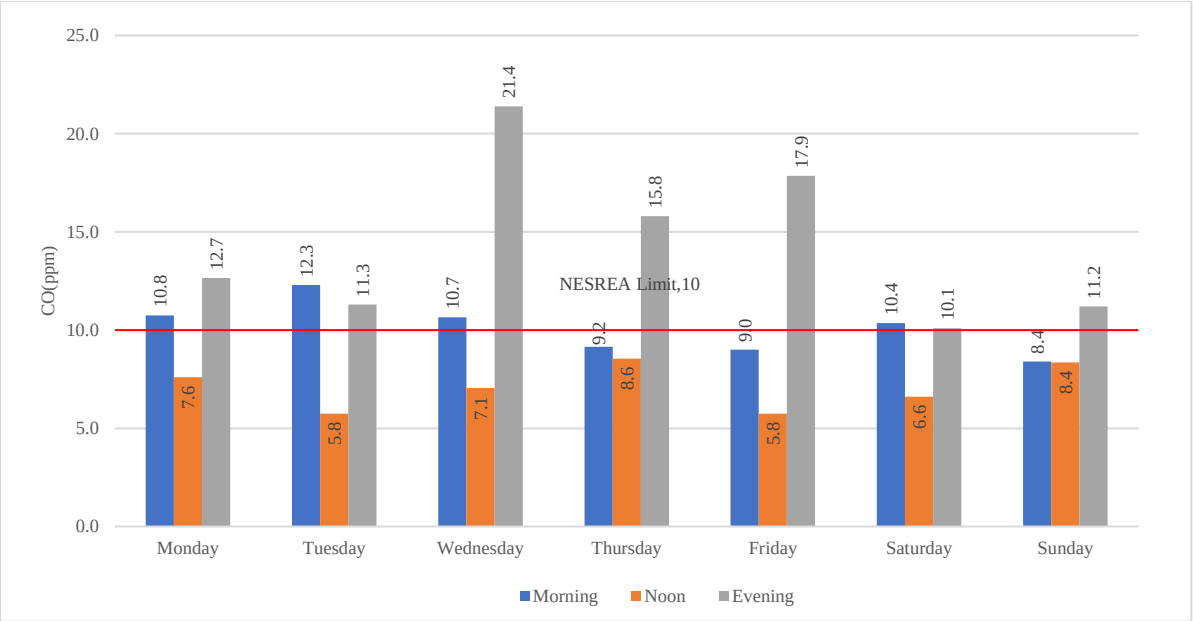

Figure 1: Concentration of CO in the study area

Ambient concentration of SO_2 and comparison with NESREA limit

The ambient concentration of SO_2 measured in Zuba Motor Park between 6a.m. - 7a.m., 12p.m. - 1p.m. and 6p.m - 7p.m. is presented in Figure 2. In the morning, the highest (0.17ppm) concentration of SO_2 was recorded on Monday while the lowest (0.07ppm) was recorded on Sunday. In the afternoon, the highest (0.07ppm) SO_2 was recorded on Sunday and the lowest (0.03ppm) was recorded on Monday. It is obvious that the SO_2 concentration is more in the evenings with the highest concentration (0.25ppm) recorded on Monday while the lowest (0.10ppm) concentration of SO_2 on Wednesday and Friday. Morning and evening are recognized as period of vehicular movement at Zuba Motor Park with many people going and returning from work leading to increasing emissions of vehicular emissions of SO_2 (See Figure 2).

Figure 2 shows that in the morning, the concentration of SO_2 in the study area were above the permissible NESREA limit of 0.1ppm except for values recorded on Thursday and Sunday which are below the NESREA limit. Just as observed with CO, in the afternoon the concentration of SO_2 were within the permissible limit of NESREA while in the evening, the concentration of SO_2 for all the days of the weeks were above permissible limit of NESREA except for Wednesday and Friday which fell at permissible limit (0.1ppm) of NESREA. It is obvious that users of Zuba motor park will be at risk to health-related complications associated with SO_2 more in the morning and evening. Ogunseye *et al.* (2018) also reported high CO concentration within motor parks in Ilorin with its associated health effects on park workers, users and traders.

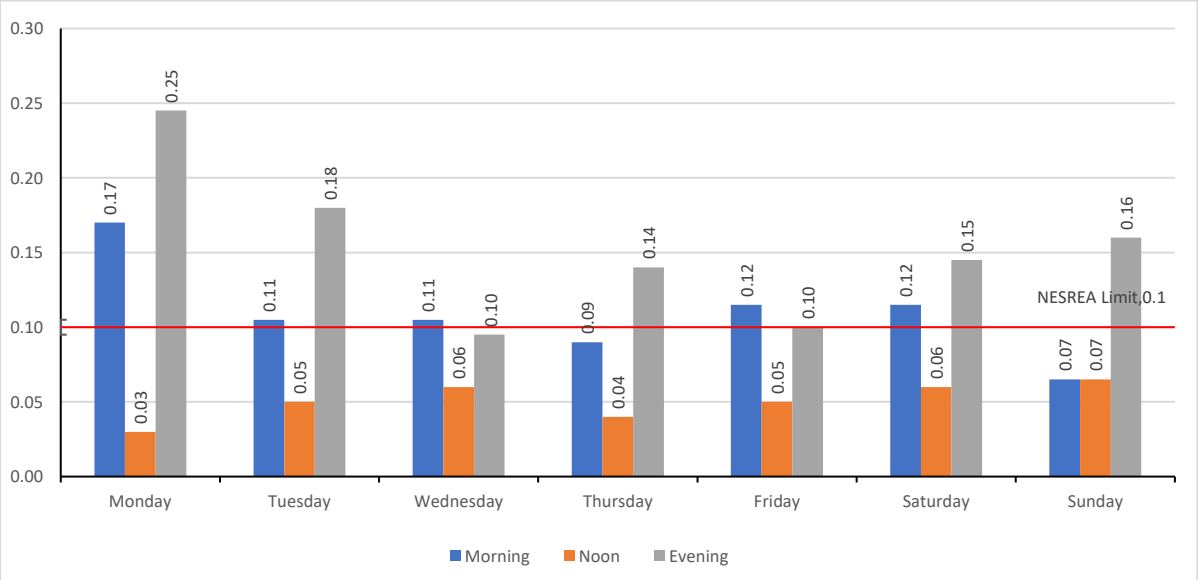

Figure 2: Concentration of SO_2 in the study area

Ambient concentration of particulate matter and comparison with NESREA limit

The ambient concentration of particulate matter in the study area for both fine particles (2.5ug/m^3) and coarse particles size (10ug/m^3) is presented in this section.

Particulate Matter 2.5 ($PM_{2.5}$)

The concentration of fine particulate matter ($PM_{2.5}$) measured in Zuba Motor Park varied temporally substantially as shown Figure 3. In the morning, the highest (85.3 ug/m^3) ambient concentration of $PM_{2.5}$ was recorded on Wednesday 88.1ug/m^3 and 85.3 ug/m^3 on Monday while lowest concentration (64.2 ug/m^3) of $PM_{2.5}$ in the morning was recorded on Saturday. In the Afternoon, the highest concentration (85.2 ug/m^3) of $PM_{2.5}$ was observed Wednesday and the lowest concentration (33.1ug/m^3) of $PM_{2.5}$ which coincides with the period Muslims usually go for Jumat prayers in Zuba town. In the evening, $PM_{2.5}$ concentration is higher on Monday with 97.3 while the lowest concentration (59.8ug/m^3). Generally, the result indicates high amount of $PM_{2.5}$ during the morning and evening period compared to the recorded values at noon. The rate of ambient $PM_{2.5}$ was higher during the peak hours (morning and evening) which are the peak transit period, implying that the concentration of $PM_{2.5}$ in the study area may be attributed to vehicular emissions.

The mean concentration of $PM_{2.5}$ varied across the days of the week as well as time of the day (morning, noon and evening period). Figure 3 shows that in the morning, $PM_{2.5}$ concentration all the values were above the NESREA limit of 80 ug/m^3 on Monday, Wednesday, Thursday and Friday. In the afternoon $PM_{2.5}$ concentration exceed the NESREA limit of 80 ug/m^3 only on Monday and Wednesday while in the evening it exceeds the NESREA limit on Monday, Tuesday, Wednesday, Thursday and Friday. Concentration of $PM_{2.5}$ is more in the Morning and Evening mostly in the working days of Monday to Friday. This depicts a potential health risk to users of the Zuba Motor Park due to exposure to $PM_{2.5}$. Similar results of $PM_{2.5}$ have been reported in Motor Parks around Kaduna Metropolis by Mohammed *et. al*., (2013) where he observed more concentration and associated health risk of $PM_{2.5}$ in the Morning and Evening within the working days. The result is also not farfetched from the observations of Salami *et. al*., (2020) whose reports showed high amount of particulate matter in motor parks around Ilorin Metropolis during the official working days.

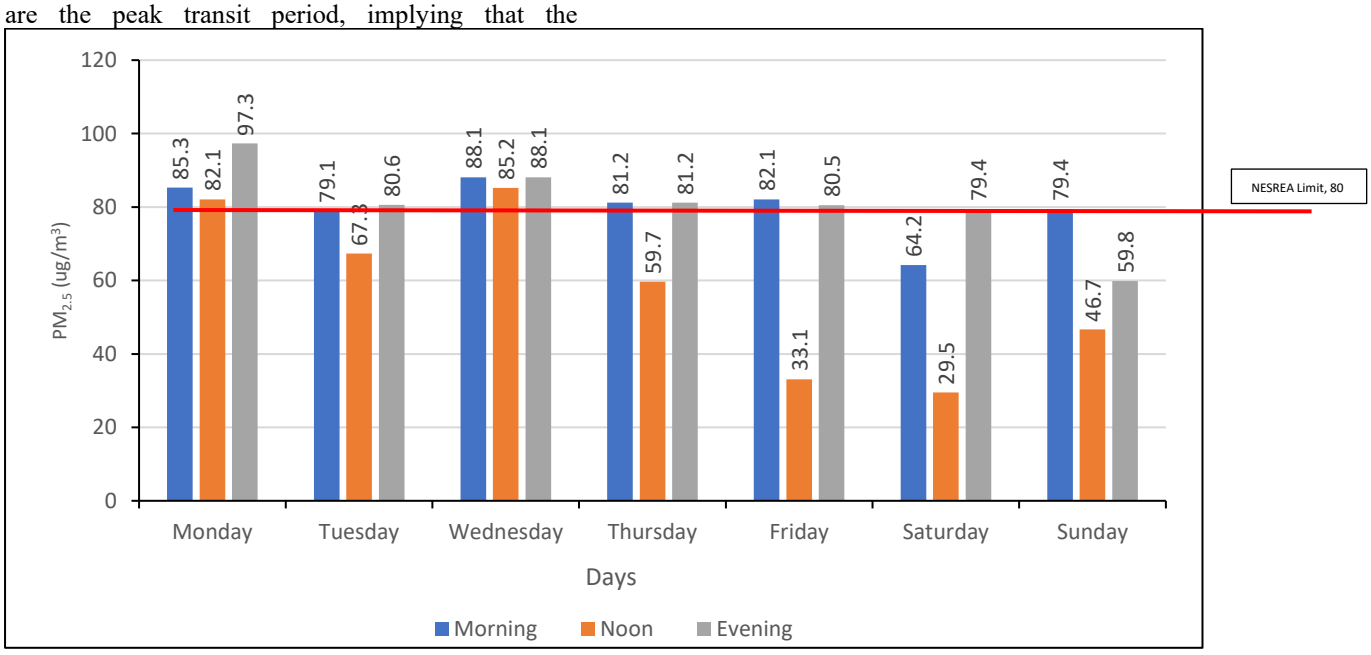

Figure 3: Concentration of $PM_{2.5}$ in the study area

Particulate Matter 10 (PM_{10})

The ambient record of PM_{10} in Zuba Motor Park varied both temporally and diurnally. In the morning, the highest ambient concentration of PM_{10} was recorded on Monday with PM_{10} value of 102.6 ug/m^3 while the lowest concentration (64.2ug/m^3) of PM_{10} recorded in the morning was observed on Saturday. At noon, the highest concentration of PM_{10} (88.3 ug/m^3) was observed on Wednesday and the lowest concentration (33.1 ug/m^3) of PM_{10} was recorded on Friday. At evening, the highest concentration of PM_{10} (137.1 ug/m^3) was observed on Monday while the lowest concentration of PM_{10} (109.2 ug/m^3) was recorded in recorded on Wednesday. The recorded ambient concentration of PM_{10} during the weekend (Saturday and Sunday) is lower than the working days in Zuba Motor Parks. All the values of PM_{10} were within the NESREA limit of 250 ug/m^3 (See Figure 4). The result implied that the concentration of ambient PM_{10} in Zuba Motor Park irrespective of time of the day nor week portrays no risk to health. Result of this study clearly shows that $PM_{2.5}$ is of more implication to health than PM_{10}. This finding coincides with the observations of Salami *et al*. (2020); Ogunseye *et al.* (2018); Mohammed *et al*. (2013) that exposure to $PM_{2.5}$ is usually higher than PM_{10} in motor parks and around urban related activities

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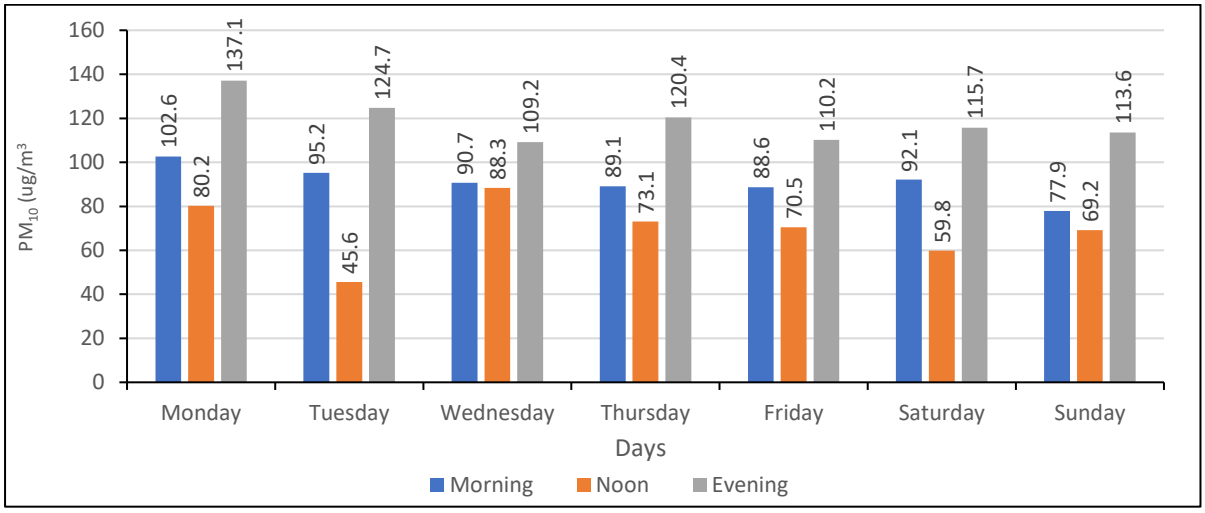

Figure 4: Concentration of PM_{10} in the study area

Test of Hypotheses

Result of ANOVA statistics testing for significance in the daily concentration of pollutants in the study area during the period of investigation (See Table 2). It provides answer to the study hypothesis one (HO_1: There is no significant difference in the daily concentration of pollutants in Zuba Motor Park). Based on the statistical outcome, it can be concluded that the atmospheric level of ambient pollutants concentration in Zuba Motor Park is not statistically significant for all the pollutant measured with the P value of 0.913 (CO), 0.874 (SO_2), 0.243 ($PM_{2.5}$) and 0.971 (PM_{10}) which are all greater than the critical value (0.05) at 95% confidence level. Thus, the postulated null hypothesis is accepted.

Table 2: Level of significant in the daily concentration of pollutants in Zuba Motor Park

Pollutant	Source of Variation	SS	df	MS	F	P-value	F crit
CO	Between Groups	107.719	6	17.95317	0.325124	0.913	2.847726
	Within Groups	773.0733	14	55.21952			
	Total	880.7924	20				
SO_2	Between Groups	0.021695	6	0.003616	0.389402	0.874	2.847726
	Within Groups	0.13	14	0.009286			
	Total	0.151695	20				
$PM_{2.5}$	Between Groups	2567.932	6	427.9887	1.517498	0.243	2.847726
	Within Groups	3948.5	14	282.0357			
	Total	6516.432	20				
PM_{10}	Between Groups	837.1695	6	139.5283	0.20075	0.971	2.847726
	Within Groups	9730.5	14	695.0357			
	Total	10567.67	20				

The postulated hypothesis two (There is no significant difference in the daily and diurnal concentration of pollutants from the NESREA limit). Based on the statistical result from the student t-test, the diurnal (morning, afternoon and evening) concentration of CO (p value 0.813), SO_2 (p value 0.423) and $PM_{2.5}$ (p value 0.846) were not significantly different from the NESREA limit with p-value higher than 0.05, while that of PM_{10} was statistically different (p value 0.000). However, the t-test direction shows a negative difference (-13.389), which implied that the diurnal concentration of PM_{10} in the study area are below the NESREA limit, depicting a good condition.

The daily concentration of CO, SO_2 and $PM_{2.5}$ were also not statistically significantly different from the NESREA limit given by the p-value of 0.327, 0.464 and 0.433 respectively. On the contrast, the p value of PM_{10} (0.000) implied significant different in the daily concentration of particulate matter to the NESREA limit. However, the significant level tilt towards the negative curve implying that the ambient concentration of PM_{10} is statistically lower than the NESREA limit. The result implied that the HO_2 is accepted only for CO, SO_2 and $PM_{2.5}$ which are statistically not significant from the NESREA hourly permissible limit for human exposure.

Table 3: Statistical result for HO_2

Pollutant	df	t-statistics	P -value
Statistical result for diurnal concentration (Morning, Afternoon and Evening)			
CO	4	0.253	0.813
SO_2	4	0.207	0.423
$PM_{2.5}$	4	0.207	0.846
PM_{10}	4	-13.389	0.000*
Statistical result for daily concentration (week)			
CO	12	1.021	0.327
SO_2	12	0.757	0.464
$PM_{2.5}$	12	0.875	0.443
PM_{10}	12	-82.5727	0.000*

*Significant at 0.05.

Air Quality Index Rating (AQI) across the Study Routes

The Air Quality Index (AQI) result of the concentration of SO_2, CO, $PM_{2.5}$ and PM_{10} measured using the United States Environmental Protection Agency (2017) equation and NESREA standard limit for outdoor concentration of atmospheric pollutant were obtained (see Table 4). The AQI rating for ambient concentration of CO showed that the study area is rate moderate to very unhealthy. During the morning period, CO was rated unhealthy for sensitive groups on Monday, Tuesday and Wednesday, Saturday and Sunday respectively, while on Thursday and Friday the ambient concentration of CO in the morning hours was rated moderate. Similarly, CO was rated moderate across all the weekdays at noon. On the contrary, the ambient concentration of CO during the evening period was rated unhealthy for sensitive groups on Monday, Tuesday, Saturday and Sunday respectively, while it was rated very unhealthy on Wednesday and unhealthy on Thursday and Friday respectively. The result showed that the study area is only safe at noontime during the study period.

The rating of SO_2 during the morning period varied from unhealthy on Monday to unhealthy for sensible groups on Tuesday, Wednesday, Thursday, Friday and Saturday, while on Sunday, ambient SO_2 was rated moderate. The result indicates hazardous atmosphere on Mondays than any other days of the week. At noon, SO_2 was rated good on Monday, Tuesday and Thursday, while on Wednesday, Friday to Sunday the atmosphere was rated moderate for SO_2. Contrarily, AQI rating of SO_2 during the evening period was very unhealthy on Monday, unhealthy on Tuesday and Sunday and unhealthy for sensitive groups from Wednesday to Saturday in the study area.

Particulate matter concentration within the study area was not hazardous based on the AQI result (Table 4). $PM_{2.5}$ was rated moderate in the entire weekdays in the morning, noon and evening period except on Monday, Tuesday, Wednesday and Thursday in which PM2.5 was rated good at noontime. Similarly, PM_{10} was rated good in the entire study period at morning, noon and evening period respectively.

General, the result indicates potential hazards during the morning and evening period in the study area for SO_2, CO and $PM_{2.5}$ with criteria pollutants capable of causing critical health effects. Thus, people in and around the Zuba Motor Park such as hawkers, road users, transport workers will be highly exposed to poor air quality. This observation is in line with the findings of Ishaya *et al.* (2017) along Urbanization Gradient in Apo District of the Federal Capital Territory of Nigeria; Salami *et al.* (2020) in Major Motor Parks in Ilorin Metropolis; Godson *et al.* (2015) in three Motor Parks in Ibadan; Harrison (2020) in Mpape Area of Abuja. Acute ambient air pollution exposure has been associated with angina, stroke, acute myocardial infarction, heart failure hospitalization, arrhythmias, cardiac arrest, heart failure hospitalization and cardiovascular mortality (WHO, 2019). Given the result of this study such health-related diseases in and around Zuba Motor Park is possible.

Table 4: AQI rating of the Study Area

Pollutant		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
CO	Morning	108	123	107	92	90	104	84
	Noon	76	58	71	86	58	66	84
	Evening	127	113	214	158	179	101	112
SO_2	Morning	170	110	110	90	120	120	70
	Noon	30	50	60	40	50	60	70
	Evening	250	180	100	140	100	150	160
$PM_{2.5}$	Morning	69.3	77.4	58.8	69.6	69.8	65.5	68.1
	Noon	39.0	31.5	29.9	46.8	58.1	61.6	71.5
	Evening	59.8	77.1	70.8	83.1	89.1	81.8	79.6
PM_{10}	Morning	27.0	32.2	36.1	32.0	31.8	30.7	34.8
	Noon	19.7	21.4	21.0	23.5	20.1	17.8	26.2
	Evening	36.6	39.7	40.6	38.4	37.7	38.8	42.2

CONCLUSION

The diurnal assessment of air quality at Zuba Motor Park, Abuja, Nigeria was carried out through the measurement of air pollutants three times (morning, afternoon and evening) in a day for a duration of one week in December 2022. Based on the study findings, the concentration of ambient pollutants (CO, SO_2, $PM_{2.5}$ and PM_{10}) are more in the morning and evening (6a.m. - 7a.m. and 6p.m. - 7p.m.) during which traffic volumes were high within the Motor Park. The ambient concentration of CO and SO_2 at the motor park in the morning and evening showed exceeding deviation from the NESREA permissible limit creating threat to human health. The ambient concentration of $PM_{2.5}$ at the motor park in the morning and evening for only the working days was above the NESREA permissible limit while PM_{10} for all time of the day and all days of the week were within the NESREA permissible limit. The study also concludes that there is potential hazards during the morning and evening period in the study area for SO_2, CO and $PM_{2.5}$ with criteria pollutants capable of causing critical health risk to hawkers, road users and transport workers. The tendencies, for angina, stroke, acute myocardial infarction, heart failure hospitalization, arrhythmias, cardiac arrest, heart failure hospitalization and cardiovascular mortality is possible in and around the Zuba Motor Park.

Based on the findings and conclusions of this research, the following recommendations were made:

i. The Zuba Motor Park should be expanded and designed to accommodate exit route in order to reduce traffic jam of vehicles within the park;
ii. Motor park traders should be placed away from the proximity of the park to limit their level of exposure to harmful vehicle emission;
iii. There is a need to promote and sensitize the vulnerable and sensitive groups on the dangers of air pollution;
iv. Vehicle Inspection Department in the FCT Metropolis should be equipped with vehicle emission testers to determine the emission status of vehicles in the area.

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Application of BIM Implementation Process in the Operation and Maintenance of Information Management System in Building Facilities

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The appalling state of building facilities in Nigeria, poses a great concern to stakeholders. This stems from lack of adequate information management in the operation and maintenance of building facilities. Therefore, the study is aimed at assessing the application of BIM implementation process in the operation and maintenance of information management system in building facilities. The study made use of a quantitative research approach, making the population for the study to encompass facility management practitioners (Onsite Facility Engineers, Onsite Facility Technicians, Facility Management Professionals [IFMA] and Facility Management Company owners) who are fully registered with International Facility Management Association (IFMA) in Abuja-Nigeria. The sample size for the study is 184 and the respondents were selected by a systematic random sampling method with a close ended questionnaire used for the data collection. The questionnaire is administered via Google forms; and questionnaires shared through the google form link were answered and the results were collected through google response tools, and 121 copies of the questionnaire were duly filled, returned and used for data analysis. The result shows that the implementation of BIM in operation and maintenance of facilities is very low as manual and stand-alone computer system are still predominant in most of the operations carried out by the practitioners and the stakeholders. The study further revealed that Improvement in asset information management that lead to increased efficiency of facility assets is significantly affect by the operational system. The result also shows that Facility managers are traditionally included late in the building lifecycle and posed a high challenge to most practitioners and this has made the application of BIM in operation and maintenance of information management in facility management very negligible, as such the paper suggest that BIM usage in the O&M of buildings should be encouraged and imbibed right from the planning and designing stages of building facilities. Facility managers/professional should also be included right from the inception of a building life cycle to the end of the building.

Keywords: BIM, Information, Facilities, Operation, Maintenance, and Management

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INTRODUCTION

Building facility management comprises of strategic management and governance of the resources and services necessary for a building to function effectively (Bascoul *et al*., 2018). The life cycle of structure, in the management phase of any facility is the last, but by far the longest, phase in a building's life cycle (Nordstrand, 2019). Various nature of information handling is one of the greatest problems of technological advancement facing the practice (Hardin, 2011; Teicholz, 2013). According to Cotts *et al*. (2015), problem often starts at project completion and handover of building documentation and these usually exacerbated later in the facility management phase due to insufficient routines. However, Chien *et al*. (2017) stated that the information handling problem is considered to take much time from the important preventive work, which results in resource waste, reduced employee productivity and impaired tenant service. Building Information Modelling (BIM) is considered by many to offer a solution to the problematic information handling within facility management (Hardin, 2011; Eastman *et al*., 2011). BIM offers the opportunity to streamline the information handling during a building life cycle and thereby improves the building information quality in the facility management phase (Gustav, 2014). Hardin (2010) argued that BIM is not just an information modelling software using three-dimensional intelligent models, but also, it is a tool for making significant changes in the workflow and project delivery processes. Ani *et al. (*2015) posed that BIM is a concept that advances product delivery, which includes quality, reliability, timelessness, and consistency of the process.

However, in Nigeria, poor Operation and Maintenance (O&M) of the building facilities is notable (Nigeria Observer News [NON], 2017). NON (2017) further stated that several studies have been conducted to find out a way to alleviate these problems that include irregularities pertaining to finances, underperforming management departments, poor and outdated records, and lack of maintenance, and cleaning up culture among many others. All of these, according to NON (2017), lead to hitches and hindrances in the operation and maintenance of the building facilities in Nigeria. Olokpo (2018) observed that the run-down syndrome which is an attribute of building facilities in Nigeria, due to poor or lack of maintenance of building facilities has been at the heels of economic development in the country.

Harpa and Freja (2016) reiterated that a lots of processes results in delays, wastages, high costs, poor decisions, and deficiencies in performances that lead

to poor maintenance of facilities and further dilapidation of facility components. Kiran (2020) stated that facility managers spent many hours on finding accurate data like drawings, material specifications, and datasheets during the periods when maintenance service is performed. According to Smith and Tardif (2012), most information created during the design and construction process that is of value to facility managers can only be found elsewhere and in scattered sources.

Therefore, to enhance the level of O&M of buildings facilities in Nigeria, new techniques are inevitably required. Azhar *et al.* (2012) asserted that BIM can be a useful tool during all stages of a building's lifecycle. In a related development, Ani *et al*. (2015) emphasised that it is tools that improve product delivery, which includes quality, reliability, timelessness, and consistency of the process. Although past efforts focused on BIM in the design and construction phase (Azhar *et al.,* 2012; Ioannis *et al*., 2020). Hence, there is a need to assess the application of BIM implementation process in the operation and maintenance of information management system in facility management with the major objective to identify novel ways to use BIM during the building operation phase, to support O&M of building facilities in Nigeria.

LITERATURE REVIEW

Operation and Maintenance Culture in Management of Building Facilities

Facilities maintenance according to Owolabi *et al.* (2014), is an important aspect of building management that is often neglected knowing fully that such maintenance assists retention of the economic life of the facilities. Guzman and Ulloa (2020) observed some shortcomings in facilities like peeling of wall surfaces, rising dampness in substructure, floor slab failure, doors, and windows defect, leaking roof, foundation failure, and sagging of beam. Mohammed and Za (2017) stated that maintenance culture requires the correct diagnosis of defects, immediate remedial measures, sound technical knowledge of material usage, management resources as well as the formulation and implementation of integrated plans and policies to sustain utility. The absence of these qualities has led to the decay of the nation's physical, social, aesthetic, and economic environment (Kunya, 2012). Most facility owners concentrate on the award of contracts for new infrastructures, giving near-to-nothing attention to the O&M of existing ones (Motamedi *et al*., 2014). Adequate O&M of the existing stock of infrastructural facilities and services is another way of keeping the sustainability of structure (Ojara, 2013).

According to Kunya (2012), it is a common knowledge that the deplorable state of building facilities in Nigeria poses a great concern to stakeholders. The present status of most buildings, airports, hospitals, schools, roads and so on around Abuja-Nigeria, give an indication that the society lacks an agent that would have helped manage, ensure effective and efficient functioning of the facilities as well as foster national development. James (2020) established that the flaws in the Nigerian Aviation sector were attributed to a lack of maintenance culture and the training of professionals in the industry. Teicholz (2013) stated that the Facilities Management (FM) practice is characterized by its reactive approach and that the lack of proactive management, that is based on planning, anticipation, and dealing with issues before they become problems, leads to inefficient use of resources. However, the problem of maintaining building facilities has become an important agenda for the country and mounts pressure on the building owners in the aspect of managing its assets and facilities (Dabara *et al.,* 2015). No matter how simple or how complex a facility may be, without a defined order of maintenance management the facilities shall sooner or later not only become non-functional but may in addition constitute a hazard for its users (Abdullah *et al.,* 2012).

Facility Management Information System (FMIS)

An information system is an integrated set of components for collecting, storing, and processing data and for delivering information, cards, and digital products (James, 2020). Business firms and other organisations rely on information systems to carry out and manage their operations, interact with their customers and suppliers, and compete in the marketplace (Nahimah, 2018). An information system is a dynamic area or field that monitors changes, perhaps the most important driving force induced by the development of computers (AfërdÖta, 2014). Systèmes (2014) added that it is a system that works and has to do with information. The lack of information on products and components in terms of usage and cost can lead to difficulties in focusing the role of FM and establishing the supply chain within it. Difficulties in monitoring and tracking financial information can also prevent efficient budget control, accurate estimation of work, and contract and purchase management.

Facilities O&M Information Asset Management

According to Hardin (2010), the most frequent and challenging issue in FM, is the concerns of the attributes of information handling. William *et al.* (2012), explain a worst-case scenario where boxes filled with unsorted building information are handed over to owners. Such often highly unstructured information handling during the handover process usually continues even later in the facility management phase, which results in an unwieldy information basis that hampers the O&M managers' daily work (Tijani *et al*., 2016). According to Zuraihana *et al*. (2016), the current practices imply inefficient use of resources, and the severe localized information leads to time-consuming search processes. Every industry is now faced with understanding on how to leverage information as an asset and the FM industry is no exception in these regard (Chuck *et al.,* 2013).

There is a frequent wide range of difficulties relative to O&M (Marquez & Gupta, 2015). Marquez and Gupta (2015) further attribute the difficulty in O&M to the lack of adequate models that could improve the

understanding of the underlying dimensions of Maintenance. Tijani *et al.* (2016) added that maintenance is composed of a set of activities for which is very difficult to find procedures and information support systems in one place to ease the improvement process. Hence, one of the key challenges in projects is always the need to have sufficient information on products readily available for any maintenance operation, such as specifications, previous maintenance work and a list of specialist professionals to conduct work. Hipkin and De Cock (2010) ranked the barriers to the implementation of O&M systems. The ranking of the barriers faced by O&M managers, supervisors, and operators are lack of plant and process knowledge, lack of historical data, lack of time to complete the analysis required, and lack of top management support (Akcamete *et al*., 2010).

Building Information Modelling (BIM)

An increasingly discussed solution to the information handling problem within FM is "Building Information Modelling (BIM)" (Eastman *et al.,* 2011). According to Abdullahi (2018), BIM is basically a 3D representation of the physical and functional characteristics of a building throughout its life cycle. Eastman *et al*. (2011) further attested that BIM is constructed from the intelligent digital assembly of building components with embedded knowledge of parametric object attributes and characteristics. Moreso, Kymmell (2018) explained BIM tool or product that can generate intelligent digital models connected with other project management tools that facilitate design optimization, constructability, and information collaboration for all stakeholders for a better project output.

Consequently, O&M require the integration of various types of information and knowledge created by different members of the team and phases in a facility life cycle (Ibrahim & Abdulkareem, 2018). O&M in FM activities covers the longest life span of facilities and involves multiple stakeholders that may be replaced over time (Nummelin *et al.,* 2013). Therefore, O&M requires a comprehensive information system that collects, stores, retrieve, and distributes information seamlessly on facilities and all the related building components. (Abdullahi, 2018).

BIM Implementation Levels

Today, the building construction industry has experienced a gradual shift from paper-based 2D CAD drawings information and data management systems to object-oriented 3D digital models which are driven by the application of BIM. According to Muhammed (2021) BIM maturity level determines the degree of efficiency in implementing the technology and process regarding collaborating and management of building information in a project environment.

BIM level 0

At the zero-level stage, drawings and information are through Computer-Aided Drawing (CAD) tools and this reflects unmanaged CAD in 2D, which is represented and exchanged in paper documents (Muhammed, 2021). He added that the collaboration at level zero is minimum, as information is exchanged using ad-hoc exchange methods that offer very little or no chance of information integration to support collaborative working.

BIM level 1

Level 1 denotes a managed CAD environment that uses 2D and 3D representations of building information. The information content at level 1 is generated using CAD standards approaches to data structures, and it is stored in standard formats that can be exchanged among different CAD applications (Muhammed, 2021). Muhammed (2021) further explained that Level 1 replaces the ad-hoc information exchange mechanisms with the introduction of a Common Data Environment (CDE), which is used to share and exchange CAD files between various project participants.

BIM level 2

Level 2 focuses on how the information is distributed among the members of the project. At this stage, two new dimensions of the project are introduced: 4D which is time management, and 5D which represents the calculation of the budget (PAS 1192-2, 2013). Biblus (n.d), mentioned that although collaborative working is at the Centre of the BIM level 2, it is not necessary that all the team members operate on the same CAD 3D models. Every project member can use a distinct CAD model in a common file type such as International Foundation Class (IFC) file type that contains all the designing information. IFC file format are BIM files, however, unlike other BIM file formats, IFC files are platform neutral and can be read and edited by any BIM software (Spatial, 2021).

BIM level 3

BIM level 3 is the final goal for the building construction sector as the main purpose of this level is to obtain a full integration of information in a cloud-based environment, and this is achievable using a common shared model that will be available to all the stakeholders of the project who can add or modify their own information (PAS 1192-2, 2013 & Biblus, n.d). This model in IFC format is the milestone that can be shared and preserved in a cloud so that all the project members can have access to the same information. In this way, the entire life cycle of a building, from its designing to its construction and maintenance can be managed.

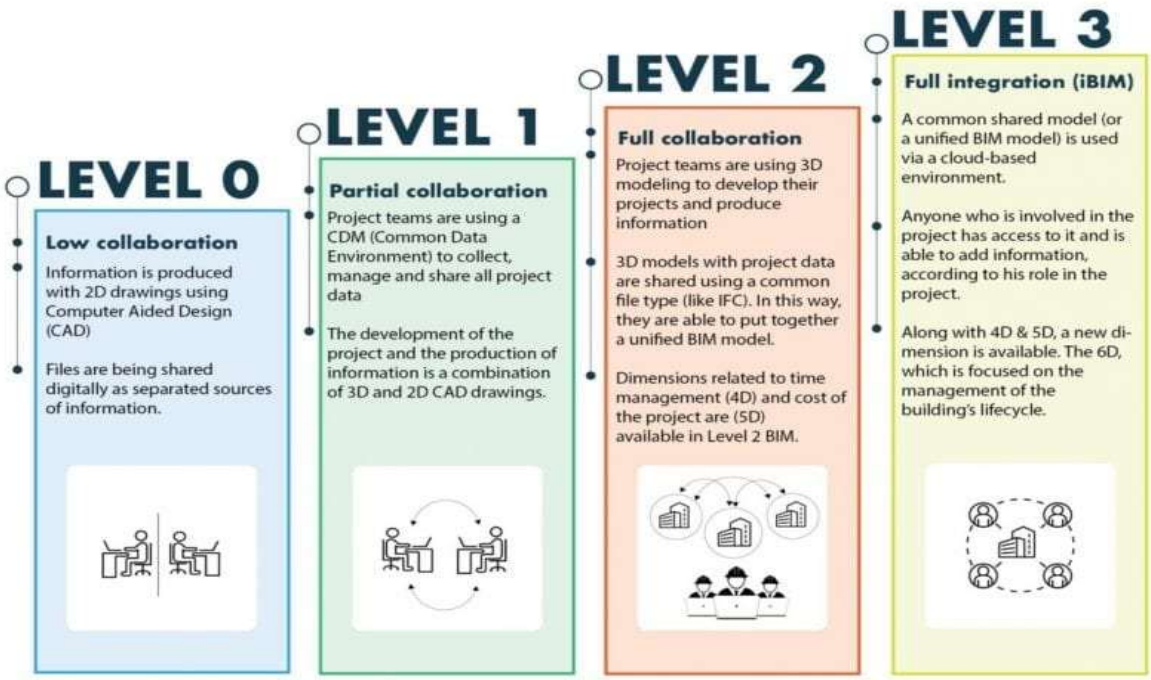

Figure 1: BIM maturity levels
Source: https://biblus.accasoftware.com

BIM in Building Facility O&M

BIM is considered by many researchers and professionals, to offer a solution to the problematic information handling within O&M activities in FM (Hardin, 2011, Eastman *et al.,* 2011). Consequently, the influence of BIM has been seen in the design and construction phase of facilities, facilities owners in recent years to see the potential benefits of the building's later stages on O&M stage (Becerik-Gerber *et al.,* 2012). BIM therefore, is seen to offers the possibility of streamline the information handling during a building's life cycle and thereby improving the building information quality in the FM phase (Nordstrand, 2019). However, in the early history of BIM, it was mainly of benefit to architects and engineers in the design phase and in areas of clash detection, visualization, and quantification (Volk *et al.,* 2014). Hence, a recently, shift in trends indicated an increase focus on the later stages of the building's life cycle which includes maintenance, refurbishment, deconstruction, and end-of-life considerations.

Studies conducted by Cotts *et al*. (2015) and Teicholz, (2013) discussed how conditions for FM practices differ, dependent on where it is performed, and especially the disparities between public and private FM on the application of BIM in their operations. Decisions for building operation and maintenance require the integration of various types of information and knowledge created by different members of the team and phases in a facility life cycle, such as maintenance records, work orders, causes and knock-on effects of failures (Ibrahim & Abdulkareem, 2018). Therefore, O&M requires a comprehensive information system that collects, stores, retrieve, and distributes information on facilities and all their related building components are made easy, effective and efficient with the application of new technology like BIM. Abdullahi (2018) stressed that BIM became popular after 2002, and its adoption in the industry was accelerated due to software vendor's marketing to increased productivity improvement. However, the concept of BIM and the underlying technology is not new and has been an area of research and development in the last three decades with a neglect in areas of maintenance operation of facilities, and mostly known as product modelling for buildings, (Eastman & Augenbroe, 1998; Abdullahi, 2018).

Therefore, to enhance the level of O&M of buildings facilities in Nigeria, new techniques are inevitably required. Hence, there is a need to assess the application of BIM implementation process in the operation and maintenance of information management system in facility management with the major objective to identify novel ways to use BIM during the building operation phase, to support O&M of building facilities in the country.

Challenges of BIM in Building Facility O&M

The nature of BIM allows and expects that new technologies have to be implemented to achieve the true potential of BIM, the characteristic of BIM is close connection to information and communication technologies thus challenges in traditional operation of FM O&M of building facilities. According to Gustav (2014) and Tulenheimo (2015), the implementation of a number of regulations and guidelines are neglected during procurement and acquisition of products and services that are used for FM O&M and this pose a serious challenge to the operation in building facilities. Tijani *et al*. (2016), however, refuted that the challenge of FM O&M is the issue of maintenance strategies. Nordstrand (2019) added that the challenges of FM O&M of building

facilities are affected by process change, when it comes to physical wearing down and user needs and preferences. Consequently, Ahmed (2021) elucidated the challenges in FM O&M of building facilities to include skill shortage in FM using BIM, lack of real-world cases on BIM applications in FM; efforts so far focused on new buildings, lack of processes for updating the designed model with as-built information, facility managers are traditionally included late in the building lifecycle, and interoperability between BIM technologies and current FM technologies.

RESEARCH METHODOLOGY

The quantitative research design was adopted in carrying out this study. The research population targeted comprises of facility professionals (Onsite Facility Engineers, Onsite Facility Technicians, Facility Management Professionals (IFMA) and Facility Management Company owners) who were duly registered with IFMA, Abuja chapter. The sample size of the study is 184. The respondents were selected by a systematic random sampling method which represented the characteristics of the entire population. Primary data for the study were collected via the distribution of a well-structured questionnaire. The questionnaire was divided into Two (2) sections; A and B. Section A considered the general information of the respondents, while section B contains questions relevant to the research objectives of the study, which was ranked based on the 5-point Likert scale.

The questionnaires were administered via Google forms; questionnaires shared through the google form link were answered and the results were collected through google response tools. In all, a total of 121 copies of questionnaires were duly filled, returned and used for data analysis. The responses obtained from the administered questionnaires were analysed using percentile, and mean score with decision been drawn from the mean score after the ranking of the parameters based on the weight from the highest to the lowest as shown in the cut-off points below.

Mean Range	**Decision Rule**
1.0 – 1.49	Not significant/no influence
1.50 – 2.49	Little significance/little influence
2.50 – 3.49	Moderate significance/moderate influence
3.50 – 4.49	High significance/high influence
>= 4.50	Very high significance/very high influence

RESULTS AND DISCUSSION

Demographic Information of the Respondents

In Table 1 below, vast majority of the respondents' acquired their qualifications, with most respondents as bachelor's degree with a percentage of 51.2, 19.8 percent obtained higher national diploma; while 14.9 percent have post graduate diploma; and 9.9 percent have master's degree, while 4.1 percent have Doctorate degree. This means that majority of the respondents obtained the minimum academic qualification of bachelor's degree. It can be observed that 81.8 percent of the respondents worked in the organisation as facilities managers and facilities officers where only 18.2 percent are assistant facilities managers. Furthermore, 81 percent of the members are fully registered with IFMA and only 19 percent had their membership registration with SFP and CFM. More also, only 24.9 percent had their working experience as facilities manager above 10 years, and 45.5 percent had their job training as facilities manager above 5 years where 29.8 percent are within the range of 5 years as facilities training manager on the job.

Table 1**:** Demographic information of respondents

Variables	Classification	Frequency	Percent
Academic Qualifications	Higher National Diploma	24	19.8
	Bachelor's Degree	62	51.2
	Post Graduate Diploma	18	14.9
	Master's Degree	12	9.9
	Doctorate Degree	5	4.1
Position Held in the Organisation	Facility Manager	50	41.3
	Assistant Facility Manager	22	18.2
	Facility Officer	49	40.5
	Maintenance Technician	0	0
Membership/Certification with IFMA	Facility Management Professional (FMP)	98	81
	Sustainability Facility Professional (SFP)	15	12.4
	Certified Facility Manager (CFM)	8	6.6
	Retired Certified Facility Manager	0	0
Years of Working Experience in FM Job	1 -5	36	29.8
	6 -10	55	45.5
	11 -15	25	20.7
	16-20	2	1.7
	More than 20 years	3	2.5

Current Practice of O&M Information Management

From Table 2 it shows that majority of the respondents uses manual systems like papers and boards which rank 1st with mean score value of 4.5; while use of standalone computer software like Excel, Word, and 2D Cad ranked 2nd with mean score value of 4.11. the least utilised is the BIM-enabled system with a mean score value of 1.00. Hence, most respondents however believed that the use of manual system is currently trending and standalone computer software is still being used for the operation and maintenance information management of building facilities in Abuja.

Table 2: Practice of O&M Information Management of Building Facilities

Handling Systems	Mean Score	Rank
Manual systems like papers and boards	4.50	1
Standalone computer software like Excel, MS Project, Word, 2D CAD, 3D CAD, and Computerized Maintenance and Management Systems (CMMS)	4.11	2
BIM-enabled system	1.00	3

Impacts of Implementing BIM in the O&M Information Management in Building Facilities

In Table 3, the respondent's perception shows the level of impact of BIM in the current systems of managing information in the O&M of building facilities in Abuja. The result, therefore, indicates that two of the perceived impact of implementing BIM in O&M of information management have a very high significance as a result of their mean values that is greater than the average weighted mean of 4.045. The impacts with a very high significance are improvement in asset information management that is leading to the increased in efficiency of facility assets and improved team collaboration/communication. Other factors with a high significance are reducing wastage of materials due to rework, misfit, enhances proper information storage/update and quick information retrieval, reducing operational delays. provides basis for adequate analysis of hazards and safety precaution before work, reduction on cost of operations, reducing managerial struggle and improving decision making, improved job planning and control, mitigating work/task abandonment and repetition, improved response to facility maintenance needs, and mitigation of dispute, conflict, misunderstanding and misinterpretation. The result, therefore, shows that there is a great influence on the areas of improving asset information management that will in turn lead to increase in efficiency of assets facility through the improved team collaboration/communication.

Table 3: Impact of implementation of BIM in O&M information management

Impact	Mean Score	Rank	Decision
Improvement in asset information management leading to the increased in efficiency of facility assets	4.66	1	Very High Significance
Improved team collaboration/communication	4.59	2	Very High Significance
Reducing wastage of materials due to rework, misfit etc.	4.42	3	High Significance
Enhances proper information storage/update and quick information retrieval	4.32	4	High Significance
Reducing operational delays	4.11	5	High Significance
Provides basis for adequate analysis of hazards and safety precaution before work	3.98	6	High Significance
Reduction on cost of operations	3.88	7	High Significance
Reducing managerial struggle and improving decision making	3.86	8	High Significance
Improved job planning and control	3.77	9	High Significance
Mitigating work/task abandonment and repetition	3.70	10	High Significance
Improved response to facility maintenance needs	3.65	11	High Significance
Mitigation of dispute, conflict, misunderstanding and misinterpretation	3.60	12	High Significance

Challenges to the Implementation of BIM in O&M Information Management

In Table 4 it was observed that most of the respondents consider facility managers traditionally been included lately in the building lifecycle a very high influencing factors affecting the implementation of BIM in O&M information management in building facilities. Furthermore, the respondents view BIM efforts so far focused on new buildings, skill shortage in FM using BIM, interoperability between BIM technologies and current FM technologies, and lack of real-world cases on BIM applications in FM and lack of processes for updating the designed model with as-built information a high influence affecting the BIM in O&M information management in building facilities whereas poor or inadequate ICT facilities for BIM implementation, and lack of BIM knowledge and awareness are viewed as moderate influence. The result shows that the inclusion of the facility managers lately in the building lifecycle is considered to be the highly influenced barrier to the application and implementation of BIM in O&M information management in building facilities in Abuja.

Table 4: Challenges of Implementation of BIM O&M Information Management in Building Facilities

Barrier	Mean Score	Rank	Decision
Facility managers are traditionally included late in the building lifecycle	4.56	1	Very High Influence
BIM Efforts so far focused on new buildings	4.38	2	High Influence
Skill shortage in Facility Management using BIM	4.23	3	High Influence
Interoperability between BIM technologies and current FM technologies	3.86	4	High Influence
Lack of real-world cases on BIM applications in FM	3.83	5	High Influence
Lack of processes for updating the designed model with as-built information	3.76	6	High Influence
Poor or inadequate ICT facilities for BIM implementation	3.00	7	Moderate influence
Lack of BIM knowledge and awareness	2.56	8	Moderate influence

CONCLUSION

The study concluded that most building facilities in Abuja, Nigeria are still using manual and standalone systems in handling information for the operation and maintenance of building facilities such as papers, shelving and standalone software. Furthermore, the implementation of BIM in O&M information management will lead to overall improvement in facility management resulting in time saving, cost and availability of information for prompt building maintenance management. However, the study is limited to the application of BIM implementation process in the operation and maintenance of information management system in building facilities. Finally, the study concludes that the late inclusion of facility managers in the building lifecycle impede the implementation of BIM in O&M information management system.

This study does not represent exhaustive work, hence, it is recommended that the following suggestions be adopted in other to apply and implement BIM in the O&M information management in building facilities.

1. BIM usage in the O&M of buildings should be encouraged and imbibed right from the planning and designing stages of building facilities
2. Facility managers/professional should be included right from the inception of a building life cycle to the end of the building.

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Analysing the Knowledge Management Culture of Construction Firms in Abuja

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Construction projects are temporal in nature and involves project managers assembling construction professionals that are often disbanded immediately a project is completed. This disbandment causes construction knowledge that firms accumulate from the experience of teams to be lost or go uncaptured. This is a concern for firms that need to retain knowledge to remain competitive and often compete for limited contracts. Research into construction knowledge tends to focus on the relationship between the culture of organisations and construction knowledge. A second piece of the literature focusses on the nexus between construction knowledge and organisational performance. However, investigations that examine the knowledge management culture in construction firms with a view to analyse various issues and factors involved is limited. Therefore, the aim of this study is to examine the knowledge management culture within organizations in the Federal Capital Territory, Abuja, Nigeria. A descriptive survey approach is adopted, and data is obtained through questionnaires in Abuja. The results showed that many construction firms struggle or fail to formally capture/share construction knowledge because many employees have little or basic knowledge of knowledge management techniques or tools and often rely heavily on face-to-face interactions to share knowledge. The study argues that a superior knowledge of as well as an increased adoption of knowledge management techniques and tools by employees can significantly enhance the ability of an organisation to share and capture construction knowledge to minimise knowledge loss.
Keywords: Construction knowledge, culture, knowledge management tools, organisations, performance

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INTRODUCTION

Construction work is very competitive and involves knowledge based activities (Egbu & Robinson, 2005). One way that construction firms compete for limited contracts to remain profitable in business is by acquiring and applying new technology or knowledge in their construction activities. The challenge with construction projects is that they are temporal and involve project managers assembling construction professionals that are often disbanded immediately a project is completed. This disbandment causes the construction knowledge that firms accumulate from the experience of teams to be lost or go uncaptured (Schindler & Eppler, 2003). This uncaptured knowledge or knowledge loss is a concern for firms that compete for limited contracts in the market and shows that construction knowledge is a critical resource for their survival in business.

Some authors present construction knowledge as tacit knowledge or embodied knowledge. For example, Wilkinson *et al.* (2015) explored the relationship between explicit knowledge and embodied knowledge. The difference between these two types of knowledge is that the former involves knowing that, while the latter involves knowing how to execute a work or task that cannot be written down. Other authors present construction knowledge as accumulated experience gained from previous projects. For example, Song *et al*. (2009) examined the influence of knowledge input on baseline programmes at the inception stage which was also referred to as contractors' input or experience. Recent authors present construction knowledge as a trade secret that underpins their business model in the construction market. For example, Saunders and Golden (2018) presented knowledge as a trade secret that is a critical asset in business. These authors show that the concept of construction knowledge is highly debateable.

Two main themes in the literature on knowledge dominate the discussions in construction management. First, is the assumption that there is a relationship between construction knowledge and the performance of organisations (Yusof *et al.,* 2012). Second, is the assumption that there is a nexus between the culture of organisations and construction knowledge (Can & Eser, 2015). However, what is missing in literature are investigations that examine the knowledge management culture in construction firms with a view to analyse various issues and factors involved. Therefore, the aim of this study is to examine the knowledge management culture in construction organisations in Abuja, Nigeria. More specifically, the objective of this study is to examine the factors affecting the adoption and extent of integration of knowledge capturing and sharing tools and techniques in construction firms.

LITERATURE REVIEW

Knowledge and the Performance of Organisations

Several authors assume that there is a relationship between the performance of organisations and construction knowledge. For example, Park *et al.* (2013) stated that construction knowledge is not only important for executing construction projects, but also for choosing the right projects and developing winning bids. This implies that how organisations engage construction knowledge at various stages of a project (i.e., pre-contract and contract stage) is key to their survival. This position aligns with Wang *et al.* (2011) argument that the knowledge creation capability of organisations enhances organizational

performance which is key to exploiting new opportunities. Similarly, Chang and Lee (2008) linked knowledge accumulation capability to organizational innovations and argued that the ability to obtain knowledge can positively influence administrative and technical innovations. This position agrees with Von Zedtwitz, (2003) assumption that an organisation's performance in subsequent projects can be improved from lessons learned using knowledge capturing techniques and post-project reviews. It can be seen that the above authors assume that the secret to improving organisational performance depends on the way organisations engage with construction knowledge. However, these authors fail to consider various factors that affect knowledge accumulation and creation in construction firms.

Knowledge and Culture in Organisations

In contrast to a focus on organisational performance, some authors assume that there is a nexus between the culture of organisations and construction knowledge. For example, Can and Eser (2015) assumed that the culture of an organization is a factor that can affect the knowledge management efforts either positively or negatively in their study. The term organisational culture has been described by Nesan (2005) as the manner of working that members of an organisation engage in over time. This implies that the actions or inactions of people working in an organisation over time can affect the way knowledge is handled or managed. This definition by Nesan (2005) aligns with Fahey and Prusak (1998) position that accumulated experience of members in an organisation shapes the culture of an organization and knowledge flow over time. These above authors show that there is a nexus between the culture of organisations and the way firms engage with construction knowledge.

Knowledge flow is key to organisational performance and can be facilitated with the aid of knowledge management techniques or tools. According to Kamara *et al.* (2003), capturing, sharing, retaining and reusing relevant project knowledge involves the use of diverse tools and techniques. Eight main techniques and tools have been identified in this study from Ramalingam (2006) and Ermine (2010) for capturing and sharing knowledge namely: (1) internet sources (e.g. websites), (2)video conferencing, (3)face-to-face interactions, (4)telephone conversations, (5) electronic mail or email, (6) written documents (e.g. reference books, training manuals, articles and minutes), (7) knowledge management database systems, (8) training and seminars. The availability of these knowledge management techniques and tools does not correlate to their adoption as some firms still struggle or fail to formally capture, share, and retain project knowledge in a manner that actively contributes to their performance (Park *et al.*, 2013). Five major factors were identified in Chen and Mohamed (2006) ; Nesan (2005) study to be behind the inability of firms to formally capture or share knowledge namely: (1) staff changing companies or industry, (2) separated teams after project completion, (3) lack of a standard platform to capture and share knowledge (4) lack of motivation and (5) implementation challenges. These factors define the culture of an organisation and indirectly the way knowledge is capture or shared. It can be seen that earlier studies on organisational performance share similar assumptions with the studies that focus organisational culture. These discussions show that the way knowledge is engaged is an integral part of an organisation's culture and performance. However, these authors fail to examine the extent of integration of knowledge capturing and sharing tools and techniques in construction firms.

RESEARCH METHODOLOGY

This study adopts a descriptive survey approach to examine the factors affecting the adoption and extent of integration of knowledge sharing and capturing techniques or tools in construction firms in the Federal Capital Territory, Abuja, Nigeria. Abuja was chosen as the study area because of the increasing number of construction projects executed by construction firms and the potential that knowledge capturing or sharing tools/techniques are being adopted by those construction firms. A pilot study was conducted to identify five construction companies with construction professionals as permanent staff that utilised knowledge capturing and sharing tools in their various projects in Abuja, Nigeria. A purposive sampling technique was adopted, and 60 questionnaires were administered. A total of 50 responses were obtained from the construction firms selected.

The survey was carried out using structured questionnaires self-administered by hand and the requisite data was collected on the factors affecting the adoption and extent of integration of knowledge management techniques and tools. The participants comprised of directors, heads of department and project managers of construction firms. The level of compliance of knowledge sharing and capturing practices was measured using a 5-point Likert scale: 1= never 2= rarely, 3= sometimes, 4= often and 5= always. This was analysed using a mean score and ranked. The extent of integration of knowledge management techniques and tools was measured and analysed using percentages and ranked. The factors affecting the adoption of knowledge management techniques and tools was measured and analysed using percentages and ranked.

RESULTS AND DISCUSSION

The characteristics of respondents in the Federal Capital Territory, Abuja, that participated in the study are presented in Table 1. The results in Table 1 show that a higher percentage of professionals in construction firms were supervisors (30%) and site managers (24 %), while the least were directors (10%) and heads of departments (16%). The results also show that a higher percentage (42%) of professionals have been working in their organisations between 6 – 10 years, while those who have worked for (21 years and above) and (11 – 15) years were the least with (10%) each. Furthermore, the results also indicated that those professionals with (16 -20) years were the

least (14%), while those professionals with (11- 15) and (21 years and above) working experience were (38%) and (32%) respectively. The implication of this combined results when compared with the length of years working at their firms show that some of these professionals had worked elsewhere before changing to their current workplace. This also implies that those firms are likely to have lost valuable construction knowledge when those staff departed to work in another place.

Table 1: Respondents characteristics

Item	Description	Freq.	%
Educational Background	PhD	12	24
	M.Sc./MTech.	11	22
	B.Sc./B.Tech.	22	44
	HND	15	30
	Total	50	100
Working Experience (Construction)	1 – 10	8	16
	11 - 15	19	38
	16 – 20	7	14
	21 & above	16	32
	Total	50	100
How long working At your firm (in years)	1 – 5	13	26
	6 - 10	21	42
	11 - 15	5	10
	16 – 20	6	12
	21 & above	5	10
	Total	50	100
Role/position in Your firm	Director	5	10
	Departmental manager	8	16
	Project manager	10	20
	Site manager	12	24
	Supervisors	15	30
	Total	50	100

The results in Table 2 show that a higher percentage (30%) of professionals in construction firms had basic knowledge and very minimal knowledge of knowledge sharing and capturing tools or techniques, while (10%) of the professionals had adequate and superior knowledge respectively. The implication is that a higher percentage of construction firms are struggling or failing to formally capture and share construction knowledge that could enhance their performance or profitability because many professionals do not know how to use knowledge capturing and sharing techniques or tools or they possess basic knowledge.

Table 2: Extent of knowledge of knowledge sharing and capturing tools/techniques

Level of knowledge of knowledge sharing and capturing	N=50	%	Rank
Superior knowledge	5	10	4th
Adequate knowledge	5	10	4th
Basic knowledge	15	30	1st
Minimal knowledge	10	20	3rd
Very minimal knowledge	15	30	1st
	50	100	

The results in Table 3 show that a higher percentage (34%) of professionals in construction firms relied on face-to-face interactions to capture and share construction knowledge. The implication is that construction professionals tend to share their experience or trade secrets more easily with people that they have a close relationship with. The results also show that 2% and 1% of construction professionals relied on knowledge management database systems and video conferencing to share and capture knowledge. This implies that there is a slow adoption or integration of knowledge management technologies by construction professionals in construction firms. This explains why many construction firms are struggling or failing to formally capture and share construction knowledge even though there is a proliferation of advanced knowledge management tools or technologies. Furthermore, the result show that 18% of construction professionals relied on telephone conversations, while 14% and 5% adopted electronic records i.e. (emails) and internet sources respectively. The implication is that a greater percentage of construction professionals prefer telephone conversations, email, and internet sources

to capture and share construction knowledge in their organisations. These findings agree with Park *et al*. (2013) suggestion that adopting knowledge management technologies supports work process.

Table 3: Percentage use of knowledge sharing and capturing tools and techniques

Knowledge sharing & capturing tools/ techniques	N	%	Rank
Internet sources	5	10	5th
Video conferencing	1	2	7th
Telephone conversations	9	18	2nd
Electronic records and mail (emails)	7	14	3rd
Written documents, minutes, and records	3	6	6th
Knowledge mgt. database systems	1	2	7th
face-to-face interactions	17	34	1st
Training and seminars	7	14	3rd
	50	100	

The results in Table 4 show that post project reviews ranked highest with a mean score of 4.2, while interviews with individuals that were exiting to another project ranked the lowest with a mean score of 2.0. The implication is that a greater number of construction professionals in construction firms waited until the end of a project before taking stock of lessons and construction knowledge. The results also imply that construction firms rarely practiced exit interviews with staff that were leaving and one reason for this is because many construction firms have no control over a staff who is unwilling to work any longer and who fails to stay in touch. Furthermore, the results also indicates that few construction firms develop or have a knowledge management policy that guides the way staff acquire or share construction knowledge. This explains why many construction firms struggle or fail to formally capture and share construction knowledge.

Table 4: Level of compliance with knowledge sharing and capturing practices

Knowledge capturing and sharing practices	Mean	Rank
Development of knowledge management policies for acquiring or sharing of knowledge	2.1	4th
Departmental procedures that promote knowledge sharing or capturing	3.9	2nd
Post project reviews	4.2	1st
Submission of minutes and periodic reports on knowledge captured or shared	2.6	3rd
Exit interviews for individual(s) before they exit or move to another project	2.0	5th

The results in Table 5 show that among the factors that affect knowledge sharing and capturing in organisations, a lack of a standard platform to share or capture knowledge ranked highest with 20 %. The implication is that there is no consensus among most construction professionals on the tools or techniques that should be adopted to share or capture construction knowledge. This explains why many construction firms struggle or fail to formally capture and share construction knowledge. In the same vein, the results also indicated that the disbandment of project teams also ranked highest with 20%. The implication is that because construction projects are temporal, the completion of the project and disbandment of teams is likely to cause construction knowledge that firms accumulate from teams to be lost or go uncaptured. The results also indicate that early exit or retirement from work in an organisation was a factor that ranked least with 4 %. One reason for this is that construction firms tend to quickly replace professionals that leave an organisation unaware that construction knowledge accumulated might have gone uncaptured. Furthermore, the results also indicated that changes to staff working in an organisation and the departure of staff ranked 3rd and 4th with 18 % and 10% respectively. The implication is that changing a staff, or the departure of a staff has significant influence on the knowledge sharing or capturing ability of construction firms and one reason for this is that construction professionals tend to move or change to another organisation that pays higher than their current organisation. These findings agrees with Nesan (2005) argument that the knowledge sharing behaviour of employees are influenced by work practices that are allowed by respective organisations.

Table 5: Factors affecting knowledge sharing/capturing in organisations

Factors affecting knowledge sharing and capture	N	%	Rank
Staff changes	9	18	3rd
Disbandment or separation of teams	10	20	1st
Lack motivation	3	6	7th
Lack of standard platform to share /capture knowledge	10	20	1st
Early exit from work or retirement	2	4	9th
Relocation of staff	4	8	5th
Promotion of staff	3	6	7th
Implementation challenges	4	8	5th
Leaving for another work/job	5	10	4th
	50	100	

CONCLUSION

The study aimed at analysing the knowledge management culture and focused on examining the factors affecting the adoption and extent of integration of knowledge capturing and sharing tools and techniques in construction firm in Abuja. This study did not focus on the benefits or effects of captured or uncaptured knowledge. Rather, the analysis dissected the issues and dynamics involved in capturing or sharing knowledge in construction firms. The results show that many construction firms struggle or fail to formally capture/share construction knowledge because many staff have little or basic knowledge of knowledge management techniques or tools and often rely heavily on face-to-face interactions to share knowledge. The study argues that superior knowledge of as well as an increased adoption of knowledge management techniques and tools by employees can significantly enhance the ability of an organisation to formally share and capture construction knowledge to minimise knowledge loss.

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Influence of Plastic Waste Management on the Environment: A review

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Plastics have become a modern-day nuisance to the environment and man due to improper management at their end-of-life. The structure and additives in fossil-based plastics make them non-biodegradable and, therefore, can persist in the environment for hundreds of years. Since a small percentage of plastic waste is recycled annually (9%) most of this plastic waste is being managed by open-air incineration or disposal in landfills where these additives can easily contaminate the air, soil, and water apart from the fact that a lot of these plastic waste find their way into our water bodies resulting to a lot of harm to the Eco-system. Recycling of plastic is an effective means of tackling the menace of plastic pollution, with chemical recycling as the most effective recycling process as it completely removes the waste plastic from the environment. Manufacturing and use of bioplastics like Polylactic acid, a good substitute for fossil-based polymer polyethylene terephthalate (PET), is a welcome development with the People's Republic of China championing in the production. Legislative tools have been enacted in countries across the globe banning the use and manufacturing of single-use plastic bags. The implementation of this legislative move has been effective in some countries like the People's Republic of China, Morocco, and Rwanda. Nigeria enacted the Plastic prohibition bill banning the manufacturing, use, and importation of all plastic bags in May 2019. This ban does not affect the behavioral and plastic management system in Nigeria as plastic bags are still used in cities across the country, littered in waterways and landfills. Therefore, there is a need to review the bill to include waste generation and management. Emphasis should also be placed on the production, and use of cost-effective bioplastic polymers and products.

Keywords: Plastics, pyrolysis, waste management, recycling, bio-plastics, environmental pollution

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INTRODUCTION

Plastics have excellent properties such as light weight, low thermal and electrical conductivity, cheap and excellent durable (Thompson *et al*., 2009; Rodriguez, 2023; Kibria *et al*., 2023) which makes them suitable for use in every sector of life such as agriculture, building, food industry, packaging industry, medicine, automobiles, building construction, communication electronics (Thompson *et al*., 2009; European Commission, 2021; Moranda & Paladino, 2023). In recent times, plastics have been uses as good substitutes for other materials such as wood, metals, light ceramics, and glass for the production of many products (Schyns & Shaver, 2020; Oladele *et al*., 2023). A major challenge is that about 40% of plastic product is short lived of less than one (1) month (Hahladakis *et al*., 2018; Organization for Economic Co-operation and Development, (OECD), 2022; Kabeyi & Olanrewaju, 2023) especially the packaging industry which plastics are mostly used just once and thrown away.

According to Plastic Oceans (2022), a global estimation of 500 billion plastic bags is used and thrown away every year. The global rapid increases in human population, incessant urbanization, and rapid economic growth have increased the consumption and production of plastic waste at a precarious rate. From the 1950s to the 1970s, few amounts of plastics were produced, and these plastics were properly managed, this tripled from the 1970s to 1990s. As at the 2020s, over 400 million metric tons of plastics are produced annually (Schyns & Shaver, 2022; United Nations Environmental Programme, (UNEP), 2023), and this is estimated to increase to 1,100 metric tonnes by 2050 (Geneva Environment Network, 2023; UNEP, 2023).

In 2021, the estimated worth of plastic produced was $593 billion and this is estimated to increase to $750.1 billion by 2028 with an increase rate of 3.4% between 2021 and 2028 (Oladele *et al*., 2023). The demand for plastic is also increasing and is projected to increase by 37% within the next decades which amounts to about 100 million metric tonnes of plastics. Despite the huge quantity of plastics produce yearly, only about 9% of these materials are recycled globally (OECD, 2022; UNEP, 2023). These plastics at their end of life find their way to the environment, dump sites, water bodies and incinerators.

Plastics are petrochemical hydrocarbons with additives such as stabilizers, Oxidants, and flame-retardants making them have a long half- life (it takes about 4500 years to degrade) (Geyer *et al*., 2017; United Nations, 2021; Harris, 2023) and non-biodegradable thereby persisting in the environment. A huge amount of energy required, and a lot of greenhouse gases is evolved during the production process (OECD, 2023). Zheng *et al*. (2023) reported that in the U.S alone, an estimation of 3.2 quadrillion Btus of energy is used in the production of plastics per

year and 104 MMTCO$_2$ equivalent greenhouse gas is produced.

Plastics are made from by-products of petroleum and are mainly of two types: thermoplastics and thermosetting. Thermosetting plastics, also called engineering polymers, are cross-chained structured which becomes stronger and harder when heated. Examples of thermosetting plastics are acrylonitrile butadiene styrene, polyurethanes, and phenolic resins. They have great corrosion resistance, high mechanical strength, and thermal stability (Kibria *et al*., 2023; Oladele *et al*., 2023). These properties make them applicable in the electronic industry and automobile industries, while thermoplastics are branched, or liner structured and get soft when heated. Examples are polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), high-density polyethylene terephthalate (HDPET), low-density polyethylene terephthalate (LDPET), polyvinyl chloride (PVC), and polystyrene (PS) (Alabi *et al*., 2019; Kibria *et al*., 2023; Oladele *et al*., 2023). These polymers are the most commercially produced polymers globally with polypropylene (PP) having 68 mt, polyethylene (PE) 166mt, polyethylene terephthalate (PET) 33mt, polyurethanes (PU) 27mt, and polystyrenes (PS) 25mt (Zheng *et al.*, 2023). Thermoplastics are mostly used in the production of cups, plates, bags, bottles, packaging materials, and toys mixed up in the waste mainstream.

PET, PE, and PP are the most recycled polymers with occupies a large percentage of 95.2% of the recycled materials (Kökkılıç *et al*., 2022; Zheng *et al.*, 2023). Generally, the municipal solid waste contains a large amount of plastic, of which polyvinyl chloride (PVC) at 6%, polystyrene (PS) at 9%, polyethylene terephthalate (PET) at 10%, polypropylene (PP) at 14%, high-density polyethylene (HDPE) at 19%, low-density polyethylene (LDPE) at 23% (Mibei *et al.*, 2023). Knowing the type of plastic is vital in determining the method of recycling the waste plastic since all polymers have different mechanical, chemical, and physical properties and therefore would have different recycling conditions (Murthy *et al.*, 2020; Dhanalakshmi *et al*., 2022).

This review provides insight into the effects of plastic waste on man, marine environments, land, and air. The management techniques for plastic waste, innovations on bioplastics in tackling plastic pollution, and analysing the pros and cons of the use of bioplastic. A critical analysis on the policy and legislation banning the use of single-use plastic bags in Nigeria was conducted providing an insight into its level of implementation compared to similar legislations in other countries. This analysis could be useful to government officials on the tackling the ravaging plastic pollution crisis.

EFFECTS OF PLASTIC WASTE ON THE ENVIRONMENT

Water Pollution

In recent times, there has been a rise in concern about the increase in deposition of plastic in the ocean and other water bodies. A forecast has shown that by 2050 the mass of plastics found in the ocean, will be more than fish (Letcher, 2020). The percentage of sea birds with plastic found in their intestine has grown to 90% (Wang, 2021; Live Science, 2022). Plastic particles have been found in human blood (Ocean Care, 2022; Leslie, 2022).

As reported by the UNEP (2023), 75 -199 million tonnes of plastic are present in the ocean and, an average of 8 million tonnes of plastics finding their way to the oceans annually, and about 5 trillion pieces of plastic objects floating on the oceans.

Diana *et al*. (2020) reported that plastic waste poses harm to marine animals through ingestion, and entanglement causing restriction of movement and consumption of additive leaching from plastic. Studies by Koongolla *et al*. (2019), Kilic (2022), Lin *et al*. (2023), and Riaza *et al*. (2023) on fishes revealed that plastic is present in the guts, gills, and intestines of some examined fishes indicating that these plastics were unintentional consumed as food thereby exposing them to plastic additives. Though, not much is known about the effects of consuming plastic on humans, plastic is known to cause gastrointestinal obstruction, translocation and development of oxygen-reactive species, ulcers, laceration, and death among marine animals (Diana *et al*., 2023).

Land Pollution

Plastics have been found in unbelievable places, like deserts and inhabitable places (The Guardian, 2017; Li *et al*., 2022; Akanyange *et al*., 2022). Over 20% of waste found its way to landfills due to difficulty in sorting and separating these plastics from the main waste stream and separation from other materials during recycling. Researchers have proven that the illicit deposition of plastics on the soil causes several health issues and decreases soil fertility (Ferdous, 2021; Stubenrauch & Ekardt, 2022; UNEP, 2022). As reported by Alabi *et al*. (2019), chlorinated plastics leach toxic chemicals into the soil, thereby contaminating the groundwater and the soil resulting in a negative impact on the ecosystem. They also reported that during microbial degradation of the plastic, harmful greenhouse gases evolved into the atmosphere contributing to global warming.

Air Pollution

The extraction process of fossil fuel for the production of plastics releases toxic chemicals such as benzene, methane, H_2S, and volatile organic compounds (Sarkingobir *et al*., 2021; Adebiyi, 2022). Also, the incineration/burning of plastic waste produce hazardous environmental pollutants which contaminate the atmosphere. Some examples of hazardous chemicals emitted are heavy metals, furans, Dioxins, Carbon (ii) oxide, volatile organic compounds, and microplastics (Verma, 2016; Sarkingobir *et al*., 2021; Takada & Bell, 2021). These harmful substances cause harm to plants, animals, and humans. The inhaling of carbon (ii) oxide causes suffocation and chronic respiratory health problems in human, heavy metals are neurotoxin, and Volatile Organic Compounds (VOCs) are carcinogenic (Sarkingobir *et al*., 2021).

Effect of Plastic Pollution to Man

Most food packaging materials are made from plastics such as PET which is impregnated with Antimony as a catalyst during the polymerization process. Antimony tends to migrate into beverages (Oyen *et al.,* 2016; Montserrat, 2020; Carneado *et al., 2023*). Oyen *et al.* (2016) also conducted some experiments on electronic plastic waste. They discovered that plastics from electronic waste contained high concentration of cadmium (2016 ppm), lead (1124ppm), bromine (1985 mg/kg) and antimony (1356mg/kg), which exceeded the recommended limits. Antimony triode is believed to be carcinogenic to humans, and excess exposure might lead to lungs damage, skin irritation, and stomach problems (Oyen *et al.,* 2016; Saerens *et al*., 2019). Exposure to excess antimony can lead to reproductive problems (Copper & Harrison, 2009; Oyen *et al.,* 2016). Lead exposure leads to cardiovascular problems, high blood pressure and kidney damage. It also causes miscarriages and stillbirth in pregnant women (World Health Organization, WHO, 2023). Exposure to small dose of Cadmium over a long period of time leads to kidney problems like kidney stone and lung damage (Oyen *et al.,* 2016; Genchi *et al*., 2020).

MANAGEMENT OF PLASTIC WASTE

Refuse, Reduce, Reuse, Repurpose and Recycle

The 5 R's (refuse, reduce, reuse, repurpose, and recycle) are steps that ensure that waste is properly managed, reducing the amount of waste plastics ending at landfills, with recycling as the last action to take in waste management. Refuse deals with rejecting the use of plastic when possible. For instance, plastic packaging bags could be replaced with more biodegradable paper bags, reject the use of disposable plastics for reusable plastics, and rejecting the use of non-recyclable plastics. Plastics can be reduced by avoiding all unnecessary use of plastics. Groceries can be bought in bulk to reduce the use of plastic packaging and take a reusable shopping bag when shopping. Reuse involves the conscientious reuse of plastics. Reusable cutleries, plates, cups, and packaging materials could be used in place of single-use plastics, which are thrown-away after use. When refusing, reducing, and reusing plastic material seems difficult, and then repurposing comes in handy. Repurposing involves the use of an item meant for a particular purpose for another purpose. For instance, converting plastic bottles into planters and creating bottle pen and pencil holders from plastic bottles. The last 'R' represents recycling of waste plastic. Recycling involves the total conversion of plastic to different products such as fuel, and other chemicals (Geyer, 2020; Balwan *et al*., 2022).

Mechanical Recycling of Plastics

Mechanical recycling of plastic is the most commonly used method for recycling waste plastics (Ragaert *et al.,* 2017; Zheng *et al.,* 2023). Mechanical recycling of plastic involves the conversion of plastics into secondary products or raw material without altering its chemical components. The mechanical recycling of plastics involves the collection of the plastic waste, sorting according to types and colour (manually and automatically), shredding into smaller bits, washing, and elimination of impurities. These steps might follow a different order or be performed several times depending on the source and composition of the plastic waste. (Ragaert, 2017; Schyns & Shaver, 2021).

The use of recycled plastics has been proven to be three times more efficient as regarding the amount of greenhouse gas emission compared to manufacturing from virgin plastics. Mechanical recycling is faced by the challenges of inconsistent quality products, degradation of mechanical properties and the challenge of sorting (Letcher, 2020). Mechanical recycling is limited to a single feed stock, therefore, must be sorted into types and colour hence, several detectors such as Near-Infrared spectroscopy (NIR) and Ultraviolent-visible (UV-Vis) is needed. These detectors have the limitation to detect polymers which have similar chemical properties but different mechanical and physical properties. This blend can result to incompatibility in the process regarding the temperature for melting the mixture and the entire extrusion process (Schyns & Shaver, 2021).

Recycled plastics have lower mechanical strength due to degradation during use before recycling, repeated heating and extrusion (Jin *et al*., 2023; Zheng *et al.,* 2023). Therefore, additional additives and virgin plastics needs to be added in order to increase the quality to achieve the desired strength. Some plastic textiles and packaging with multi-layers have several types of polymers and cannot be easily separated mechanically are also difficult to recycle mechanically (Zheng *et al.,* 2023).

According to Oyen *et al.* (2016), waste plastic from Automobiles and electronic materials are impregnated with antimony and bromine as flame retardant thus cannot be recycled using mechanical recycling method. They also emphasized that one of the main problems of mechanical recycling industry is the unknown history and the composition of the recyclate, thus additional analysis has to be done making recycled plastic more expensive than virgin plastics.

Mechanical recycled plastics has been effectively used as replacement of wood in furniture, replacement of bitumen in asphalt mixtures in construction of roads and bridges, production of fabrics, mixed with concrete and mortars for construction purposes, production of Television backseats, as a thickening agent in liquid lubricants, and for multilayered packaging materials (Ragaert, 2017; Schyns & Shaver, 2021).

Thermal Recycling of Waste

The thermal recycling of plastic waste involves the direct heating of plastic waste to produce thermal energy (Bujak, 2015; Kijo-Kleczkowska & Gnatowski, 2022; Moranda & Paladino, 2023). Plastics contains a complex mixture of different kind of base resin and additives such as plasticisers, additives, UV-stabilizers, antistatic agents, cross-linking agents and colouring agents, which are usually uncompact able with each other. However, some environmental pollutants such as polycyclic aromatic

hydrocarbons (PAHs), Dioxins, heavy metals, Volatile organic compounds (VOCs), Poly chlorinated dibenzodioxins (PCDDs), Polychlorinated dibenzofurans (PCDBFs), which are carcinogenic and have the ability to bio accumulate in fishes and contaminate the food chain are produced during thermal recycling of plastic waste (Moranda & Paladino, 2023).

Thermo-Chemical Recycling

Chemical recycling tends to tackle some of the problems confronted in mechanical recycling, such as problem of sorting as mixed plastics can be used as feed stock and produces a lesser amount of greenhouse gases as compared to thermal recycling (Ragaert *et al*., 2017; Vollmer *et al.,* 2020; Nikiema *et al*., 2022). Pyrolysis is one of the major thermochemical recycling processes. This process has proven to be the most efficient method of recycling waste plastic, as other methods still send the plastic back to the environment, therefore "postponing the evil days" (Geyer, 2020), whereas pyrolysis removes the waste plastic completely from the environment. Apart from confronting the challenge of plastic waste, it also resolves the challenge of the rapid need for fossil fuel (Pohjakallio *et al.*, 2020).

Pyrolysis involves the breaking down or degrading of long-chain polymers molecules of plastic into smaller and less complex molecules by the action of intense heat pressure and absence of air (Al-Rumaihi *et al*., 2022; Kabeyi *et al*., 2023). Study by Mibei *et al.* (2023) showed that the quality of the oil produced during pyrolysis is comparable to that of fossil fuel, which makes it suitable for diesel engine.

The yield of pyrolysis depends on some factors such as pressure, temperature, feed stock composition ratio, type of reactor, choice of catalyst, residence time, and particle size (Pohjakallio *et al*., 2020). According to Mibei *et al*. (2023), thermal pyrolysis produces oil paraffin, aromatic, isoalkanes and olefins, which are not suitable for combustion engins.

Catalysed pyrolysis enables the pyrolysis process to be carried out at a lower temperature than thermal pyrolysis, and lesser environmental pollutants including carbon (iv) oxide, water vapour are evolved since the reaction is done in an environment with absence of oxygen, fuel derived also contains a greater amount of octane number and lesser char (Czajczyńska *et al.,* 2017; Moranda & Paladino, 2023 Mibei *et al*., 2023). The composition of the feed stock also has a great effect on the product (Miandad *et al.*, 2019; Mibei *et al.,* 2023). Pyrolysis tends to require a lot of energy, therefore the use of a catalyst helps to reduce the temperature required, increase the rate of reaction, and ultimately reducing the long chain in products from the pyrolysis process, thereby reducing its boiling point (Thahir *et al.,* 2021; Mibei *et al.,* 2023). In recent times. Researchers have used low-cost catalyst such as fly ash, and red clay (Aisien *et al*., 2021; Mibei *et al.,* 2023). Other examples of catalyst are Fe_2O_3, $Ca(OH)_2$, natural zeolite, synthetic zeolite, and y-zeolite. (Miandad *et al.,* 2019; Aisien *et al*., 2021)

The liquid product from pyrolysis can be used for power generation, transportation fuel, heating and the gas product can be used for heating the raw materials for the pyrolysis process. (Miandad *et al.,* 2019; Aisien *et al*., 2021; Moranda & Paladino, 2023).

Establishing a chemical recycling facility is more expensive than a mechanical facility. According to Zheng *et al.* (2023), the estimation selling worth of products from chemical recycling, such as methanolysis and glycolysis is $0.96- 1.04 Kg, which is about twice the price of mechanical, recycled plastic, $0.54 kg. Therefore, efforts should be put in place to reduce the cost of chemical recycling.

INNOVATION ON PLASTIC MATERIALS-BIOPLASTICS

According to Kabasci, (2020) and European Bioplastic (EUBP) (2023a), bioplastics can be biodegradable, biobased or both. The biodegradable property of a plastic depends on the molecular structure of its polymer. Not all biobased plastics are biodegradable (Narancic *et al.,* 2020). An example is bio-polyethylene, which is non-biodegradable despite being derived from cane sugar while polycaprolactone, a fossil-based polymer is biodegradable (Kabasci, 2020).

Biobased plastics are plastics derived from biomass or non-fossilized and biodegradable organic materials gotten from animals, microorganisms and plants. Studies have shown that biodegradable plastics can be made from cane sugar, humbled masked bee, sea weeds, shrimps, avocado seeds, banana peels, rice, cassava (Censi *et al.,* 2022). Bioplastic made from starch is the most popular type of biodegradable plastic due to its low cost, avalability and its ability to degrade totally into environmentally friendly substances such as glucose. (Narancic *et al.,* 2020; Kabasci, 2020).

Global Production of Bio-plastics

The global production of bioplastics as of 2020 was estimated to be 2.11 million metric tons. This was forecasted to increase to 2.87 million metric tons by 2025. The largest market for bioplastics is the packaging industry with a production capacity of 555,000 metric tons. Asia is the world's largest producer of bioplastics with over 50% of the world's bioplastics (Statista, 2023). As reported by Statista (2021), BBCA Group, a Chinese Company, forecasted to increase its production of PLA from 50,000 tons by August 2020 to reach 700,000 tons annually by 2023, almost doubling the global demand for Polylactic acid (PLA) polymer (360,000 tons) for the year 2023 The use of PLA polymer that is the best substitute for PET (the most globally used type of plastic) is derived from corn and other plants presently used in producing drinking straws, apparel, bottles, medical devices, and nonwoven fabric masks. (Jiaming *et al.,* 2023)

Regulatory Frameworks for Single-use Bags and Bioplastics

Most countries are now aware of the problems associated with fossil-based plastics that have led to new legislations related to the use of single-use

plastics and the replacement of fossil-based plastics with biobased plastics. Countries in Africa, such as Nigeria, Senegal, Tanzania, Madagascar, Mali, Morocco, and Kenya, already have legislation regulating the use of single-use plastics with Rwanda as the first African country to place a complete ban on all single-use plastics (Greenpeace Africa, 2020).

According to European Bioplastics (2023b), the European Union is putting a lot of effort into introducing regulatory frameworks, policies, and standards to improve bioeconomy in Europe that is beneficial to the bioplastic sector. Some of such policies, frameworks, and strategies are the EU Green Deal (2019), the Packaging & Packaging Waste Directive (review 2022), Policy Framework for biobased, biodegradable, and compostable plastics (2022). The People's Republic of China in 2020 introduced a ban on the importation, sale, use, and manufacture of non-biodegradable plastic bags (Arias, *et al.*, 2022; Bairong *et al*., 2023). However, there is a gap between public awareness and behavioural changes in most countries due to a lack of political will and the misconception that all biobased plastics are biodegradable (Moshood *et al.*, 2022)

The Pros and Cons of Bioplastics

Bioplastics have properties such as the ability to biodegrade within a short period into environmentally friendly products such as water and carbon(iv)oxide, thereby causing the environment no harm, low melt flow index, high impact strength, good elongation, anti-UV, anti-oxidation, and anti-moisture properties. Also, the production process of bioplastics emits a lesser carbon footprint compared to fossil-biased plastic (Greenhome, 2008; Jiaming *et al*., 2023). Bioplastics such as PLA and Polyhydroxybutyrate (PHB) are better for health. Therefore, suitable for producing food packaging materials.

However, the EU has recently raised concern about the degradability of biobased plastics in certain environments, as bioplastics are produced to degrade only in specific environments, such as soil in a marine environment (Havstad, 2020; European Bio-plastics, 2023). Studies have shown that bioplastics do not degrade in landfills, which is the final destination of most plastics (Folino, *et al*., 2020). Also, bioplastics are more expensive than fossil-based plastics, therefore increasing the cost of production of goods making products more expensive for the final consumer. Land used for cultivating crops competes with land for food production that might threaten food security and deforestation to grow crops for the feedstock of bioplatics. (Greenhome, 2008; Jiaming *et al*., 2023)

Therefore, a lot of issues remain unresolved regarding the use of bioplastics to tackle the current issue related to plastic pollution. Hence, facilitating an effective waste management system would be beneficial to the growth of the bioplastic industry. Also, bioplastics tend to leach harmful chemicals into the environment. Therefore, if not properly handled would be hazardous to the environment (Folino, *et al*., 2020).

Plastic Prohibition Policy in Nigeria: Lesson Learned from other Countries

The ban on the use of single-use plastic bags in Nigeria since 2019 has shown little or no effects on the behavioural and plastic management system in Nigeria, as the bill does not provide a holistic solution to the problem of plastic generation, management of plastic waste, public awareness and consultation but is just a punitive measure. Public awareness and education on environmental policy is essential and could result in voluntary initiatives. This has been effectively applied in countries like France, Finland, Luxembourg, and Indonesia. Also, the provision of a suitable, cost-effective, and accessible alternative to plastic single-use bags and the enforcement of plastic bag prohibition policies as used in countries like Morocco and Kenya would go a long way in tackling the problems of plastic pollution in Nigeria. The ban of plastic bags in Rwanda has shown positive impact on the environment, such as a reduction of flooding, erosion and harm to wildlife. The Nigerian Government can also look into the production and use of biobased biodegradable plastics as a lot of research has been done by academia on the use of cassava peels, an abundance of agricultural waste in Nigeria, for the manufacturing of bioplastics (Nwafor & Walker, 2020; Muposhi *et al*., 2022).

CONCLUSION

With the rapid increase in the demand and production of plastic, there is an urgent need to ensure that plastics are properly managed at their end of life. Researchers should concentrate on developing polymers that are easier to process at end-of-life and develop efficient methods for breaking plastics into valuable products. Technologies developed should look into tackling the environmental effects of the technology, such as minimizing energy, water, and toxic chemicals used. Also, technologies should be focused on developing cost-effective bioplastics that can biodegrade easily irrespective of environmental factors. In Nigeria, radical public awareness and advocacy should be done to ensure the reduction in the use of plastics, especially single-use plastic bags, and replacement of packaging materials with other eco-friendly materials. The production and commercialization of biobased plastics should be encouraged. Bioplastics must be properly managed by reducing, reusing, and recycling at their end of life. The Nigerian Government should also review the bill on the banning of single-use plastics to include public participation, public awareness, plastic waste generation and management. The scope of this review did not cover recycling of bioplastics and limited number of articles on the single-use plastic ban in Nigeria because of limited studies has been conducted in Nigeria.

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Ethno-religious Conflict in Kaduna, Nigeria: Perceptual implications for Residential Property Development

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This study investigates the causes of ethno-religious conflicts prevalence in Kaduna and its attendant influence on residential property development decisions in Kaduna, Nigeria. Data was collected through structured questionnaires and administered by trained Assistants to residential property owners/investors in selected neighbourhoods of Kaduna North and Kaduna South. A total of 5,439 questionnaires were administered to respondents (Property Owners/Investors) and 3,431 was retrieved. This includes 1,608 from Kaduna North and 1,823 from Kaduna South representing a total of 63.08% response rate. Quantitative data obtained from the questionnaires were analysed using descriptive statistics and logistic regression. The findings indicate that in Kaduna North, the incessant ethno-religious conflicts in the area, resulted to problems associated with low occupancy ratio occasioned which is a consequence of voids in many completed residential properties in the area, negatively affected investment decisions ($B = 1.275$, $p = 0.049$). In Kaduna South, the incessant conflicts in the area resulted to more significant problems which negatively affected residential property investment decisions including property loss due to violent attacks ($B = -1.102$, $p < 0.001$), limited access to financing ($B = -3.392$, $p < 0.001$), overall insecurity in the location ($B = -1.816$, $p < 0.001$), low property demand ($B = 9.269$, $p < 0.001$), and challenges with disposal and attracting quality tenants/occupants/buyers ($B = -7.029$, $p < 0.001$). The study recommends the need for strengthened security measures, improved access to financing, peace-building initiatives, infrastructure development, market support and capacity building. These findings provide valuable insights for policymakers and stakeholders in residential property development ventures in developing targeted strategies to promote sustainable residential property development in Kaduna.

Keywords: Ethno-religious conflict, property development decisions, Kaduna-Nigeria, investment decisions

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INTRODUCTION

Residential property development is a crucial catalyst for socio-economic progress, addressing the fundamental need for housing and fostering social connections within communities (Ogunbajo *et al*., 2015). The rapid urbanization witnessed across Nigeria has intensified the demand for housing, with diverse factors shaping the choices individuals make regarding their residential locations. These factors include economic indicators, lending rates, proximity to amenities, and safety considerations, which influence investment decisions and residential preferences (Ogunbajo *et al*., 2015; Aliyu *et al*., 2012). However, Nigeria grapples with the challenge of unity amidst inter-group tensions arising from its rich ethno-religious diversity. Ethno-religious conflicts have emerged as a significant source of violence, leading to the destruction of various types of properties, including residential, commercial, industrial, and agricultural (Ademiluyi, 2010). Of particular concern is the vulnerability of residential properties, given their symbolic significance and the perceived impact of their destruction on rendering individuals helpless (Alagbe *et al*., 2014). This destruction not only entails immediate losses but also results in a reduction in housing supply, contributing to the rise in homelessness and internally displaced persons (IDPs) (Schittone, 2011; Ezeonwuka & Igwe, 2016).

The importance of safety and profitability influences investors in residential property development, while tenants and purchasers prioritize personal safety when considering residential properties (Wapwera & Gajere, 2017). Unfortunately, several States in Nigeria, including Plateau, Bauchi, Taraba, Benue, Kano, Nasarawa, Ogun State, Lagos, Abia, Ebonyi, Enugu and Kaduna, have experienced distressing levels of ethno-religious violence (Aleyomi, 2012; Wapwera & Gajere, 2017). Kaduna, in particular, has been a hotbed of violent clashes, often fuelled by political, economic, and religious rivalries, with religion playing a prominent role in these conflicts (Human Rights Watch, 2012).

This study examines causes of ethno-religious conflicts and its consequential effects on residential property development activities within the Kaduna metropolis, Kaduna State, Nigeria. Kaduna, like other Nigerian states, has witnessed recurrent conflicts characterized by political, economic, and religious rivalries (Human Rights Watch, 2003). Historical instances of violence, such as those in 1987, 1992, and 2000, have resulted in clashes between different ethnic and religious groups, profoundly affecting lives and leading to extensive property damage (Human Rights Watch, 1993; Akinteye *et al*., 1999). Consequently, the realm of residential property development in Kaduna has been significantly hampered by these repeated conflicts. Available literature and other research work on the impact of ethno-religious conflicts around the world, Africa and Nigeria in particular focused essentially on the impact of ethno – religious conflict on Socio-Economic development, political, property values and other forms of casualty (Uhunmwuangho & Aluforo, 2011; Madu & Ibrahim,2013; Ugorji, 2016). However, no work has looked into the effect of the conflict on

residential property development activities which is usually impacted by these conflicts. This study therefore would fill that gap.

Aliyu *et al*. (2012) in their work, focused on the impact of ethno-religious conflicts on residential property values in Jos. Their findings included amongst others that ethno-religious conflicts are the main indicator of residential property values in the study area and that ethno-religious chaos motivates peoples' choice of where to stay, how much they are willing to pay for their accommodation which in turn is a function of security and safety of their lives. Gambo and Omirin (2012) on their part, focused on the effect of ethno-religious conflicts on settlement pattern in Northern. The study revealed that ethno – religious conflicts has shaped and influenced property market and has ushered in settlements and property developments along religious and ethnic lines. Alagbe *et al*. (2018) revealed that the importance of residential properties in the African setting is beyond mere shelter but are sacred and generational assets worth bequeathing which make it an object of attacks during ethno – religious conflicts.

From the foregoing, it is clear that none of these previous works investigated the impact of ethno-religious conflict on residential property development activities in an area prone to ethno-religious conflicts. Against this backdrop, this study aims to investigate the causes and dynamics of the incessant ethno-religious conflicts in Kaduna, with a particular focus on their influence on residential property development activities in the area. The study would provide valuable insights that would inform policies and interventions, mitigating the adverse consequences and fostering sustainable development in conflict - affected areas.

LITERATURE REVIEW

Ethno-religious conflicts have long been a recurrent phenomenon throughout history, impacting nations globally and documented in religious texts (Mohammadzadeh, 2016). The rise of ethnic and religious consciousness poses a threat to co - existence, peace and unity in multi-ethnic and multi-religious states, necessitating proactive identification of root causes and effective resolution (Gberevbie *et al*., 2013; Umana *et al*., 2019).

One of the key factors influencing ethno-religious conflicts is the presence of literature and publications by religious elites, exacerbating tensions and fostering a divisive atmosphere (Omotosho, 2003). These publications distort views and positions, fuelling the flames of conflict. Similarly, poverty contributes to the frequency of ethno-religious crises in Nigeria (Omorogbe & Omohan, 2005), resulting from mismanagement of resources, wrong policy directions, marginalization, favouritism, and religious and ethnic prejudices.

Omorogbe and Omohan (2005) found that poverty accounted for the frequent occurrence of crises in Nigeria. Smith's (2007) study in India revealed that history, cultural and religious differences, victimization, politicization of religion, political ideology, intolerance, lifestyle differences, oppression by minority groups, and disillusionment fuelled by corruption and authoritarian tendencies contribute to ethno-religious conflicts. Government failure to decisively address these conflicts often leads to retaliations or reprisals. Ibrahim (2008) conducted a study specifically on the causes of ethno-religious crises in Kano State, finding that poverty accounted for the highest percentage (34.9%), followed by religious fundamentalism (31.8%). Poverty, stemming from mismanagement of resources, wrong policy directions, marginalization, favouritism, ethnic and religious bias, drives constant agitation in economically impoverished areas. In a related development, Dung-Gwom (2008) established that unemployment is one of the causal factors in ethno-religious conflicts. The government's failure to provide employment opportunities, infrastructure, and basic services exacerbates ethno-religious conflicts (Tamuno, 1991; Ochegbu, 1992). Residential property development activities, like many other economic activities, is usually disrupted in any area prone to incessant ethno-religious conflicts (Gambo & Omirin,2012; Wapwera & Gajere,2017).

Property development according to Wurtzebach and Miles (1995), is a process starting with an idea or concept that is brought to successful execution in bricks and space with associated services. It is an intricate process that requires the combined knowledge and expertise of many professionals. Sources of the financing must be attracted by the promise of sharing the cash flow generated by the development in a manner that properly balance risk and return (Wurtzebach *et al*., 1995). Residential property development is an important development activity which brings about significant changes in land uses. It requires understanding to enable an effective environmental management and land use planning in order to facilitate land use management decisions. Bello and Agbatekwe (2009) considered property development as the use of land in its broadest sense to obtain a satisfactory environment taking into account, the social and economic needs of the society. It is a creative process activity that covers a wide range of processes. Property development industry is risky, cyclical, highly regulated and lengthy in production (Ratcliffe & Stubbs, 1997). Bello and Agbatekwe (2009) posited that the objective of property development is to provide accommodation for occupation by the developer as owner – occupier or for someone else in a way to be economically beneficial to the developer. This need can be met depending on the choices of individuals which can be influenced by several distinct factors including ethnic-religious inclinations, security and safety reasons.

Ethno-religious conflicts significantly and negatively impact residential property delivery as it leads to the destruction of residential properties and displacement of individuals. Omankhanlen *et al*. (2011) emphasized that the prevalence of ethno-religious conflicts poses a threat to existing and future property investments in Nigeria. The historical significance of conflicts, such as the 1967 civil war and the annulment of the June

12, 1993 election, influenced by ethnic and religious factors, further highlights their consequences (Ajimotokin, 2003). The detrimental effects on stability and development include disrupted schooling, economic loss, and displacement (Alagbe, 2010). Gambo and Omirin (2012) investigated the effect of ethno-religious conflicts on settlement patterns in Northern Nigeria, finding that conflicts shape and influence the property market, leading to the development of settlements along religious and ethnic lines. Residential properties are often targeted during conflicts due to their value and homeownership status. The climate of insecurity discourages investments, including residential property development, contributing to stagnant economies and hindering sustainable development (Aliyu *et al*., 2012; Gambo & Omirin, 2012; Alagbe *et al*., 2014; Olukolajo *et al*., 2014; Olumide, 2014).

RESEARCH METHODOLOGY

This study adopted questionnaire survey design to gather data to investigate the causes of ethno-religious conflicts prevalence in Kaduna and its attendant influence on residential property development decisions in Kaduna, Nigeria. The sample size was determined using Yamane's (1967) formula, considering a population size of 206,903 in the selected neighbourhoods. With a desired level of precision of 5%, the calculated sample size was 3,905 respondents. To account for non-response associated with questionnaire survey, the initial sample size was increased to 5,439 respondents using the estimated response rate (ERS) method thereby enhancing the representativeness of the sample. This follows the work of Willimack *et al*. (2002) and Neuman (2005). A total of 3,431 questionnaires were retrieved from the 5,439 questionnaires distributed representing 63 .08% response rate. This included 1,608 questionnaires from Kaduna North and 1,823 questionnaires from Kaduna South.

Structured questionnaires were administered in person to residential property owners/investors in the selected neighbourhoods. Trained data collectors administered the questionnaires while adhering to ethical considerations, obtaining informed consent and ensuring the confidentiality of participants' responses. Quantitative data obtained from the questionnaires were analysed using descriptive statistics and logistic regression. Descriptive statistics such as Weighted Mean Scores (WMS) was employed to rank the perceived causes of ethno-religious conflicts in Kaduna. Logistic regression analysis was deployed to examine the relationship between the decision to invest or not and independent variables, including demographic factors, economic factors, and perceived risks and benefits of property investment. The logistic regression model estimates the probability of the dependent variable (investment decision) based on independent variables using the formula: $\text{logit}(p) = \beta 0 + \beta 1X1 + \beta 2X2 + ... + \beta nXn$. Here, logit (p) represents the logarithm of the odds of the dependent variable, $\beta 0$ is the intercept, and $\beta 1$ to βn are the regression coefficients for the independent variables X1 to Xn (Hilbe, 2015). Logistic regression analysis provides insights into the significance and direction of the relationships between independent variables and the likelihood of investment.

RESULTS AND DISCUSSION

Causes of Ethno-religious Conflicts Prevalence in Selected Areas of Kaduna North

On ascertaining the causes of ethno-religious conflict prevalence in the study area, questionnaire was also administered to property owners/investors in residential property in the selected areas of Kaduna north in a bid to attract relevant data from these stakeholders. The response received from the respondents of the study area (Kabala Doki, Malali, Ungwar Dosa, Ungwar Shanu, and Kawo) is shown in Table 1

Table 1 displays the responses received from property owners/investors in Kaduna North neighbourhoods. The table reveals that in Kabala Doki neighbourhood, the top-rated causes of ethno-religious conflicts include ethnicism and religious extremism (Weighted Mean Score: 4.4033), bad/poor religious teaching/preaching (Weighted Mean Score: 4.2565), religious intolerance (Weighted Mean Score: 4.0101), and feeling of marginalization/oppression and neglect by the government (Weighted Mean Score: 4.0000). These factors occupy the 1st, 2nd, 3rd, and 4th positions, respectively. Other significant causes, as indicated by the property owners/investors, are poverty and unemployment, majority/minority people's struggle, and family failures in children upbringing, with respective Weighted Mean Scores of 3.9282, 3.7680, and 3.6409, ranking 5th, 6th, and 7th. The table also shows other causes of the conflict in the area, such as poor representation in governance (Weighted Mean Score: 2.1271) and underdevelopment in some areas (Weighted Mean Score: 2.1215), occupying the 17th and 18th positions on the ranking table.

In Ungwar Dosa, the table indicates that the top-rated causes, according to property owners/investors, are majority/minority people's struggle (Weighted Mean Score: 4.0517), political grievances (Weighted Mean Score: 4.0345), and illiteracy and ignorance of people (Weighted Mean Score: 3.9138), ranking 1st, 2nd, and 3rd, respectively. Other identified causes include feeling of marginalization/oppression and neglect by the government, and ethnicism and religious extremism, with respective mean scores of 3.7328 and 3.5172, ranking 4th and 5th. Conversely, property owners/investors in Ungwar Dosa consider bad/poor religious teaching/preaching and lack of political will to deal with successive conflict situations as the least influential causes, with Weighted Mean Scores of 2.6724 and 2.6121, respectively, in the study area.

Table 1 also shows that in Ungwar Shanu, the major causes of ethno-religious conflict, from the perspective of property owners/investors, are religious intolerance (Weighted Mean Score: 3.5263), ethnicism and religious extremism (Weighted Mean Score: 3.5263), and illiteracy and ignorance of the people (Weighted Mean Score: 3.4211), ranking 1st,

2nd, and 3rd, respectively. The table further indicates that bad/poor religious teaching/preaching (Weighted Mean Score: 3.3158) and feeling of marginalization/oppression and neglect by the government (Weighted Mean Score: 3.2105) are also identified as prominent causes, ranking 4th and 5th, respectively. Additionally, the action of politicians/politics and lack of political will to deal with successive conflict situations, with Weighted Mean Scores of 2.1191 and 1.9474, are further identified as causal factors by property owners/investors, although they rank 17th and 18th in terms of relevance/prominence in the study area.

In Kawo and Malali communities, Table 1 demonstrates that property owners/investors attribute the critical causes of ethno-religious conflict in the areas to illiteracy and ignorance of people, with Weighted Mean Scores of 4.1053 and 3.6250, respectively, ranking 1st. In addition, poverty and unemployment, and bad/poor religious teaching/preaching, with Weighted Mean Scores of 3.4107 and 3.6842, respectively, are also significant. In Malali, the table reveals that the least influencing causes are under-development in some areas, poor representation in governance, proliferation of small arms/ammunition, with Weighted Mean Scores of 2.2143, 2.6786, 2.1053, and 2.2143, respectively, across Kawo and Malali neighbourhoods.

To harmonize respondents' views in Kaduna North neighbourhoods, an overall mean score was calculated. It captures property owners/investors' perspectives on the causes of ethno-religious conflict across the five selected areas. Top causes include ethnicity and religious extremism, illiteracy and ignorance, feeling of marginalization/oppression and neglect by the government, religious intolerance, bad/poor religious teaching/preaching, majority/minority struggle, poverty and unemployment, family failures at children upbringing, colonialism-related problems, political grievances, social discord, and lack/poor implementation of recommendations. These causal factors are ranked 1st to 12th in the overall mean score, capturing the true situation across neighbourhoods.

Table 1: Causes of ethno-religious conflicts in the selected Kaduna North areas – Property Owners'/Investors' perspective

Causes of ethno-religious Conflicts	Kabala Doki		U Dosa		UShanu		Kawo		Malali		Overall	Rank
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	
Ethnicism	4.4033	1	3.5172	5	3.5263	2	3.5536	2	3.8421	2	3.768	1
Illiteracy of people	3.1768	11	3.9138	3	3.4211	3	3.6250	1	4.1053	1	3.648	2
Feeling of marginalization / Neglect by government	4.0000	4	3.7328	4	3.2105	5	3.3929	4	3.1053	10	3.488	3
Religious intolerance	4.0101	3	3.0431	13	3.5263	1	3.2500	7	3.5789	5	3.481	4
Bad/ poor Religious Teaching/Preaching	4.2265	2	2.6724	17	3.3158	4	3.3750	6	3.6842	3	3.454	5
Majority/minority people's struggle	3.7680	6	4.0517	1	2.8421	7	3.1607	9	3.2105	8	3.406	6
Unemployment	3.9282	5	3.5172	6	2.2105	16	3.4107	3	3.2632	7	3.265	7
Family failures at children upbringing	3.6409	7	3.0345	14	2.6842	9	3.3913	5	3.5263	6	3.255	8
Problems associated with colonialism	3.3149	10	3.2759	9	2.8947	6	2.8214	14	3.0000	12	3.061	9
Political grievances	2.7514	15	4.0345	2	2.4211	12	2.8036	15	3.1053	9	3.023	10
Social discord	3.4586	8	3.2845	8	2.4211	13	2.8571	13	2.8421	15	2.972	11
Lack/poor implementation of recommendations by successive Government panel	3.0884	13	3.2155	12	2.3158	15	3.1786	8	3.0526	11	2.970	12
Poor mass media Reportage of the conflicts	3.1160	12	3.3362	7	2.5263	10	2.7321	16	2.8947	13	2.921	13
Action of Politicians/ politics	2.7514	16	3.2586	10	2.1191	17	3.1071	10	2.8947	14	2.826	14
Under - development in some areas	2.1215	18	2.7241	16	2.5093	11	2.7143	17	3.6842	4	2.750	15
Proliferation of small arms/ammunition	2.8398	14	2.7845	15	2.7368	8	3.0893	11	2.1053	17	2.711	16
Lack of political will to deal with successive conflict situation	3.3260	9	2.6121	18	1.9474	18	3.0714	12	2.1053	16	2.612	17
Poor representation in governance	2.1271	17	3.2328	11	2.4051	14	2.6786	18	2.2143	18	2.531	18
Average Mean Score	**3.3361**		**3.2911**		**2.7241**		**3.1231**		**3.1111**		3.1195	

Causes of Ethno-religious Conflicts in the Selected Areas of Kaduna South

Also, the causes of ethno-religious conflict prevalence in Kaduna south neighbourhoods, was considered. Table 2 shows response received from respondent property owners/investors in the five (5) selected neighbourhoods of Kakuri, Tudun Wada, Badiko, Barnawa and Ungwar Sanusi in Kaduna South.

The Table 2 presents the top-ranked causes of ethno-religious conflict prevalence in the Kaduna South area from the perspective of property owners/investors. The highest-ranked factors identified are the feeling of marginalization/oppression and neglect by the government, with a Weighted Mean score of 3.824. This is followed by illiteracy and ignorance of people, with a Weighted Mean score of 3.751, and ethnicism with a Weighted Mean score of 3.711. The majority/minority struggle is ranked fourth, with a Weighted Mean score of 3.612, while religious intolerance is ranked fifth, with a Weighted Mean score of 3.561. Other significant factors include social discord (Weighted Mean score of 3.537), bad/poor religious teaching/preaching (Weighted Mean score of 3.507), family failures at children upbringing (Weighted Mean score of 3.502), lack/poor implementation of recommendations by successive government panels (Weighted Mean score of 3.459), and poverty and unemployment (Weighted Mean score of 3.431), respectively occupying the 6th to 10th positions. These factors provide insight into the main causes of ethno-religious conflicts in the area, as perceived by property owners and investors.

Additionally, the analysis extends to specific neighbourhoods within Kaduna South. In Tudun Wada, Badiko, and Ungwar Sanusi, respondents identified similar causal factors, including family failures at children upbringing (Weighted Mean score of 3.502), illiteracy and ignorance of people (Weighted Mean score of 3.751), feeling of marginalization/oppression and neglect by the government (Weighted Mean score of 3.824), ethnicism (Weighted Mean score of 3.711), majority/minority struggle (Weighted Mean score of 3.612), bad/poor religious teaching/preaching (Weighted Mean score of 3.507), social discord (Weighted Mean score of 3.537), poor mass media reportage of the conflicts (Weighted Mean score of 3.034), poverty and unemployment (Weighted Mean score of 3.431), and lack of political will to deal with successive conflict situations (Weighted Mean score of 3.319). These factors highlight the common underlying causes of ethno-religious conflicts across these specific areas.

Furthermore, in the Barnawa neighbourhood, the identified causal factors align with those identified in other areas of Kaduna South. However, additional key factors specific to Barnawa include the action of politicians/politics and problems associated with colonialism.

The overall mean score reveals the top-ranked causes of ethno-religious conflict prevalence across the selected areas in Kaduna South. These causes include the feeling of marginalization/oppression and neglect by the government (Weighted Mean Score of 3.824), illiteracy and ignorance (Weighted Mean score of 3.751), ethnicity (Weighted Mean Score of 3.711), majority/minority struggle (Weighted Mean Score of 3.612), religious intolerance (Weighted Mean Score of 3.561), social discord (Weighted Mean Score of 3.537), bad/poor religious teaching/preaching (Weighted Mean Score of 3.507), family failures at children upbringing (Weighted Mean Score of 3.502), lack/poor implementation of recommendations by successive government panels (Weighted Mean Score of 3.459), poverty and unemployment (Weighted Mean Score of 3.431), and lack of political will to deal with successive conflict situations and political grievances (Weighted Mean Score of 3.252). These factors are ranked from 1st to 12th based on the overall mean score, representing the comprehensive perception of respondents across the selected neighbourhoods.

Similar to the analysis conducted in Kaduna North, the examination of the overall mean of results from the selected areas in Kaduna South reveals that certain factors may be ranked 1st in one area, such as Kakuri, but rank lower in the overall ranking due to differences in respondent perceptions. The overall mean score provides a holistic representation of the true situation across the selected neighbourhoods by harmonizing the various views and rankings of the causal factors.

Table 2: Causes of ethno-religious conflict in the selected areas of Kaduna South - Property Owners'/Investors' Perspective

Causes of ethno-religious Conflicts	Kakuri		T/Wada		Badiko		Barnawa		U/Sanusi		Overall	Rank
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	
Feeling of marginalization/Neglect by government	4.8333	1	3.4615	3	3.8421	1	3.8571	6	3.1304	8	3.824	1
Illiteracy of people	3.8750	4	3.6538	2	3.5789	3	4.1905	1	3.2609	6	3.751	2
Ethnicism	3.6667	7	3.3846	4	3.8421	1	4.1429	2	3.5217	4	3.711	3
Majority/minority people's struggle	3.7917	6	3.3077	5	3.8421	1	4.0337	4	3.0870	9	3.612	4
Religious intolerance	3.8333	5	2.8217	13	3.8421	1	4.0476	3	3.2609	6	3.561	5
Social discord	3.3750	12	3.1154	7	3.1053	6	3.5714	10	4.5217	1	3.537	6
Bad/ poor Religious Teaching/Preaching	3.4583	9	3.1154	7	3.7368	2	4.0078	5	3.2174	7	3.507	7
Family failures at children upbringing	3.4167	10	4.8077	1	3.1053	5	3.6190	10	2.5652	15	3.502	8
Lack/poor implementation of recommendations by successive Government	3.5833	8	2.8063	15	3.1053	6	3.7143	9	4.0870	2	3.459	9
Unemployment	3.9167	3	2.9615	9	3.4737	4	3.7619	7	3.0414	10	3.431	10
Lack of political will to deal with successive conflict situation	3.4167	10	2.9231	10	3.4737	3	3.7619	8	3.0221	10	3.319	11
Political grievances	4.3750	2	2.7692	16	3.1579	5	3.0476	15	2.9130	12	3.252	12
Action of Politicians/ politics	3.3333	13	2.8071	14	3.3158	4	3.4286	12	2.7826	13	3.133	13
Problems associated with colonialism	2.6667	17	2.8462	11	3.6316	3	2.2857	18	3.9565	3	3.077	14
Poor mass media Reportage of the conflicts	3.0000	14	3.1923	6	3.0000	7	3.2857	13	2.6957	14	3.034	15
Proliferation of small arms/ammunition	2.9583	15	2.8462	11	2.7895	8	3.0952	14	2.5217	16	2.842	16
Under - development in some areas	2.8333	16	2.4615	18	2.5263	9	2.7619	17	2.3478	17	2.586	17
Poor representation in governance	2.4167	18	2.6154	17	2.5263	9	2.9048	16	2.3043	18	2.553	18
Average Mean Score	**3.4861**		**3.1053**		**3.3275**		**3.5288**		**3.1242**		3.314	

Agreement analysis on Perceived Causes of Ethno-religious Conflict at Kaduna North and Kaduna South

Agreement analysis was performed on the opinions gathered for the causes of conflict in Kaduna North and Kaduna South. The outcome of the agreement analysis shows the level of agreement or disagreement among the participants' opinions. To conduct agreement analysis on the mean scores of the responses from Kaduna North and Kaduna South, inter-rater reliability using the mean scores for each cause of conflict was conducted. One commonly used measure for agreement analysis is Cohen's kappa. However, Cohen's kappa requires categorical data, and since data for this analysis is continuous mean scores, intraclass correlation coefficient (ICC) was considered suitable to measure the difference. ICC is suitable for assessing the agreement between raters on continuous data. The ICC ranges between -1 and 1. A value close to 1 indicates high agreement between the mean scores of the two locations, while a value close to 0 suggests low agreement. The result is as shown in Table 3.

An examination of potential causes of ethno-religious conflict in Kaduna involved soliciting ratings from two distinct groups, specifically respondents from Kaduna North and Kaduna South, on 18 variables. The reliability of these ratings was assessed using the Intra-Class Correlation Coefficient (ICC) in SPSS version 27. The reliability analysis yielded a high Cronbach's Alpha coefficient of .903, indicating robust internal consistency among the variables. The ICC analysis produced noteworthy results. The Single Measures ICC, gauging agreement between any two randomly selected raters, demonstrated a substantial level of agreement with a value of 0.824 (95% CI: 0.589 to 0.930). The F-test, statistically significant at $F = 10.349$, $df1 = 17$, $df2 = 17$, $p < .001$, further supported the validity of this agreement. The Average Measures ICC, reflecting the agreement across multiple measures, exhibited an even higher level of agreement at 0.903 (95% CI: 0.742 to 0.964), with a statistically significant F-test ($F = 10.349$, $df1 = 17$, $df2 = 17$, $p < .001$).

Table 3: Reliability and Intraclass Correlation Coefficient (ICC) Analysis

	No. of Items	Cronbach's Alpha	Intraclass Correlation Coefficient	95% Confidence Interval	F Value	df1	df2	Sig
Reliability Statistics								
Cronbach's Alpha	2	.903						
Intraclass Correlation Coefficient								
Single Measures			.824	.589 to .930	10.349	17	17	.000
Average Measures			.903	.742 to .964	10.349	17	17	.000
Model			Two-way mixed effects					

Effect of the Ethno-religious Conflict of Property Development Decision

This section employs logistic regression analysis to examine the impact of the ethno-religious conflict on property owners'/investors'' decisions in Kaduna. The dependent variable is the investment decision, while the independent variables encompass various risks and issues arising from the repercussions of the ethno-religious conflict. By analysing these factors, a focused understanding emerges regarding how the conflict influences investment choices in residential property development. This investigation sheds light on the perceptual implications and ramifications of the conflict on residential development/investment decision-making processes.

Effect of the ethno-religious conflict of property development decision in Kaduna North areas

The Hosmer and Lemeshow test was performed to assess the goodness or fit of the logistic regression model. In this analysis, the test yielded a chi-square value of 10.725 with 8 degrees of freedom (df) at Step 1. The associated p-value was .218, indicating that the model did not significantly deviate from a good fit to the data. The logistic regression analysis as presented in Table 4 revealed that one variable, "Problems associated with occupancy ratio," reached statistical significance ($p = .049$). The positive coefficient ($B = 1.275$) suggests that an increase in problems associated with occupancy ratio is associated with a higher likelihood ($Exp(B) = 3.577$) of investors being willing to invest in residential properties. None of the other variables, including

"Challenges of attracting quality tenants/ occupants/ Buyers" (p = .793), were found to be statistically significant in predicting the willingness of investors to invest in residential properties.

Table 4: Effect of Ethno-religious Conflict on Property Investment Decision in Kaduna North

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Willingness of investors to invest in residential property: High tendency of losing property to violent attack during ethno-religious	-.125	1.190	.011	1	.916	.882
	Probability of property suffering void	.419	1.216	.119	1	.730	1.521
	Tendency of low return on investment (ROI)	.411	1.089	.143	1	.706	1.509
	Lack of willingness of financial institution to finance development in such areas	-.721	1.196	.363	1	.547	.486
	Increasing insecurity of life and properties	.612	1.115	.301	1	.583	1.844
	Low demand of property in some location	-.374	1.058	.125	1	.724	.688
	Cheap/ affordable land/ property/ mix	-.244	.593	.169	1	.681	.784
	Fall in rental income	-.615	.821	.561	1	.454	.541
	Change in tenant character	-1.199	.981	1.495	1	.221	.301
	Problems associated with occupancy ratio	1.275	.648	3.875	1	.049	3.577
	Maintenance related problem	-.161	.582	.077	1	.782	.851
	Challenges of disposal of property in such locations	-.471	1.128	.174	1	.676	.624
	Ease of disposal of property	-.724	.982	.544	1	.461	.485
	Challenges of attracting quality tenants/ occupants/ Buyers	.186	.709	.069	1	.793	1.205
	Constant	-4.083	.399	104.979	1	.000	.017

Effect of the ethno-religious conflict of property development decision in Kaduna South areas

The results of Logistic regression are presented here. The Hosmer and Lemeshow Test - a statistical test used to assess the goodness-of-fit of a logistic regression model indicates that the Chi-square value is 0.000, indicating that there is no significant difference between the observed frequencies and the predicted probabilities in Step 1 of the logistic regression model. The p-value (Sig.) is 1.000, which is greater than the conventional significance level of 0.05 suggesting that the logistic regression model provides a good fit to the data in terms of the investment decision variable.

From Table 5, the findings revealed that several variables significantly influenced the willingness of investors to develop properties in these conflict-prone areas. Specifically, factors such as the high tendency of property loss due to violent attacks during ethno-religious conflicts (B = -1.102, p < .001), the probability of property suffering void (B = -8.441, p < .001), and the lack of willingness of financial institutions to finance development in such areas (B = -3.392, p < .001) had a significant negative impact on the decision to invest.

Furthermore, variables related to the overall insecurity of life and properties (B = -1.816, p < .001), low demand for property in certain locations (B = 9.269, p < .001), and challenges associated with disposal and attracting quality tenants/occupants/buyers (B = -7.029, p < .001) also played significant roles in shaping investment decisions. Interestingly, factors such as the tendency of low return on investment (B = -0.775, p < .001), maintenance-related problems (B = -10.071, p < .001), and the affordability of land/property (B = -10.954, p < .001) were found to have significant negative associations with investment willingness.

Table 5: Effect of Ethno-religious Conflict on Property Investment Decision at Kaduna South

Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Willingness of investors to invest in residential property: High tendency of losing property to violent attack during ethno-religious	-1.102	5430.321	.000	1	1.000	.332
	Probability of property suffering void	-8.441	1725.510	.000	1	.996	.000
	Tendency of low return on investment (ROI)	-.775	5612.279	.000	1	1.000	.461
	Lack of willingness of financial institution to finance development in such areas	-3.392	5319.095	.000	1	.999	.034
	Increasing insecurity of life and properties	-1.816	6655.144	.000	1	1.000	.163
	Low demand of property in some location	9.269	4699.170	.000	1	.998	10603.586
	Cheap/ affordable land/ property/ mix	-10.954	1864.318	.000	1	.995	.000
	Fall in rental income	.260	1237.757	.000	1	1.000	1.297
	Change in tenant character	-8.899	1196.088	.000	1	.994	.000
	Problems associated with occupancy ratio	-3.303	3416.656	.000	1	.999	.037
	Maintenance related problem	-10.071	1225.317	.000	1	.993	.000
	Challenges of disposal of property in such locations	-1.263	3711.696	.000	1	1.000	.283
	Ease of disposal of property	-1.122	4075.946	.000	1	1.000	.326
	Challenges of attracting quality tenants/ occupants/ Buyers	-7.029	2779.911	.000	1	.998	.001
	Constant	-6.678	1.001	44.544	1	.000	.001

CONCLUSION

The study examined the causes of ethno-religious conflict in Kaduna, Nigeria and the effect of these conflict on the investors' willingness to develop residential properties in the crisis torn areas. Based on the findings of the study, it can be concluded that ethno-religious conflict has a significant impact on property development decisions in Kaduna, Nigeria. The analysis revealed varying effects of the conflict on investment decisions in different regions, highlighting the complexity of the issue. In Kaduna North, problems associated with occupancy ratio were found to negatively influence investors' willingness to develop residential properties. On the other hand, in Kaduna South, several factors such as property loss, financial institution reluctance, overall insecurity, low property demand, and challenges in disposal and attracting quality tenants/occupants/buyers negatively influenced residential property development decisions. These findings have important implications for policymakers and stakeholders involved in promoting sustainable residential property development and peace building in conflict-affected areas. Some of the implications include low level of residential property development activities in such areas, clot/high number of voids in finished properties, demotivation of existing/potential investors in residential property development projects.

Based on the study's findings, it is recommended that:

i. The security measures in conflict – affected areas should be strengthened as a matter of priority. This may involve deploying adequate security forces, implementing community-based security initiatives, fostering inter - ethnic and inter - religious dialogue to mitigate the risks associated with property development.

ii. Access to financing should be improved by encouraging financial institutions to provide financing options for property development in conflict - affected regions. This can be achieved through the establishment of specialized loan programmes, risk-sharing mechanisms, and partnerships between financial institutions and local communities.

iii. Efforts should be made to promote peace building Initiatives through collaborative peace

building efforts to address the root causes of ethno-religious conflict. These initiatives should focus on promoting social cohesion, fostering trust among communities, and facilitating reconciliation processes to create an enabling environment for property development.

iv. Capacity building and technical assistance should be provided to stakeholders by providing training programmes, workshops and technical assistance to property developers, investors, and local authorities with a view to enhance their capacity to navigate the challenges associated with property development in conflict-affected areas.

By implementing these recommendations, policymakers and stakeholders can foster a conducive environment for property development, attract investment, and contribute to the overall socio-economic development and peace building process in Kaduna, Nigeria.

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Assessing the Chemical Durability of Textured Glass-Coat for Building Application

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The need to assess the chemical properties of coats produced for building applications is of essence, especially in an acidic or alkaline environment. To determine this property, this study investigates the reactions of textured Glass-coat to chemicals. Samples of textured glass-coat developed from Post Consumer Glass (PCG) were subjected to Adhesion test (ASTM D3359), pH test (ASTM D5464), Chemical resistance test (ASTM D3260 and D1308), and Abrasion test (ASTM D4060). Results show an adhesion of 4A and a pH of 8.50 respectively. The chemical resistance result shows the following: A 5% flick rate was observed when reacted with Sodium hydroxide (NaOH) solution; decolouration with the following solutions was observed: Magnesium hydroxide ($Mg(OH)_2$) 3% decolouration, Hydrogen Fluoride (HF) 5% decolouration , Potassium hydroxide (KOH) 7% decolouration and NaOH10% decolouration was observed. Also, the analysis show that the coat exhibits 0.2g abrasion rate. The results from the analysis confirm that the developed textured glass-coat is in line with the pH standard which ranged from 8–9 (ASTM D5464), significant resistant to acid and base solutions were observed except for HF, NaOH, KOH and $Mg(OH)_2$ where a negligible flick rate and colouration defects was observed. Also, based on the result, an excellent adhesion and abrasion properties was established. Finding shows that the developed Glass-coat exhibits excellent resistant to chemical degradation especially in an acidic situation and it is recommended as a suitable engineering material for building applications.
Keywords: Glass-coat, PCG**,** Chemical durability, Building application

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INTRODUCTION

Chemical tolerance is one of the basic factors considered during material development whose effects account for the acceptability and applicability of the material as such, material producers considered these factors during production (Macko *et al.,* 2018). Coatings, or coats, are materials whose applications cut across most fields of endeavour due to its unique properties which is beyond aesthetic (Kc *et al.,* 2017). These materials vary in type depending on their areas of application and consumer choice, as such, they range from acrylic, alkyds, epoxy, and polyurethane, and based on their texture, i.e., emulsion, oil-based coating, and textured coating, to mention but a few (Liu *et al.,* 2019). Texture coating is a type of decorative and protective coating that adds texture and visual appeal to various surfaces. It is composed of aggregates such as sand, talc, glass cullet, stone, or polymer particles mixed with a binding agent (Advameg, 2014; Adejo, 2022). This mixture is applied to surfaces such as walls, ceilings, or furniture to create a textured finish with unique aesthetics and improved surface durability. A glass coating is a type of texture coating that contains post-consumer glass as a texturizing agent in the presence of a binding agent to create a durable and visually appealing surface (Soltani-Kordshuli *et al.,* 2023). The use of textured coatings, such as glass-coat, provides both aesthetic appeal and enhanced durability for surfaces such as walls, ceilings, and exteriors.

The effect of chemicals on the coating is a factor that should be carefully considered, as certain chemicals, especially in the areas of application, have the tendency to damage or degrade the coating (Mai *et al.,* 2020). Since the quest for urbanization continues to be on the rise, this has directly affected the demand for buildings for habitation and for other purposes, as the need for durable coatings for building finishes is also required. Over the years, coating industries have been developing, while technology continues to play a significant role in this development. None the less, this material has faced diverse forms of challenges and deterioration, ranging from chalking, crazing, blistering, peeling, loss of colouration, flaking, and other forms of degradation that can be traced to defects in its optical, microbial, mechanical, chemical or physical properties (Jirouš-Rajković & Miklečić, 2021).

According to Special-Chem (2023), coating on the surface of a substrate works mainly as a protector from external defects such as strains, interactions, or a harsh environment that can occur naturally or induced by man's activities. However, the coat becomes subjected to degradation when in contact with chemicals mostly during cleaning and it results in different forms of degradation ranging from crazing to flicking, to mention

but a few. Also, the effect of chemical attacks on coatings can further lead to swelling, discoloration, adhesion loss, gloss reduction, and blistering, which mostly result in deterioration of performance and eventual failure under certain conditions. As such, it is important to study the behaviour of this material with respect to its interactions with chemicals.

The importance of coatings on the surface of any material is a phenomenon. In this light, Bibi *et al.* (2015) observed that even structures built with the best of concrete are prone to developing durability problems, which are mostly the result of the deterioration of concrete when exposed to harsh environmental conditions. As such, in order to mitigate the onslaught of concrete, protective coatings with chemical resistance are required. Also, in the studies of Noor *et al.* (2012), Mirza *et al.* (2013) and Bhutta *et al.* (2023), it is revealed that regardless of the composition of concrete, without coating it is prone to deterioration, which in most instances is chemically induced due to the ingress of chemicals such as chloride, sulfate, and ammonium ions and carbonation stress leading to the alkali-silica reaction of the concrete.

In order to address the aforementioned challenges and ensure the longevity and performance of the textured-building glass-coat, it is important to evaluate the chemical compatibility of the coating with a view to assessing its tolerance and durability level without compromising the coating's integrity.

RESEARCH METHODOLOGY

The methodology of this study will evaluate some mechanical (Abrasion and Adhesion test) and chemical (pH test, Acidity and Alkalinity test) properties and the ASTM standard techniques will be adopted. Adhesion test was conducted on the produced glass-coat according to ASTM D3359 (2017), in order to determine its binding ability to the substrate. The standard tape test method A was adopted since the coat film thickness is greater than 125mm. Samples of the produced glass-coat were applied to a flat metal sheet so that it was freed from blemishes and minor surface imperfections, then allowed to dry at room temperature. The plate was placed on a firm base, in a steady motion, and the dried glass-coat was cut through using a clean sharp straightedge cutting knife. The glass-coat was cut into two at a length of 40mm making an intersect in the middle with a small angle range of 30^o and 45^o to make an X inscription, so as to make the metal sheet visible. Using a standard masking tape of 2.5mm in width, two revolutions of the tape were cut off from its roll, and 75mm of the tape was cut and placed on the centre of the intersection of the cut glass-coated plate such that it ran in the direction of the smaller angle. It was smoothed using a finger in the area of the incisions so that entrapped air was removed, and the tape was rubbed firmly with some pressure until the colour appeared uniformly on the coated surface. Seizing the free end of the tape, it was pulled off rapidly backward at an angle of 180° after every 60 seconds of application. This test was carried out three times, respectively, on the produced coat and the result presented.

This study was conducted to determine the acidity or alkalinity of the produced glass coat. A sample of the produced glass-coat was collected and subjected to pH testing in accordance with the ASTM D5464 (2011) standard. The pH meter was turned on, calibrated in a buffer solution, and the tip of the electrode was inserted into a container containing the produced glass coat. Readings were taken and recorded accordingly.

A chemical resistance test of the coat was conducted to determine the reaction of the glass-coat with household chemicals, *u*sing the standard test method for the effect of household chemicals on clear and pigmented coating systems as ascertained by ASTM D3260 (2017) for acid resistance and ASTM D1308 (2013) for alkali resistance on the coat. To carry out this analysis, a sample of the produced glass-coat was applied to a flat plate measuring 50mm by 120mm and allowed to dry at room temperature. The plate was coated by the edge with paraffin and bee wax in a mix ratio of 1:2 in order to avoid the edge sipping of the acidic solution into the coat. The acid resistance procedure was conducted by immersing the dry coat in a 10% concentration of acidic solution, i.e., HF, HCl, H_2SO_4, and NHO_3 respectively at an ambient temperature of 25^{o}C for 6 hr. The coated plate was rinsed, dried, and examined for defects such as blistering, peeling, lifting, crazing, flaking, and discoloration.

In determining the glass-coat reactions to alkaline chemicals, the same procedure used for acidic analysis was adopted.

Sample of the produced glass-coat was applied to a flat plate measuring 50mm by 120mm and allowed to dry at room temperature. The plate coated with glass-coat was coated by the edge with paraffin and bee wax in a mix ratio of 1:2 in order to avoid edge sipping of the alkaline solution into the coated plate. The coated plate was immersed in a 10 % concentration of an alkaline solution of KOH, NaOH, CaOH, and MgOH, respectively, at ambient temperature of 25^{o}C for 6 hours. The coated plate was rinsed, dried, and examined for defects such as blistering, peeling, lifting, crazing, flaking, and discoloration.

In order to determine the aggregate flick rate of the coating after exposure to an acidic and alkaline solution, a standard abrasion resistance test for coatings was conducted using ASTM D4060-19. In doing this, a sample of the produced glass-coat was applied uniformly to a plate, it was allowed to dry hard at room temperature, and the weight of the coated plate was determined using a Mettler balance. Using a Taber

abraser of a known weight of 3.5 kg, the coated plate was kept in a rigid position, and the abraser was used to make a 60-cycle rotation on the sample, after which the weight of the coated plate after abrasion was determined. The abrasion rate was determined using the formula below.

$$Z = x_1 - x_2 \quad \text{ASTM D4060 (2019)}$$

Where:

Z=Abrasion Rate

X_1 =Weight of coated plate before the test

X_2 =Weight of coated plate after the test

RESULTS AND DISCUSSION

Adhesion Test

The result of the Adhesion test on produced Glass-coat (Table 1) shows the binding ability of the coat to surfaces, the study established that the developed Glass-coat exhibits a 4A binding ability. This implies that less than 5% flick rate of coarse aggregates will be noticed and that the produced Glass-coat exhibit a very good binding ability to surfaces, and conforming with the ASTM Adhesion scale (5A=0% flick rate, 4A=less than 5% flick rate, 3A=5-15% flick rate, 2A=15-35% flick rate, 1A=35-65% flick rate and 0A= Grater that 65% flick rate) (Dilik *et al.,* 2015) and (ASTM D3359, 2017) as compared to conventional coating whose adhesion value is mostly below 3A classification.

Table 1: Adhesion test on produced glass-coat

S/N	Glass-coat colour	Classification	% of Removed area
1	Yellow	4A	Less than 5%
2	Red	4A	Less than 5%
3	Blue	4A	Less than 5%
4	Black	4A	Less than 5%

pH Test

The result in Table 2 shows the pH analysis of the produced glass coat. This analysis was conducted to investigate the behaviour of the material, viz., its acidity and alkalinity. The result demonstrated that the developed glass coating was alkaline in nature, despite the variation in the pH values, which might be influenced by the colorants or vice versa. The study was able to identify that the glass-coat of yellow glass-coat coloration has the highest pH value of 8.62 and the blue glass-coat coloration has the lowest pH value of 8.30, though this might make the coating prone to some level of degradation that is highly negligible in the long run. In comparison with other study such as Ogu *et al*, (2016), CropLife (2018) and Ndibe *et al*. (2021), the developed coat pH value falls within the acceptable standard of 7.0–9.0 pH thereby making it durable for application in buildings.

Table 2: pH test on produced glass-coat

Coat colour	Yellow	Blue	Red	Black
pH value	8.62	8.30	8.42	8.50

Chemical Resistance Test

The results of the analysis in Table 3 show the behaviour of the produced glass-coat and its resistance to acidic and alkaline conditions when applied to building surfaces. The results show that the developed glass-coat generally exhibits resistance to chemical attack based on its general percentage behaviour to the acidic and alkaline solution and the investigated defects i.e., blistering, peeling, lifting, crazing, flaking, and discoloration (Akinterinwa *et al*., 2015). However, some chemical alkaline solutions such as sodium hydroxide (NaOH), magnesium hydroxide (Mg(OH)2), potassium hydroxide, and an acidic solution of hydrofluoric (HF) acid had some effect on the glass coating. The effects range from flaking and discoloration to a defect rate of not more than 10%. It was also observed that there was a slight reduction in the weight of the coating on reaction with NaOH. As such, the polymeric component of the coating is slightly prone to degradation when exposed to NaOH solutions or environments (Ndibe *et al*., 2021).

Table 3: Results of acid and alkali resistance tests on produced glass-coat

Chemical	Blistering %	Peeling %	Lifting %	Crazing %	Flaking %	Discoloration %
			Acid			
HF	0	0	0	0	0	5
HCl	0	0	0	0	0	0
H_2SO_4	0	0	0	0	0	0
HHO_3	0	0	0	0	0	0
			Alkali			
KOH	0	0	0	0	0	7
NaOH	0	0	0	0	5	10
$Ca(OH)_2$	0	0	0	0	0	0
$Mg(OH)_2$	0	0	0	0	0	3

Abrasion Test

The result in Table 4 shows the abrasion rate of the developed glass coating on application to the substrate. This analysis is needed for this study so as to ascertain the level of degradation caused by exposure to acidic and alkaline conditions, considering its composition (largely composed of coarse aggregate) and type of developed coat (textured coat). This analysis was able to establish that the developed coat is prone to abrasion. However, the coating under a load of 3.5 kg in 60 cycles manifests an abrasion rate of 0.2 g, irrespective of the coat's colour, with negligible physical damage to the surface of the coat. In comparison with the standard (4g ± 0.5g), it was observed that there is a weak chemical attack on the coat such that it was unable to degrade the coating by abrasion leading to a negligible abrasion rate when compared to the standard abrasion rate of 4 ± 0.5g as approved by *ASTM D4060* (2019).

Table 4: Abrasion test of the produced glass-coat

Coat type	Weight of coated plate before test (g)	Weight of coated plate after test (g)	Abrasion rate (g)
Black	54.30	54.10	**0.20**
Red	54.30	54.10	**0.20**
Blue	54.30	54.10	**0.20**
Yellow	54.30	54.10	**0.20**

CONCLUSION

In conclusion, the study established that the developed glass-coat has a 4A adhesion rate, a pH range (8.30 - 8.62), a negligible chemical degradation rate (3-10%), and an abrasion rate (0.2g) that conforms to standard (ASTM D3359), (ASTM D5464), (ASTM D4060 ASTM D3260 and ASTM D1308). Findings shows that the developed glass-coat exhibits an excellent pH and a 4A adhesion rate which confirmed the negligible abrasion rate and the weak chemical degradation that is not above 10% regardless of the nature of the chemical solution (acidic or base). Owing to the analysis conducted, this study recommends that the glass-coat developed from recycled PCG is suitable for interior and exterior application most especially in environment that is pose to chemical degradation.

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Curtailing the Environmental Impact of Waste Plastics through Re-use for Sustainable Paving Stone Manufacture in Kinshasa City

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In Kinshasa, attacks on the environment and human well-being continue to increase with the accumulation of thermoplastic waste (LDPE, HDPE and PET) mainly produced. Collected in unsanitary landfills, this waste pollutes the environment with all the consequences on health. This study makes it possible to reduce the socio-environmental impacts of thermoplastic waste by reusing them for the manufacture of paving stones for the sanitation of Kinshasa. Specifically, it initiates the collection of thermoplastic waste, recycling techniques for the production of paving stones and raising awareness among Citizens and Decision-Makers of the importance of their management. Thus, a survey questionnaire was administered to a sample of 1276 households. The proportions of materials used to obtain the resistant paving stones are: 60% fine sand, 35% LDPE and HDPE and 5% PET. Melted at 200°C, the thermoplastics are mixed with sand until a homogeneous paste is obtained to be poured into moulds prearranged on a metal table. The consolidated pavers are removed from the mould after 45 minutes using a hammer. The results obtained show that 4% of households manage their waste better and that 96% contribute to plastic pollution. 87.1% of households denounce the harmful effects of thermoplastics on the environment and point out the clogging of gutters (28.4%), the pollution of space (25%) and the pollution of rivers (16.5%). Twenty-two pavers with an average weight of 1953.33 ± 6.22 gr are manufactured. The weight loss of the materials is 14.2% (7.1 kg). The compressive strength of the pavers is 32.74 ± 0.94 N/mm². In short, reducing the socio-environmental impacts of thermoplastic waste in Kinshasa is complex and requires a multidimensional approach with the efforts of all stakeholders.

Keywords: Kinshasa, impacts, waste, thermoplastics, pollution, sanitation, paving stones

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INTRODUCTION

Over the last four decades, the city of Kinshasa has experienced a demographic surge resulting from the rural exodus and displaced people fleeing the war in the east of the country (OCHA, 2022; Ngoie and Lelu, 2009). This increase in population is not without consequences on the living environment which is mainly occupied by spontaneous neighbourhoods (Kibala, 2020) and therefore the production of solid household waste is enormous, and their management poses great difficulties. Indeed, nowadays, out of the estimated 10,000 tonnes of solid household waste generated per day in Kinshasa, thermoplastic waste represents 15% (Holenu *et al*., 2020). Studies conducted by Weya *et al*. (2013) showed that without a real destination, this thermoplastic waste used as packaging and thrown away without standards or control in micro-ecosystems, pollutes the soil (such as in a certain place in the city in the commune of Lingwala, the layer of thermoplastics buried under the ground reached a depth of 2 meters as shown in Figure 1) and waterways, harm biodiversity, contribute to climate change and pose public health problems.

This production is extremely dangerous when we know that it takes at least 100 years for a thermoplastic to completely degrade (Kassay, 2015). De Bock *et al*. (2020) noted that, of the three main classes of plastics (thermosets, elastomers and thermoplastics), the last class with low density polyethylene (LDPE), high density polyethylene (HDPE) and polyethylene terephthalates (PET) is the one that combines the properties of recyclability and does not pose the major problem of incompatibility when they are mixed for the production of other plastic or semi-plastic materials such as paving stones. Despite this recycling potential, the revaluation of thermoplastic waste for the manufacture of paving stones is not yet well applied in Kinshasa (Epusaka, 2019) due to the absence of waste collection and recycling infrastructure in this city, lack of awareness of the importance of recycling thermoplastic waste, difficulties in sorting waste according to their composition and quality, lack of precision on the types of plastic waste to be recycled between thermoplastics, thermosets and elastomers, lack of partnership between public, private and academic actors to promote cooperation and synergy in this area and the lack of definition of the formula leading to the determination of the proportions of materials for the production of paving stones with better resistance to simple compression.

This study therefore, seeks to understand how thermoplastic waste can be efficiently collected, sorted and recycled to produce paving stones with better compressive strength values. It also aims to raise awareness among citizens and decision-makers of the importance of thermoplastic waste management and to promote the adoption of environmentally and health-friendly recycling practices. Finally, it seeks to evaluate the socio-environmental impacts of this waste, in order to present the advantages of this approach which demonstrates that in Kinshasa, thermoplastic waste which causes serious pollution and health problems are raw materials that are potentially recyclable for the production of other plastic materials with a high compressive strength value, such as paving stones (32.74 ± 0.94 N/mm²).

Figure 1. View of a 2 m profile of the ground occupied by thermoplastic waste in Kinshasa/Lingwala

MATERIALS AND METHODS

Four neighbourhoods were selected. The choice of municipalities was made based on their average which is 6 municipalities. Taking into account the fact that the districts of Mont-Amba and Tshangu only have 5 communes, we selected 4 communes per district with a view to subjecting all the districts to the same exercise. An exception for the Tshangu district of which 3 urban communes (Kimbanseke, Masina and N'djili) were retained while excluding the 2 rural communes (Maluku and N'sele) whose extent of plastic pollution is not accentuated. For the choice of neighbourhoods, one neighbourhood per municipality was selected, with the exception of the municipalities of Masina and Kimbanseke where 2 neighbourhoods were selected per municipality given the extent of poor waste management collected. This gives a total of 17 sample neighbourhoods for the entire city. The selection of neighbourhoods was done randomly by drawing lots and the surveys were carried out using a survey questionnaire administered to 1276 households according to Table 1 and the counting was carried out using statistical computer software: Epi-info, Epi-data, Stata 12 and Excel.

The size and choice of households to be surveyed followed the following approach:

Sample size of households at the municipal and neighbourhood level

Sample size at the municipal level

When the total number of households (population) is greater than 10000

$$n = \frac{z^2 dpq}{\alpha^2} \quad (1)$$ (Ngondo, 2001; Andrew & Coll, 1983)

With: n = The desired sample size when the number of households (population) is greater than 10000 households;

z: The difference generally set at 1.96 (or more simply at 2.0) which corresponds to a confidence level of 95%;

d: Correlative factor whose value is equal to 1;

$p = \frac{pc}{pt}$ (2) $\frac{(\text{Target population})}{(\text{Total population})}$ (Andrew & Coll, 1983): proportion of target households (population) having a given characteristic. If no estimate exists, we can use 50% or 0.50. With p = 0.50; the value of n (sample size) is significant at a confidence level (Z) of 95%;

q = 1,0 – p : is the difference in population proportions;

α = desired degree of precision, usually 0.05 or sometimes 0.01 to increase precision.

When the total number of households (population) is less than 10000

$$nt = \frac{n}{1+\frac{n}{N}} \quad (3)$$ (Rau, 2017; Crépon & Latif, 2017) ;

nt = the desired sample size (when the population size is less than 10,000 households (individuals);

$n = \frac{z^2 dpq}{\alpha^2}$;

N = household size (population) less than 10000 individuals.

Sample size at neighbourhood level

$n_x = \frac{n.n1}{N}$ (4) (Andrew & Coll, 1983)

With: n_x = number of sample households per neighbourhood ;

n_1 = number of residential households per neighbourhood;

n = total number of sample households for the municipality (found using the two formulas (N > or < 10000 households;

N = number of residential plots (households) in the municipality of the district concerned.

Interval (I) or "no survey" or even "reason"

To give all households (plots) the chance to be surveyed, stratification was used by calculating the interval I.

$I = \frac{ni}{nf}$ (5) (Kiye, 1997)

With : ni = number of residential plots per district;

nf = total sample of households to be surveyed;

I = interval between two households (plots) to be surveyed.

In order to ensure good representation of the sample, the plot was retained as the sampling unit, the household was used as the unit of analysis (survey); in this case, only one household was considered per plot. This process is scientifically authorized within the framework of priority investigations in a given population (Grotoiert & Marchout, 1992; Verma, 2009). Thus, the municipalities and neighbourhoods selected, the number of households per municipality and per neighbourhood, the size of the sample per municipality and per neighbourhood, the proportion (%) retained, the size of the sample retained per neighbourhood and the stratification by interval are presented in Table 1.

Table 1: Sample size at the level of: municipality (N) and neighbourhood (nx) and interval (I)

Districts	Number of municipalities selected (15)	Number of districts selected (17)	Number of plots by		Size of the sample by		Percentage (%) retained	Retained sample size per neighbourhood (nx) sd	Interval (I)
			Municipality	Neighbourhood	Municipality (n, nt)	Neighbourhood (nx)			
Funa	1. Selembao	1. Nfafani	48111	1134	10.000	236	20%	47 ≈ 50	23
	2. Ngiri-ngiri	2. 24 Novembre	5286	593	3458	388	15%	58 ≈ 60	10
	3. Makala	3. Mfidi	24087	757	10.000	314	10%	31 ≈50	15
	4. Bandalungwa	4. Lingwala	22184	3420	10.000	1542	5%	77 ≈ 80	43
	5. Ngaliema	5. Joli-Parc	67887	2595	10.000	382	20%	73	36
Lukunga	6. Gombe	6. Gare	48019	1084	10.000	226	15%	41 ≈40	27
	7. Mont-Ngafula	7. Kindele	82077	3243	10.000	395	20%	79	41
	8. Kinshasa	8. Mongala	4257	690	2986	484	17%	81	9
Mont-Amba	9. Matete	9. Totaka	12027	1554	10.000	1292	10%	129	12
	10. Limete	10. Industriel	21899	3370	10.000	1539	5%	76 ≈ 80	42
	11. Ngaba	11. Bula-Mbemba	18022	1639	10.000	1640	10%	164	10
	12. Lemba	12. Mbanza-Lemba	21761	2885	10.000	1326	5%	66 ≈ 70	41
	13. N'djili	13. 8/Ubangi	34551	5749	10.000	1664	10%	166	35
Tshangu	14. Masina	14. 3-Congo	64.373	3476	10.000	540	10%	54	64
		15. Imbali/Petro-C.	64.373	7081	10.000	1100	10%	110	64
	15. Kimbanseke	16. Kingasani1(ya suka)	96222	3268	10.000	339	15%	51 ≈ 50	65
		17. Maviokele	96222	2447	10.000	254	50%	127 ≈ 120	20
		Total			6444	13661	-	1276	-

Recycling Process of Thermoplastics for the Manufacture of Paving Stones

The materials (thermoplastic waste (LDPE, HDPE and PET) and fine sand) proportioned by a Saco brand scale with a maximum weight of 200kg were mixed in a metal tank heated with the charcoal which was fanned by an electric blower. The homogeneous paste obtained after melting at 200°C, the thermoplastics mixed with fine sand using a casting ladle was poured into moulds lubricated with engine drain oils (SAE 40) and placed on a table metal serving as a support. After cooling, the pavers were removed from the mould using a plastic hammer. The proportions of materials used are those predefined by previous studies carried out by Weya *et al*. (2013) which gives the best resistance value, 60% (i.e. 30 kg) of fine sand, 35% (i.e. 17.5 kg) of LDPE and HDPE and 5% (i.e. 2.5 kg) of PET.

Compressive strength test of paving stones

The compressive strength test of the paving stones was carried out at the National Public Works Laboratory/Research and Development Directorate of the Roads Office located at No. 482 Avenue de la Science in Kinshasa/Gombe using the Dreux method. It consists of sizing the block, weighing it, determining its density, compressing it, observing its reaction from the start of its compression until rupture and reading the maximum load observed at rupture in the pressure gauge of the block.

RESULTS AND DISCUSSION

Impacts of Thermoplastic Waste on the Environment and Health

According to the results presented in Tables 2 and 3 and Figure 4 which respectively deal with the aspects relating to the use or not of plastics, the socio-environmental impacts of thermoplastic waste in the city of Kinshasa and the future of thermoplastics post-use, it is observed that 93.2% of households compared to 6.8% use thermoplastics, of which 41.2% represent the large proportion of those who use them for packaging. They are followed by those who use it to buy food (i.e. 28.7%), sales (i.e. 16%), domestic use (10.2%) and lighting a fire (4%). According to the impacts, it shows that 87.1% of the households questioned recognize the harmful effects of thermoplastic waste on the environment and health: this concerns clogging of gutters (28.4%), space pollution. urban (25%), the birth of disease vectors (36.2%), followed by bad odours (33%), the tasting of sachets by herbivores (goats and cattle) leading to their death (20.8%) and pollution of the aquatic living environment (10.1%). The future of post-consumer waste shows that 4% of households made up of sale (1%), recovery (1%) and reuse (2%) recycle thermoplastic waste and therefore, 96% contribute to plastic pollution.

Indeed, majority of households (93.2%) use thermoplastics, while there is only a small proportion (4%) of households which recycle their waste thermoplastics. This means that 96% of households contribute to plastic pollution due to the absence of "urban culture" linked to bad habits rooted in the culture of "everything is ready to throw away, everything down the drain, in spaces public or in waterways", the lack of initiative for the recovery of waste and the absence of an urban sanitation service thus constituting a serious waste management problem in the city of Kinshasa (Vuni *et al*., 2020). This is why a majority of households (87.1%) recognize that thermoplastic waste has negative impacts on the micro-ecosystems of Kinshasa and on public health. These observations are also made by UEMOA (2013) which found that in the majority of cities in developing countries, there are multiple attacks on the environment and human life due to the absence of urban culture and the lack of importance given to waste, always considered as utilities or negative externalities.

Table 2: Distribution of respondents according to whether or not they use plastics

Variable	Modality	Absolute frequency	Relative frequency
Do you use thermoplastics?	Yes	1189	93,2
	No	87	6,8
	Total	**1276**	**100,0**
If yes? for what use?	Packing	490	41.2
	Sale	190	16.0
	Domestic use	121	10.2
	Purchage food	341	28.7
	Fire lighting	47	4.0
	Total	**1189**	**100.0**
If not, why?	Not important	16	18.4
	Prohibited use	32	36.8
	Make the city dirty	33	37.9
	Damages the ground	6	6.9
	Total	**87**	**100.0**

Table 3: Distribution of respondents according to the impacts of thermoplastic waste in the Kinshasa environment and on life (health)

Variable	Modality	absolute fréqu.	relative fréqu.
In your opinion, does thermoplastic waste cause harm to the environment and to life (health)?	Yes	1112	87.1
	No	164	12.9
	Total	**1276**	**100.0**
If yes, which ones in the environment?	Blockage of gutters	316	28.4
	Pollution of urban space	278	25
	Water impermeability in the ground	153	13.8
	Floods	109	9.8
	River pollution	184	16.5
	Atmospheric pollution	72	6.5
	Total	**1112**	**100.0**
If yes, which ones affect life (health) ? é	Birth of disease vectors	402	36.2
	Creation of bad odours	367	33.0
	Harm to aquatic life	112	10.1
	Attack on herbivorous life	231	20.8
	Total	1112	100.0

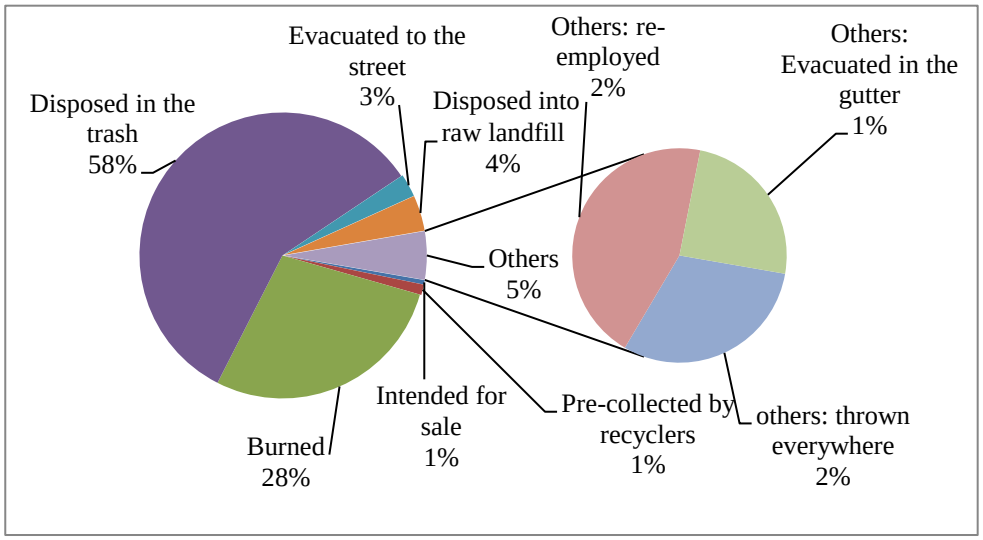

Figure 4. Distribution of respondents according to the fate of post-use thermoplastics

Recycling of Thermoplastics (pavers manufacturing)

Table 4 shows that the mixture of 17.5 kg of sachets, 2.5 kg of bottles and 30 kg of fine sand produced a fairly heavy homogeneous black paste after 95 minutes of mixing. 22 consolidated paving stones measuring 240 mm in diameter and 5 cm thick were manufactured. Of the 42.97 kg total weight of the 22 pavers, the average weight of the pavers is 1.95 kg and the weight loss of the materials is equal to 14.2% (i.e. 7.1 kg).

It was noted for the manufacture of the paving stones that it took 95 minutes to homogenize the mixture of bags, bottles and sand. This time, greater than that of the experiments of Indjeku (2017) which only used bags mixed with fine sand (i.e. 65 minutes), is a function of the difference in the melting temperature of each type of thermoplastic and their chemical composition (Glotin, 2021).

These two factors (melting temperature and chemical composition) influence the homogenization time of the paste and the cooling of the paving stones (Racine, 2009). The above is corroborated by the observations of Sadoun (2018) who indicated that temperature influences the degree of melting of plastics. This is the reason why Levesque (2002) states that thermoplastics (polyethylene, polypropene, polyvinyl chloride and polystyrene), made up of linear or branched polymers, melt by simple heating, while Lakhdar (2015) emphasised that the range of melting temperature of 100 to 200 °C of plastics depends on the physical and chemical composition; a property also used for their formatting.

The difference test was carried out to find out whether or not there is a significant difference between the average weight of the pavers resulting from the mixture: LDPE, HDPE, PET and fine sand (i.e., 1953.33 ± 6.22 gr) and those paving stones resulting from the simple mixture of LDPE and fine sand (i.e., 1872 ± 4.51 gr) found by Indjeku (2017). It implies that at the threshold of $\alpha = 5\%$, with standard deviations of 3.02 and 3.46 respectively, the critical value read in the student table at 21 dof is $t\alpha = 2.08$ and tc (calculated) = 0.21. As $tc < t\alpha$, the null hypothesis is accepted.

This means that there is no significant statistical difference between the average weight of two types of paving stones and two types of materials used; therefore, the mixture resulting from the use of different types of thermoplastics for the manufacture of paving stones does not influence the weight of the different types of paving stones, since it depends on the amount of homogeneous paste contained in the moulds (Rasoatahinjanahary, 2014), although mixing simple sachets with fine sand homogenizes quickly.

The pavers resulting from the mixture of sachets, bottles and fine sand gave an average resistance of 32.74 ± 0.94 (≈ 33) N/mm² greater than that of the pavers resulting from the mixture of sachets with fine sand (i.e. 24 N/mm²) found by Indjeku (2017). It means that, whatever the composition of the two types of mixtures, the resistance values are higher, compared to other materials used for the manufacture of paving stones (see table 6), simply because the thermoplastics are endowed properties of being good for recycling and having better resistance to compression, due to their very high density (Aucher, 2011). They also have other properties including good resistance to acids, bases and solvents (St-Charles, 2015).

Table 4: Aspect relating to the manufacture of paving stones

Variables	Values
Quantity of bag (LDPE and HDPE): 35% (in kg)	17.5
Quantity of bottles (PET): 5% (in kg)	2.5
Quantity of fine sand: 60% (in kg)	30
Homogenization time for bags + bottles + sand (in minutes)	95
Quality of the paste (bags + sand)	Black, quite heavy
Number of pavers produced	22
Diameter of a paver (in mm)	240
Thickness of a paving stone (in cm)	5
Total weight (in kg)	42.97
Average weight of a paving stone (in kg)	1.95
Weight loss of materials (in kg)	7.1 (i.e., 14.2%)

Resistance Test by Compression of the Paving Stones

It was observed that at an average of 4 minutes of compression, the blocks which have 1125 cm^3 of average volume, 1953.33 ± 6.22 gr of average weight, 1.74 ± 0.14 of average density, 225 cm² of surface average total compressed stress and 73666.67 ± 161.56 kg average total breaking load gave 327.4 ± 1.73 kg/cm² average total stress at break and therefore an average compressive strength of 32.74 ± 0.94 (≈ 33) N/mm².

Table 5: Aspects relating to paving stone strength testing (high and low density)

Variables	Average per block
Average volume (in cm^3)	1125
Average weight (in gr)	1953.33 ± 6.22
Average medium density	1.74 ± 0.14
Average total compressed surface (in cm^2)	225
Average compression time (in minutes)	4 ± 0.67
Average total breaking load (in kg)	73666.67 ± 161.56
Average total breaking stress (in kg/cm^2)	327.4 ± 1.73
Average useful breaking stress at 28 days of age: Strength (in N/mm^2)	32.74 ± 0.94 ≈ 33

This value (33 N/mm²) is higher compared to other mixtures as presented in table 6. This can be explained by the fact that the mixture of several thermoplastics with almost the same recycling properties has in most cases leads to an increase in the compressive strength of the material produced (Besson, 2014).

Table 6: Resistance values of paving stones obtained from different materials

Matter	Resistance (in N/mm^2)
Paver made from bags, bottles and find sand	33
Paver made from bags and fine sand	24
Paver concrete paver	18
Paver made from bags and slag	11
Paver made from pure clay	7

According to Table 7, the paving stones resulting from this study having a resistance of 33 N/mm² included in the value scale of concrete with high compressive strength are useful for large works and present a novelty and deserve attention particular in the city of Kinshasa.

Table 7: Scale of average resistance values and appropriate uses

Quality of concrete	Cement dosage (in Kg/m^3)	Average resistance (in N/mm^2)	Proper use
Low strength concrete	150-300	20-25	Small works: simple house (without floor), septic tank
Common concrete	300-350	25-30	Small works: simple house (without floor), septic tank
High strength concrete	350-400	30-35	Major works: building, powder column of house on floor, bridge, abutment (bridge edge), …
Exceptional strength concrete	400 and more	35-40	Special works: skyscrapers, dams, major bridges

Source: Dreux (1981)

CONCLUSION

The goal assigned to this study "reduction of the socio-environmental impacts of thermoplastic waste (low density (LDPE), high density (HDPE) and polyethylene terephthalate (PET)) in the city of Kinshasa thanks to their revaluation for the manufacture of paving stones sustainable" was verified. In short, thanks to the recycling of thermoplastic waste (LDPE, HDPE and PET) for the manufacture of sustainable paving stones with a view to enhancing circular economy, this study, has just demonstrated that the reduction socio-environmental impacts of thermoplastic waste which is mainly produced and without real destinations in the city of Kinshasa is possible. It is therefore necessary to popularize and support this technology which confirms the possibility of recycling thermoplastic waste (LDPE, HDPE and PET) in the city of Kinshasa, and which provides a sustainable solution to the sanitation of the city in the face of the impasse caused by this type of waste.

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Post Disaster Housing Reconstruction in Lokoja-Nigeria: Major Problems Experienced and the Way Forward

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There is an observable increase in the frequency of natural disasters (floods) in recent times and the appalling nature of destruction emanating from natural disasters on housing has become a global concern and is putting everyone on their feet to find out strategy to enhance the efficiency and effectiveness of post disaster undertakings. Housing reconstruction which is supposed to give succour to the disaster affected people often fail due to some issues. This study considered the major issues that are peculiar to the Post Disaster Housing Reconstruction (PDHR) settings in the study area since each setting is confronted with different impediments. This was done through a self-administration of structured questionnaires to 257 flood victims directly or indirectly involved in the reconstruction projects. Findings indicated unethical conducts of professionals and non-engagement of beneficiaries or communities during reconstruction. These indicators are threats to the success of PDHR projects. Therefore, offering beneficiaries the opportunity to meaningfully contribute in reconstruction affairs that is to shape their lives in terms of housing and livelihoods, will in no small level minimize problems experienced in PDHR. This will deliver a more sustainable and resilient PDHR development where satisfaction and acceptability of the project will be evident, and the donor will have value for his money.

Keywords: Floods impact, PDHR projects, community involvement, sustainable strategy, Lokoja-Nigeria

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INTRODUCTION

Natural disasters in recent times, occur more frequent and it is causing damage, losses, and disturbance to lives, built and social assets, and economy across the globe. Natural hazards caused disasters such as floods, earthquake, and drought are a central global predicament (Benson *et al*., 2001; Adaji, 2021), and about 250 natural and 125 human-made disasters occur each year (Alexander, 2004; Adaji, 2019; Adaji *et al*., 2023). Recent years, a series of universal disasters hit numerous parts of the globe, which posed challenges to the existing risk reduction, and management that was in place (Malalgoda *et al*., 2014). Indian Ocean tsunami in 2004, hurricane Katrina in 2005, Haiti earthquake in 2010, New Zealand earthquake in 2010, Japan earthquake and tsunami in 2011, Typhoon Haiyan in 2013, Nigeria floods in 2012, 2018 and 2022, Malaysia floods in 2014 and 2022, are some of the foremost tragic disasters over the past decade, which caused overwhelming and long-term impacts to the affected nations and the entire world (Adaji *et al*., 2023).

Developing countries tend to endure the pain of the impact of disasters, with the poor in these countries often being the most severely affected (Schilderman, 2004; Adaji, 2019; Adaji *et al*., 2021). Developing countries also experienced the highest figures of deaths and people affected by the flooding disasters (Ahmed, 2011). Predominantly in developing countries, the effect of disasters on the built environment is much greater compared to developed countries, estimated at more than 20 times in magnitude (Barakat, 2003; Goswami *et al.*, 2018). Housing is usually viewed to be the most valuable asset for people in developing countries. In any flooding, houses are principally the component that is most extensively damaged, and repeatedly represent the greatest portion of the loss in the overall impact of a disaster on the national economy (Lyons, 2009; Adaji, 2019; Adaji *et al*., 2021). For example, Roosli *et al.* (2015) reported that during 2014, flooding in Malaysia, housing was the sector that experienced extreme damage. In an attempt to describe the precise scenario of the 2014 floods in Malaysia, Mohamed *et al.* (2017)

expressed that it is not out of place for one to say that the speed of the flood water in the affected regions flowed so fast with vitality equivalent to that of Tsunami, displacing anything that obstructs its channel of flow including buildings (residential and non-residential houses) and other infrastructures.

Similarly, Richard *et al*. (2017) and Jinadu (2015) reported that Nigeria is not excluded from the flood devastation on housing. In October 2012, a flood devastated some States in Nigeria that included Kogi. The flood of 2012 is considered as the worst since Nigeria became independent in 1960 (Adaji, 2019). The discovery of the Post-Disaster Needs Assessment (PDNA) conducted immediately after the floods showed that 11 States were ravaged by the floods (see Table 1). The experience of the 2012 floods cannot be forgotten in a hurry since the effects are overwhelming and always fresh in the minds of the victims as well as the Federal government of Nigeria (Adaji *et al*., 2023). In Kogi State alone, more than 500 thousand people were displaced; nine out of the 21 local government areas were affected by the flood, including Lokoja the State headquarters (NEMA, 2013).

Table 1 shows that Nigeria in general, and Kogi State in particular, may be on the watch list of natural disaster-prone settlements. It further discloses the vulnerability of Kogi State poorer residents to disasters as a result of the lesser capacity and fewer resources to prepare and recover. The life-threatening physical and socio-economic shocks of 2012 floods became a crucial matter of interest among stakeholders in disaster management where safe actions on victims' rehabilitation, recovery and risk vulnerability reduction were swiftly taken to mitigate flooding impacts in the future. However, the implementation of some of the resolutions was incompetently done due to corruption manifesting through the diversion of resources for personal interests (Jinadu, 2015). The consequences of poor implementation are leaving the affected population vulnerable to the menace of flooding now and in the future. This record among others supports the justification for conducting this research with the year 2012 flood as a central focus to bring long term respite to the residents by developing strategies that will offer a disaster resilience community in the study area and other similar communities. Housing reconstruction is a crucial element of post-disaster recovery initiatives in developing countries, and thus, the need arises to recognise what approach makes it effective or achievable in the aftermath of disasters (Lyon, 2009; Adaji, 2019).

Table 1: Number of totally and partially destroyed houses by 2012 floods in the most affected states in Nigeria

State	Traditional buildings			Modern/Sandcrete buildings			Total number affected
	Number totally destroyed	Number partially damaged	Total number affected	Number totally destroyed	Number partially damaged	Total number affected	
Adamawa	117,829	36,134	153,963	-	23,401	23,401	177,364
Anambra	16,186	6,719	22,905	-	95,394	95,394	118,299
Bayelsa	79,730	26,577	106,307	-	26,577	26,577	132,884
Delta	79,834	4,465	89,299	-	-	-	89,299
Edo	13,153	14,249	27,402	-	-	-	27,402
Jigawa	11,623	5,230	16,853	-	282	282	17,135
Kebbi	103,048	52,555	155,603	-	-	-	155,603
Kogi	124,085	3,102	127,187	-	16,259	16,259	143,446
Nasarawa	16,326	136,049	152,375	-	5,759	5,759	158,134
Rivers	36,999	4,111	41,110	10,121	192,290	202,411	243,521
Taraba	81,688	32,675	114,363	-	-	-	114,363
Total	**685,501**	**321,866**	**1,007,367**	**10,121**	**359,962**	**370,083**	**1,377,450**

Source: NEMA (2013)

Post-disaster housing reconstruction (PDHR) are obviously multifaceted, undefined, multi-stage and affect multiple actors and agencies (Darabi *et al*., 2013). The process is multifaceted because it requires different talents, qualities and stages. Adaji (2019) reported that the efforts to reconstructing houses for the beneficiaries in the event of floods have not yielded the desired result. Since survivors in the flood-impacted areas are left confronting the significant challenges of recovering from disaster. Increased complexities and uncertainties in a post-disaster environment mean that delivery of housing is more difficult than it is for conventional projects. As such, the techniques in which housing and resources are gotten may not be able to cope with challenges posed by the major disaster recovery (Jha *et al.*, 2010). The unavailability of local human resources at all stages to facilitate the management of post-disaster housing reconstruction and the sustainability of

reconstruction projects is a principal challenge or bottleneck faced by several housing reconstruction projects (Adaji *et al*., 2023). This study reported PDHR in Lokoja from the perspective of the flood victims in those areas because Sadiqi *et al*. (2012) established that most of the time, emergency relief efforts are usually seen as being successful, but the same cannot be said of PDHR projects because they often fail to meet the set objectives. Hence answer was sought to the following research question: What are the major difficulties experienced in PDHR in the study area?

To successfully solve these problems, community participation is progressively being sought (Adaji *et al*., 2021). The contribution of disaster-affected communities in housing reconstruction is serious to the accomplishment of the programme (Lawther, 2009) and cannot be overemphasised. Ophiyandri *et al*. (2013) stressed that it is the community who understands what they need and at the same time, tell what is best for the community. Hence, the contribution of the community in PDHR projects must be guaranteed (Hayles, 2010). This is the way forward if difficulties encountered in PDHR programmes is to be discontinued. It is in this light that this study is making the proposition of community involvement in practicality to accomplish PDHR goals as well as safeguard its sustainability as the way forward.

LITERATURE REVIEW

Impacts of Disaster

The occurence of natural disasters are more frequaent nowadays and it is causing damage, losses, and disturbance to lives, built and social assets, and economy worldwide. Disasters usually destroy houses and claim many human lives; the lucky survivors in a disaster-affected location often opt not to leave their residences or home region (Baldry and Thurairajah, 2010). Hence, the requisite for reconstruction arises and may possibly provide the opportunity to build back better (Labadie, 2008; Mannakkara and Wilkinson, 2013). Because of the peculiarities attached to PDHR as being more complex, dynamic and unpredictable, there is a need for stakeholders to focus more interest on development. Davis (2014) and Adaji (2019) indicated that the 21st Century is emerging to be more stakeholder focussed. Quite several research work have recognised the importance of effective stakeholder engagement in reconstruction project (Yang *et al.*, 2009; Shafique and Warren, 2015; Adaji *et al*., 2023).

Problems of Post Disaster Housing Reconstruction

One of the most intricate responsibilities being faced by recovery managers in the aftermath of disaster regardless of the form is to decide on and execute the correct approaches to housing reconstruction. Jha *et al*. (2010) opined different methods through which PDHR can be achieved in terms of a household's degree of control over the reconstruction procedures. The selection of an appropriate reconstruction delivery approach depends on several influences including resource availability, speed, efficiency, capacities and experience, technological and socioeconomic views (Barenstein, 2006; Davidson *et al*., 2007; Hayles, 2010; Chang *et al*., 2011; Adaji, 2019). International Recovery Platform (2007) and Jha *et al*. (2010) advised that the choice of reconstruction approaches to be engaged should be based on context. It should also give attention to many fundamental factors such as broader political environment and operational criterions, cultural background, cost of reconstruction, improvement in housing and community safety, reinstatement of livelihoods, hopes and priorities of the most affected individuals.

Experience shows that planners and developers of PDHR projects tend to reposition and resettle disaster-affected communities (Sadiqi *et al.,* 2017). Housing reconstruction projects constructed by donors (international/ national NGOs or governments), predominantly those that demand relocating affected communities, are usually decided by an inflexible top-bottom approach, which is symbolized by complete absence of community consultation and community involvement in the planning and physical execution of reconstruction developments (Andrew *et al*., 2013; Adaji, 2019; Adaji *et al*., 2023). Besides the intrinsic contests such as rigid short time limit, organizing broadly dispersed affected communities, fiscal constrictions as well as validating housing quality (Roseberry, 2008; Olshansky, 2006), reconstruction projects are susceptible to swindle and corruption that can lead to massive losses of project funding (Lyons, 2009; Alexander, 2013).

In a post-disaster situation, Smirl (2008) notifies that donors (governments as well as NGO staffers) can potentially become prone to swindle and corruption specifically when rushed disbursement of bulky sums of recovery funding and dispersal of relief assistance was poorly coordinated and unsatisfactorily supervised. Furthermore, Tas *et al*. (2011) reported that quick disaster recovery led to hurried design where sensitive elements such as the local climate and environment, socio-cultural aspects and user's identity were being ignored alongside construction scheduling and output were also affected due to inappropriate selection of materials, ineffective engagement of labour, poor workmanship and administration. All of these factors compromised the quality of the reconstructed houses.

PDHR that is not appropriately planned and instigated has the potentials to create more exposures in the disaster-stricken community. In the aftermath of a large scale catastrophe, susceptibility of housing

reconstruction projects to various resourcing restrictions embedded in post-disaster scenarios, such as price increase (Nazara & Resosudarmo, 2007), resource insufficiencies (Steinberg, 2007), and interference in the supply chain (Zuo *et al.*, 2009), in no small measure obstruct the reconstruction procedure in communities affected by disaster.

According to Chang (2012), the resource mobilisation level and the potential for procuring crucial resources for reconstruction are determined by the transformed statuses in the aftermath of a disaster. The prospective factors that have the tendency to interrupt the mobilisation of resources in post-disaster reconstruction can be grouped in five classes namely: factors linked to transportation, factors linked to the construction market, factors linked to project stakeholders, factors linked to the reconstruction project, and factors linked to the project operational surroundings (Ibid, 2012).

The preceding review showed that issues inhibiting PDHR cut across four sensitive sections, namely, reconstruction approaches, stakeholders' consultation, resilience strategies, and resource mobilisation strategy. These identified factors capable of affecting resource mobilisation in PDHR settings and other factors prevailing in the PDHR situation can also affect the overall intentions and objectives of reconstruction and recovery efforts in the study area. However, housing reconstruction is not the same as traditional construction due to the plethora of issues that people will have to contend with at the same time (Davidson *et al.*, 2007; Siriwardena *et al*., 2009). This study will consider the major issues that are peculiar to the PDHR settings in the study area since each setting is confronted with different impediments and recommend the one factor that can influence the identified issues to enhance the satisfaction of beneficiaries and sustainability of the PDHR projects.

RESEARCH METHODOLOGY

This study, which was part of larger study conducted in 2019, adopted a quantitative technique with data from the administration of questionnaire. This quantitative research saw the world as made up of observable and measurable realities, emphasising positivist paradigm. It endeavoured to group issues into measurable classes which can be generalised on every one of the populations (Golafshani, 2003). The survey tool used was a structured questionnaire that was designed drawing on the factors derived from the literature. The respondents of this study were the 2012 flood victims in Lokoja who were severely affected by the 2012 floods and has since benefited from the latest housing reconstruction and community recovery projects and who the authors believed would have been involved in the reconstruction projects as well as possessed the required experience that will guarantee reliable information for the study. The study adopted the random sampling method which is a method under the probability sampling technique that was chosen so that every member of the target population would have equal chances of being selected in the sample. A total number of 400 (four hundred) questionnaires were administered as recommended by Krejcie and Morgan (1970) and Saunders *et al*. (2016) against a population of about 5817 houses reported under the introduction section. The questionnaires were self-administered to these flood victims on a 5-point Likert scale from 1 to 5, where 1 symbolises 'very Less' and 5 represents 'very high'. Two hundred and fifty-seven (257) valid questionnaires were used for the analyses as shown in Table 2. The data obtained were analysed using mean scores and ranked which formed the basis for the conclusion reached and the recommendations made.

RESULTS AND DISCUSSION

The valid questionnaires used for the analyses was 257 as shown in Table 2. This represented a response rate of 85.3% which is far above the 30% rate, as a satisfactory response rate in construction studies (Williams, 2007).

Demographic Information of the Respondents

Gender distribution in Table 2 showed that about 63% of the respondents were males, and 37% were females. As the family heads were mostly males in the Nigerian context, the margin of difference between males and female is justifiable. The result also showed that more than 88% of the respondents were aged between 26 years to 65years. Based on the age bracket, the conclusion of the study will be satisfactory since, over 88% is advanced enough to understand the difficulties experienced. More than 52% attended a higher education level with equivalent to the first degree and above, while about 48% have attended at least primary school. This is an indication that the majority of the respondents have requisite qualification and training for efficient delivery of responsibilities.

Table 2: Demographic Information of the Respondents

	Attributes	Frequency	Percentage (%)
	QUESTIONNAIRE ADMINISTRATION		
1	Questionnaires Administered	400	-
2	Questionnaires collected	301	75
3	Questionnaires screened	257	64
	GENDER		
1	Male	162	63.0
2	Female	95	37.0
	AGE		
1	Under 26	16	6.2
2	Between 26 to 35	62	24.1
3	Between 36 to 45	76	29.6
4	Between 46 to 55	64	24.9
5	Between 56 to 65	25	9.7
6	66 years and above	14	5.4
	EDUCATIONAL QUALIFICATION		
1	Living certificate	33	12.8
2	Secondary certificate	28	10.9
3	ND/NCE	61	23.7
4	B.Sc./HND	105	40.9
5	Master and above	30	11.7

The Major Difficulties Experienced with the Reconstruction Strategy Employed

A mean ranking was conducted on the major issues experienced from the PDHR by the respondents in the study area. The ranking order for the observed factors was done from highest to lowest using the mean and standard deviation possessed by an individual factor as shown in Table 3.

Problem with non-involvement of affected community ranked highest among the major problems experienced during reconstruction. Then, the high capacity of stockpiling of supplies meant for reconstruction by the donor's agencies, distribution of basic amenities like water, food, shelter, evacuation techniques, transportation networks and political pressure for quicker reconstruction ranked higher. These are logistic and chain supply issues which have always been an attribute of humanitarian operations. Housing reconstruction programmes count on the ability to acquire, transport and receive supplies at the point of need and inadequate provision of resources for PDHR significantly borders the prospects for successful implementation of the reconstruction works (Chang *et al*., 2010; Ahmed, 2011; Alexander, 2013; Adaji, 2019). Problems with political pressure for quicker reconstruction, problems with the restoration of urban infrastructures and services, problems with compromises on essential elements of the reconstruction programme, problems with unethical conducts of professionals during reconstruction and problems with victims rebuilding on their own ways were ranked next (middle). Problems with return of the evacuees, problems with bureaucracy during reconstruction and prevalent emotions such as abuses to reconstruction workers occupied the bottom ranking. These identified hindrances connote irregularities in the process of PDHR in the study area. There was little or no recognition of the affected community perhaps, responsible for the victims rebuilding on their own ways and early return of evacuees as seen in the table.

Sadiqi *et al*. (2017) reported that from the large proportion of PDHR interventions already implemented, unsuccessfulness can be traced to non-engagement of, or hitches with, community participation. This is affirmed in the findings on past PDHR projects that such projects are highly susceptible to failure without the active involvement of the affected community (Johnson *et al*., 2006; Lemanski, 2008; Galtung & Tisné, 2009; Hayles, 2010; Ophiyandri *et al*., 2010; Adaji, 2019). Several authors have faulted ill-coordinated approach to reconstruction of post-disaster housing. According to Shaw and Ahmed (2010), reconstruction is habitually delivered in such a manner that essentially addresses the implementer's requirements rather than the affected population requirements and this makes these projects often insatiable because community desires are swallowed up by the constructors' bigger benefits such as speed and project costs (Lloyd-Jones, 2006; Brun & Lund, 2008; Alam, 2010).

PDHR projects that are devoid of community participation often result in ugly outcomes. As illustrated by Nadiruzzaman and Paul (2013), that negative impacts were prominent and obvious on the affected communities in Bangladesh over the reconstruction approach initiated by the government of Bangladesh because of non-recognition for community

participation. As Mafukidze and Hoosen (2009) expressed that if the fundamental ethics of community participation are overlooked, it can create long term undesirable effects on community development. Hence, requires putting the right people in the right shape so that the intended objectives can be achieved.

The effectiveness of PDHR also depends on effective resource supplies hence the need for the engagement of procurement experts and local community members to assess and identify resource requirements, locally available resources and local markets and transportation alternatives. There is less issue connected to the speed of reconstruction and bureaucracy during reconstruction. Perhaps, because the affected community were not or actively involved in the reconstruction activities.

Table 3: Major issues experienced

SN	Variables	Mean	Std. Deviation	Rank
1	Problem with non-involvement of affected community	4.15	0.865	1
2	Problems with stockpiling of supplies	4.09	0.928	2
3	Problems with the distribution of basic provisions such as water, food, clothing, shelter, medical care	3.94	1.075	3
4	Problems with evacuation techniques used	3.86	1.000	4
5	Problems with the rescue of survivors	3.79	0.919	5
6	Problems with transportation networks	3.61	1.496	6
7	Problems with political pressure for quicker reconstruction	3.47	1.330	7
8	Problems with the restoration of urban infrastructures and services	3.42	1.236	8
9	Problems with compromises on essential elements of the reconstruction programme	3.39	1.141	9
10	Problems with unethical conducts of professionals during reconstruction	3.29	1.131	10
11	Problems with victims rebuilding on their own ways	3.25	1.343	11
12	Problems with insufficient workforce across local organisations	3.20	1.293	12
13	Problems with the removal of debris	3.19	1.243	13
14	Problems with speed of reconstruction	3.14	1.231	14
15	Problems with return of the evacuees	3.13	1.184	15
16	Problems with bureaucracy during reconstruction	2.97	1.256	16

CONCLUSION

The appalling nature of destruction emanating from natural disasters has become a global concern and is putting stakeholders on the quest to develop a strategy that will enhance the efficiency and effectiveness of post-disaster undertakings. Affected community's influence on any decision relating to the disaster relief measures provided is crucial to positive results on post-disaster recovery. Scholars in sustainability and resilience have agreed that involvement of beneficiaries is imperative for the achievability of PDHR targets. This is valuable because each PDHR has special goals to be achieved, and only those with background knowledge can be of reliable help and guide. Hence, offering beneficiaries the opportunity to meaningfully contribute to reconstruction affairs that are to shape their lives in terms of housing and livelihood, will in no small level minimise problems experienced in PDHR projects. Therefore, community involvement in PDHR is the way forward. Studies should shift dimension from laying emphasis only to restore normal life in disaster-affected areas but more efforts to address PDHR as an opportunity to offer a safer, sustainable and resilient built environment. This is expected to deliver a more sustainable and resilient PDHR development where satisfaction and acceptability of the project will be evident, and the donor will have value for his money.

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Establishment and Evaluation of Electronic Distance Measurement (EDM) Calibration Baseline

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Electromagnetic distance measurement (EDM) instrument requires a regular and proper calibration to determine the performance of the instrument and its standardization. This paper aims to describe the field procedures for the establishment of an EDM calibration baseline for distance measurements verification to cover the educational and research activities of the Federal university of Technology, Minna, Gidan-Kwano Campus. An outdoor calibration baseline in a straight line configuration was established for such purpose. The measurement of the baseline was performed using Leica TPS 1200 0.2 second (0.2'') Total station. The calibration baseline was divided into four bays and a total number of two hundred (200) observations were done in combinations. The analysis of the obtained 200 sample data set yielded the most probable value for the four bays as; instrument constant K= -0.0047m. The standard error of the unknown parameter was determined as;$\sigma = \pm 0.00058$m. The analysis of the obtained 200 sample data set yielded the most probable value for the four bay; X1 =101.650m, X2 =199.7968m, X3 = 299.9189m, X4 =502.6423m. The result of the hypothesis testing reveals that $V^T PV = 0.0028$, at 95% significance (α) level, with a degree of freedom of 195. The computed value for the chi square is given as; $\chi^2 = 4.76980$, the lower limit and upper limit as obtained from the statistical table is given as 0.052 and 6.23 respectively. The result of the hypothesis test indicate that the adjustment process was consistent and without distortion. It was concluded that the result obtained can reliably be used for the calibration of Electromagnetic Distance Measuring Equipment in Minna, Nigeria.

Keywords: Baseline Calibration, Electronic Distance Measurement Instrument (EDMI), Total Station, Least Squares

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INTRODUCTION

With the introduction of electronic distance measuring instruments (EDMI) in the United States in 1952, the standardization problem was compounded since EDMI measurements are affected by meteorological conditions other than temperature and by several instrument uncertainties that require frequent periodic re-evaluations. Although the need for calibration base lines was evident, a test range specifically designed for EDMI re-evaluations was not available for more than a decade. Early in the 19th century, the Survey of the Coast, subsequently named the U.S. Coast and Geodetic Survey (USC&GS), now the National Geodetic Survey (NGS)] adopted the meter as the standard for use in geodetic surveys of the United States. Land surveyors, on the other hand, employed the foot as their standard, as did most surveyors involved in engineering and associated surveying activities. In 1963, USC&GS measured a multi-monumented line in Beltsville, Maryland, using high-precision taping techniques (Joseph *et al*., 2014). The distance of the Beltsville base was approximately 1,800 meters, different from the 1,650-metre distance normally utilized. Later, a much longer line (about 9,050 meters) near Culpeper, Virginia, was measured using similar procedures. Although no major restrictions were placed on the use of these base lines, few surveyors other than those from federal agencies used these facilities to calibrate their equipment (Joseph *et al*., 2014).

As more surveyors acquired EDMI, the surveying profession became concerned about the accuracy of their measurements. It has been shown that whereas accuracies attributed by the manufacturers to the instruments are reliable, errors in the observations, which are often systematic, can result from normal usage due to a reduction in the efficiency of electronic and mechanical components. Periodic maintenance, preferably by the manufacturer or a designated representative, is required to minimize such errors. It is equally important to verify the instrument constant and evaluate the measuring accuracy at more frequent intervals in conformity with International standard Organization (ISO 17123-4 -Optics and optical instruments, 2001).

The lack of EDM calibration Baseline in FUTMINNA posed a challenge to provide traceability of length for electro-optical equipment with; total stations, reflectorless total stations, laser scanners (Japhet *et al.,* 2021; Pagounis *et al*., 2022; Florian *et al.,* 2023). Hence, the aim of this research work is to highpoint the processes involved in the establishment of an Electromagnetic Distance Calibration baseline and the associated mathematical computation by method of least squares. The objectives of the study include;

1. Establishment of a calibration baseline subdivided into four bays marked with survey monuments.
2. Determination of angular and linear measurements on four (4) zeros on the established inter-pillar of the bays in combination.
3. Computation and evaluation of the acquired data using the least squares technique of adjustment.

LITERATURE REVIEW

Electro-optical Distance Meter (EDM) calibration is the determination of instrument correction by comparing the value indicated by the measuring equipment with the known or true value. Due to the aging of the instrument, after repairs and services, jolts of the instrument would inculcate a lot of errors (Janssen, 2015; Japhet *et al*., 2022; Kinga *et al*., 2022; Pagounis *et al*., 2022; Florian *et al.,* 2023).

Zakar and Aliyu (2014) established a baseline using electronic distance measurement at the federal polytechnic Mubi to take care of some of the operations that may require the need for a Calibration baseline. This was achieved by taking thirty different measurements in their combination on the baseline. All measurements were corrected for meteorological and geometrical effects. The developed computer program using Fortran 77, based on the principles of least squares by method of observation equation reveals the computed result of the adjusted baseline to be; 1184.50027m, at a degree of freedom; 29 and the computed statistic V^TPV was also found to be 0.01554 at a level of significance (α) of 0.5.

Karim *et al*. (2022) observed that Laser-based Electronic Distance Meters (EDMs) are used extensively to measure inner/outer dimensions in constructions and large volumes and needs to be calibrated regularly to assure its proper function. In their paper, a distance measurement system based on Opto-Electronic Oscillator (OEO) was used for EDM calibration. The calibration was performed in three steps; the first step was to construct a reference OEO system using off the-shelf optical telecommunication components. Then, the OEO system was used to calibrate an indoor baseline consisting of eleven distances ranging from 2.4 to 58 m. Finally, the calibrated baseline was used to calibrate the EDM.

One important perquisite for SI traceability is the correct estimate of the associated measurement uncertainty. To determine the magnitude of the errors and their statistical properties of distance measurements of EDM equipment, baselines (outdoor or laboratory based) are commonly used (Janssen, 2015; Florian *et al.,* 2023; Robert 2020; Japhet *et al.,* 2022; Kinga *et al*., 2022; Pagounis *et al*., 2022). However, establishing a direct link to the SI definition with low measurement uncertainty is laborious and hence, the need for calibration baseline for verification of distance meters on a regular check (following standards), further as legal metrological control of measurement or for error detection and more accurate results (Vsevolod *et al.,* 2022). This paper aims to describe a test field facility for distance measurements verification that has been established to cover the educational and research activities of the Federal University of Technology, Minna, Gidan-Kwano Campus.

THE STUDY AREA

The Federal University of Technology, Minna, Gidan-Kwano Campus is located along Minna – Bida Road, in Bosso Local Government Area of Niger State, Nigeria.

Figure 1 depicts the FUTMinna Campus located at 09^0 32’ 30.46”N, 06^0 26’14.37”E at the top left, 09^0 31’15.84”N, 06^0 27’ 20.”67E at the bottom of the longitude and latitude respectively.

Figure 1: Map of Niger State showing Bosso LGA
Source: Department of Urban and Regional Planning, Federal University of Technology, Minna

Figure 2 depicts the Google image of the established EDM calibration baseline along a relatively flat terrain between the school workshop and the staff quarters at the main campus of FUTMINNA.

Figure 2: Established Calibration Baseline in FUTMINNA, Gidan-Kwano campus (2023)

MATERIALS AND METHODS

Full determinations of the Instrument corrections (IC) Parameters were carried out for this study, as no existing calibration baselines was available for EDM checks. Checks were effected according to the manufacturer's manual and in accordance to survey the field procedures for EDMs (ISO 17123-4-Optics and optical instruments, 2001). The following checks: additive constant, scale error, cyclic error, thermometer and barometer checks, pointing error were carried out at the test field at Gidan Kwano Campus.

The test field consist of one marked instrument station (A) and three permanently mounted reflectors at typical distances for the usual working range of the particular EDM instrument (from 50m to 300m). The reference lengths of the lines were determined with a more accurate type of distance meter (Leica TS 1201). This testfield was established purposely for this research work on EDM checks and calibrations. Table 1 depicts the field observations of the straight-line calibration bay on the site carried out on 11/11/2020.

Table 3: Field observations

Date of Observation	EDM Station order	X1	Temp 0^c	Pressure Hpa	Relative Humidity
11/11/2020	A1 – A2 `	101.6501m	29.3	1015.4	80%
11/11/2020	A2- A3	199.7967m	29.3	1015.4	80%
11/11/2020	A3- A4	299.9189m	29.3	1015.4	80%
11/11/2020	A1- A4	502.6423m	29.3	1015.4	80%

The first day's (11/11/2020) results gave the actual reference values and was recorded in a logbook for future reference. Analysis of the performance check are as follows: If the results from Check 2 indicate significant differences for all the checked distances, it is recommended that the check be repeated very carefully. If the second comparison check confirms the result of the first, a change in the instrument's performance (or instrument station) is suspected and it is necessary to find out the cause of the change before using that instrument for the project.

The next step was to determine the Additive Constant (a)

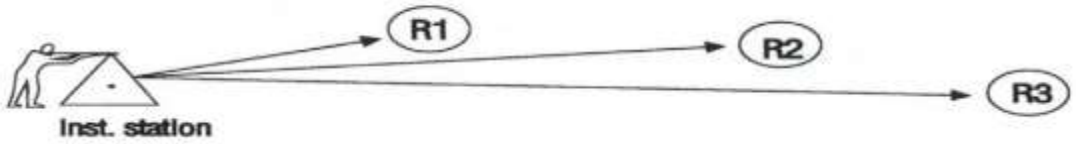

Figure 3: Performance Check on stability of the EDM at a Testfield at Gidan -Kwanu Campus

Establishment of Calibration Baseline

The field operation started with the concrete monumentation of the station mark using wild T2 theodolite and ranging poles to set out the calibration baseline. The EDM was set up on the starting point (A) and observations taking to the four bays established at varying lengths. This was followed by height measurement of EDM instrument and reflector's height using line tape and recorded in the field book. This was to determine the slope correction to bring the measured slope distance to horizontal distance. The reflector was sighted, and the centre of the prism was bisected, then the vertical and horizontal movement of the EDM was clamped. Checks for battery and signal were made by switching on the instruments on/off switch. The display showed 0000, indicating that the instrument was ready for operation.

Measurement was triggered by lightly touching "MEASURE" knob. The distance measurement was performed automatically within 5" (second), during this time, points were flashing at the digital display and finally the measured distance was displayed. The vertical angle reading was recorded from the EDM for slope correction. The atmospheric temperature was also recorded. Redundant measurements (200) were made in order to evaluate standard errors and establish probabilities. These redundant measurements were used to detect mistakes in the field work and to find an estimate for a true value by the principles of least squares.

When the slope distance L has been obtained from an EDM measurement, a slope correction must be applied to it in order to obtain the equivalent horizontal distance. Electromagnetic waves travel through the air with a velocity (V) and since by definition,

Distance (D) = $\frac{v \times t}{2}$ (i)

Where v is the velocity of the wave signal, t is the time of travel of the wave signal, and D is the measured distance. The unknown distance, D can be found by measuring the travel or transit time, t, if the velocity is known.

Measurements of Inter-pillar Distances of the Bays in Combination

Linear measurements of the various bays were taken in combination with the aid of the Leica TPS 1200 Total Station on a single reflector. The linear measurement was carried out in two phase the first phase in the morning and the later in the evening. This is to reduce the effect of refraction on the electromagnetic signal. The least squares observation equation was used, been the most rigorous method of adjustment which yields unbiased estimates for the parameters to be determined. Least squares adjustment is a statistical technique for carrying out objective quality control of measurements by processing set of redundant observations according to mathematically well-defined rules. The fundamental condition of least squares method is that the sum of the squares of the residual is a minimum. Thus, the least squares produce the most probable value (MPV) by simultaneously considering all factors and the same time making the sum of the square of the residual a minimum (Japhet *et al.,* 2022; Florian *et al.,* 2023).

Computation and Evaluation of the Acquired Data using the Least Squares Technique

Observation equations are sets of equations that show the functional relation between observed parameter and the adjusted parameter, the adjusted parameters to be determined are; x_1, x_2, x_3, x_4 and the instrument constant (k).

For each observation, an equation was set up expressing the relationship between the variation and the adopted parameters on one hand and the difference between the observed quantity and its corresponding computed values for the provisional distances on the other hand. The functional relationship between the measured distances and the unknown parameter can be expressed as;

$$x_1 + v_1 + k = 101.651\text{m}$$
$$x_1 + x_2 + v_2 + k = 301.442\text{m}$$
$$x_1 + x_2 + x_3 + v_3 + k = 601.365\text{m}$$
$$x_1 + x_2 + x_3 + x_4 + v_4 + k = 1104.017\text{m}$$
$$x_1 + v_5 + k = 101.65\text{m}$$
$$x_2 + v_6 + k = 199.796\text{m}$$

The design matrix (A), and the matrix of observation (L^b) for the 200-sample size was developed from the parametric relationship as;

$$A=\begin{bmatrix}1&0&0&0&1\\1&1&0&0&1\\1&1&1&0&1\\1&1&1&1&1\\1&0&0&0&1\\0&1&0&0&1\\0&1&1&0&1\\0&1&1&1&1\end{bmatrix},\quad L^b=\begin{bmatrix}101.65\\301.442\\601.365\\1104.017\\101.653\\199.796\\499.714\\1002.353\end{bmatrix}$$

The generalized linear mathematical model of the least square observation equation is given by as; $L^b = f(X^a)$(Functional model of observation equation) (ii)

Where;

L^b = Adjusted observation

X^a = Unknown parameter

Each adjusted equation then becomes;

$L^a = L^b + V$ (iii)

L^b = =□observed parameters

V= residual

The adjusted parameter

$\hat{X} = -\ (A^TPA)^{-1}A^TPL$ (iv)

$V = A\hat{X} - L^b$ (v)

Where;

$\hat{X}$ = the adjusted parameter

V = vector of residual

A = design matrix

P = unit weight matrix

L= matrix of observation

The a-posterior

$\sigma_0^2 = \left(\frac{A^TPA}{n-m}\right)$ (vi)

Where, n is the number of equation and m is the unknown parameter.

$\sum \hat{X} = \sigma_0^2(A^TPA)^{-1}$ (vii)

RESULTS AND DISCUSSION

The data used in this work were obtained from measurement carried out on the EDM calibration baseline. Two hundred (200) different measurements were carried out on the baseline. Due to the large sample size, Matrix Laboratory program (Mat LAB) was used to for the computation. The following results was obtained;

$(A^TPA) = \begin{bmatrix}80&60&40&20&80\\60&120&80&40&120\\40&80&120&60&120\\20&40&60&80&80\\80&120&120&80&200\end{bmatrix}$; Where, (A^TPA) is the coefficient matrix of the normal equation which is non-singular matrix,

$(A^TPL^b) = \begin{bmatrix}0.00004217\\0.00007417\\0.00008620\\0.00006823\\0.000010831\end{bmatrix}$; (A^TPL^b) is linear matrix ,

$\hat{x} = \begin{bmatrix}101.6560\\199.7968\\299.918\\502.6423\\-0.0047\end{bmatrix}$; $\hat{x}$ *is* the matrix of the adjusted parameters which shows the most probable value of the various bays and the instrument constant (k)

And σ_0^2 = 0.000014359 is σ_0^2 is the a-posterior.

$$\sum \hat{x} = \begin{bmatrix}0.0000003446&-0.0000000862&0.0000000574&0.0000000574&-0.0000001436\\-0.0000000862&0.0000003446&-0.0000000862&0.0000000574&-0.0000001436\\0.0000000574&-0.0000000862&0.0000003446&-0.0000000862&-0.0000001436\\0.0000000574&0.0000000574&-0.0000000862&0.0000003446&-0.0000001436\\-0.0000001436&-0.0000001436&-0.0000001436&-0.0000001436&0.0000003590\end{bmatrix}$$

The standard deviation of the bays was computed as, σ=±0.0005870264m.

The study demonstrated the use of Total Station and the application of least squares by method of observation equation in the establishment of an Electromagnetic Distance Calibration Base at the Federal University of Technology, Minna. The analysis of the obtained 200 sample data set yielded the most probable value for the four bays as; and an instrument constant K= -0.0047m.

The standard error of the unknown parameter was determined as:σ = ±0.0005870264m.

The hypothesis test carried out on the obtain result indicate that the adjustment process was consistent and without distortion. and an instrument constant K= -0. 0047m.The analysis of the obtained 200 sample data set yielded the most probable value for the four bay; X_1 =101.650m, X_2 =199.7968m, X_3 = 299.9189m, X_4 =502.6423m.

Hypothesis testing of the obtain result was done to check if the so obtained result and the procedures used can be relied upon. A test statistic is computed from the sample values (the observations) and from the specifications of the null hypothesis. If the test statistic falls within a critical region, the null hypothesis is rejected. That is, V^TPV is statistically tested to see whether it falls within the specified confidence limit or not. This is done by means of a two tailed test of variance chi square x^2 test. The formation of the hypothesis is as follows;

$H_0; \sigma_0^2 = V^T PV, H_1; \sigma_0^2 \neq V^T PV$.

The zero hypothesis states that the prior variance of the unit weight statistically equals the a-posterior variance of unit weight. If the zero hypothesis is accepted, the adjustment is judged to be correct. But if the numerical value is such that;

$x^2 \propto x^2_{n-1,1-\alpha/2}$, $x^2 \propto x^2_{n-r,\alpha/2}$the zero hypothesis is rejected. This is a two tailed test where the Alternative Hypothesis (H_1) is rejected if the computed statistics is outside the confidence limit. The confidence limits are the upper limit and the lower limit of the statistics table. They are obtained in the statistics table as, $x^2 \propto x^2_{n-1,1-\alpha/2}$ for upper limit and $x^2_{n-r,\alpha/2}$, for lower limit, where α is the level of significance.

The result of the hypothesis testing reveals that V^TPV = 0.0028 T, at 0.05 level of significance (α), with a degree of freedom of 195. The computed value for the chi square is given as;

$x^2 = \left(\frac{V^T PV}{\sigma_0^2}\right)$lower limit and upper limit as obtained from the statistical table is given as 0.052 and 6.23 respectively.

CONCLUSION

The study demonstrated the use of Total Station and the application of least squares by method of observation equation in the establishment of an Electromagnetic Distance Calibration Base at the Federal University of Technology, Minna. The EDM Calibration Baseline which was established on a straight-line configuration was divided into four bays. The analysis of the obtained 200 sample data set yielded the most probable value for the four bays as; and an instrument constant K= -0.0047m and a standard error:σ = ±0.00058m. The study recommended for the establishment of indoor calibration baseline that would be free from the effect of the atmospheric conditions on measured distance in further studies.

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Assessment of Web3 Technology in Land Ownership Transactions

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The advantages of publicly distributed, transparent, accountable, traceable, safe, and well organized database ledger has made the blockchain technology gained popularity and acceptance. As the world keeps growing in the knowledge and the adoption of the technology, it is very important to practically harness the opportunities in this technology in land administration system to combat the insecurity, poor database and copyright challenges facing land ownership transactions in the Cadastre System in developing countries. The aim of this paper is to examine the practicability of harnessing the Web3 Technology in Land Ownership Transactions with an objective to mint and transact a Registrable Instrument on a cryptographic blockchain. To achieve this, two Non- Fungible Token (NFT) accounts were created on Core blockchain, two templates of survey plans were also minted into an Art NFT on the same blockchain. The Minted NFTs were transacted (transferred and sold) between the two accounts on the YoungParrot NFT marketplace. These two transactions (sales and transfer) were completed, recorded and stored on the blockchain public ledger, with evidence that can be traced and viewed on the blockchain using the transaction hash/ID. The blockchain transaction was found to be fast, effortless, secured and organized on the blockchain transaction ledger, hence presenting the Web3 blockchain Technology as a possible solution to the challenges facing the Cadastre System. However, the acceptance of the technology in land administration, land ownership and transactions still face some other administrative challenges which this paper further addressed.

Keywords: Cadastre System, Land Transaction, Art Non-fungible Token, Web3, Core Blockchain, YoungParrot market place

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INTRODUCTION

The invention of blockchain technology has triggered a new wave of technological advancement in industrial methods of engagement, processing and systems of administering and managing transactions, which is optimal than the usual (Sakiz & Gencer, 2021). Transactions on a blockchain are processed by computers (referred to as nodes) working together on a public or private network on a specified blockchain to confirm blockchain transactions in blocks. These blocks are sequentially and continuously linked with previously confirmed transactions to form a transaction ledger on the blockchain. A blockchain ledger is a publicly transparent architecture of continually confirmed blocks of transactions which is recorded on every single node (computer) on the blockchain. An advantage of this ledger is that it cannot be altered (Liu, 2023).

Over the years, the challenges of land transaction have been insecurity, lack of transparency and lack of database. To add to the list is the time taken to complete such transactions between two partners. According to Muller and Seifert (2019), the advantages of the blockchain technology includes: faster implementation of pending ownership changes; automated notification and transparency of ownership changes; automation of archives for contracts and files; and flexibility, resilience and greater security for land registration actors. For this purpose, the blockchain technology for the real estate market is considered as a feasible technology (Ibrahim, 2021; Eder, 2019). The aim of this paper is to examine the practicability of harnessing the Web3 Technology in Land Ownership Transactions with an objective to mint and transact a Registrable Instrument on a cryptographic blockchain.

Surveying is the art, science and technology of making measurements and observations about the earth surface or part of the earth surface as well as presenting it on plans/maps drawn to scale (Babalola, 2022). This exercise of measurement and observations can be done for the purpose of land registration, construction, deformation and disaster monitoring and so on. The introduction of Web3 technology into surveying profession tends to be very useful (with non-fungible token). The rigid nature of current system of land administration and ownership transactions in countries around the world has a common problem of system security (Eder, 2019; Muller & Seifert, 2019; Ibrahim *et al*., 2021). These problems can be effectively addressed via the use of the blockchain technology, but the hindrances to the adoption of this technology still includes conceptual challenges, trust issues, regulatory challenges, complexities and volatility and market risks (Patil, 2020).

In Nigeria for instance, there are professional bodies governing the rules and regulations in respective professional careers aiming at a standard and will coordinate land administration and cadastre system.

Examples are the Town Planners Registration Council of Nigeria (TOPREC) and Surveyors Council of Nigeria (SURCON). With emphasis on cadastre system, this work tends more to the survey aspect of the cadastre system with reference to the Surveyors Council of Nigeria (the body that controls the practice of the Surveying profession in Nigeria) as the legislations regulating the practice of the surveying profession in Nigeria include the SURCON Enabling Act (2014) and the SURCON Survey Rules and Regulations. The law that governs land Ownership in Nigeria is the Land Use Act of 1978, now Land Use Act (2004).

Limitations to the adoption of the blockchain technology in Land Administration and Cadastre System of developing and underdeveloped countries are subjected to the inability to synchronize the technology with the existing customary and statutory laws governing the Cadastre System of these countries (Racetin *et al*., 2022; Bakar *et al*., 2022; Shuaib *et al*., 2022). It is important to understand that for a successful adoption of this new technology in the cadastre system of a country, it is necessary that the technology is built in line with the laws, rules and regulations of such country (Racetin *et al*., 2022). For instance, in Nigeria, the consent of the Governor on matters relating to land ownership or transfer of ownership by lease, assignment is necessary, else such transaction would be null and void (Section 26, Land Use Act, 2004). The problems facing Land Administration and Cadastre system of developing Nations include lack of efficiency, transparency, security and organized database; high cost of transaction and high time complexity (Shuaib *et al*., 2022). To assess the possibility of the blockchain technology to address these issues, the research questions is, how can a cryptographic blockchain for Land Administration and Cadastre system be developed and maintained for a developing and underdeveloped countries?

LITERATURE REVIEW

Introducing web3 as a solution requires a brief insight into the previous web generation. The initial Web is a linked information system, which is based on graph and link organization mode. A significant feature of Web 1.0 applications is static pages. Visitors are permitted to perform a few simple operations, such as clicking, reading and downloading from static websites. Web 2.0 was developed and built on the previous. It is capable of writing and uploading on the internet which promotes interactions on the web. Other added advantages of this generation are novel technologies (Java script, XML) enjoyed on the web. This also brought light into the entertainment industry via social media like Facebook, TikTok and Twitter (Gan *et al*., 2023). To improve on Web 2.0 technology, Web 3.0 and Web3 are built to break monopolies, which are the default constraint of Web 2.0 (Gan *et al*., 2023).

Table 1: Differences among Stages of Webs

S/N	Web	Period	Architecture	Representative Products	Characteristics	Benefit Distribution
1	Web 1.0	1989 – 2001	centralized	Yahoo, Sina, Netscape	host-generated content, host-generated authority	Platform monopoly
2	Web 2.0	2004 – now	centralized	Baidu, Google, Facebook	host-generated content, host-generated authority	Profit-sharing (platforms and netizens)
3	Web 3.0	2006 – now	Distributed model, decentralized	Tor, Twine	user-generated content, user-generated authority, efficiency and intelligence, adopts solid pod storage, data records can be modified or deleted effortlessly.	Peer-to-peer, RDF schema, resource description framework
4	Web3	2014 – now	distributed mode, decentralized	Ethereum, Binance, Core DAO, etc.	user-generated content, user-generated authority focuses on Security and ownership, utilizes a cryptocurrency digital wallet, Data records are difficult to modify or delete.	Blockchain, smart contract, cryptocurrency

Source: Gan *et al*. (2023) and Wan *et al.* (2023)

The application of Web3 can be by blockchain, smart contract, decentralized finance, non-fungible token, decentralized autonomous organization, and Metaverse (Wan *et al*., 2023). Among all these, the most applicable form of Web3 in the world of Surveying and Geoinformatics, Land Administration and ownership transaction is the Non-Fungible Token, a special and unique kind of digital token of collection that cannot be divided, unlike a Bitcoin, Ethereum and other tokens that can be divided (Fungible tokens). To effectively adopt a Web3 technology to solve land transaction and administration related problems, there is a need to have the blockchain technology.

NFTs and Marketplaces

NFTs are unique tokens which cannot be exchanged 'like-for-like', making it suitable for identifying something or someone in a unique way. NFT is a type of Cryptocurrencies that is derived by smart contracts. As Ethereum cryptography gave birth to other blockchains (other than the Bitcoin), so are the non-fungible tokens built on ERC-20, ERC-721, and ERC-1155 (Kim, 2021; Patil, 2020). However, it is a remarkable effort that recent blockchains are implementing their versions of NFTs and smart contracts that is Ethereum Virtual Machine (EVM) supported. Such blockchains include Core DAO, Binance, Polygon Network, to list but a few.

The trends in blockchain for land right as stated by Biasolo (Eder, 2019), can also be adopted in performing land ownership transactions on blockchains such as: public registries, facilitating the recordkeeping of relevant transactions; Tokenized trading: tokenization of the registered survey plan for trading on a blockchain as NFTs; and trading such NFTs through Cryptocurrency (native tokens) of the blockchain.

(a)

(b)

Figure 1: (a) Template 1 (b) Survey Plan

Transacting Survey Plan as Art NFT

The Survey plans were minted into an Art NFT on the Core DAO blockchain on YoungParrot marketplace as follow;

1. Create a collection account on the desired market place;
2. Validate and confirm the created NFT collection account;
3. Convert the survey plan into an electronic format acceptable by the NFT blockchain (JPG, JPEG, PNG, GIF, SVG, MP3, MP4, WEBM, OGG, MOV, WAV, GLB, GLTF formats but must be less than of 100mb size);
4. Select the NFT categories you wish to mint (Art NFT category in this case);
5. Mint the art into a Non-Fungible token on the Blockchain; ascribing NFT Name (Survey Template), descriptions, metadata and required information. This also includes the percentage you would like to earn whenever the buyer wishes to re-sell again.

The descriptions and metadata (like the geographical description beacon numbers and coordinates of the

MATERIAL AND METHODS

In this paper, a cryptographic blockchain technology was used to transact two sets of "Survey Plan templates" that was minted as art NFTs (Figure 1), with the aim to practically examine the possibility of land ownership transaction on cryptographic blockchain. Two accounts (Account1 and Account2) were created in YoungParrot NFT marketplace built on Core blockchain. NFT transactions (sales and transfer) were performed between these two accounts. Due to the high cost of Ether and transactions on Ethereum blockchain network, core blockchain was adopted as an alternative.

Data Acquisition

The sets of data used were survey plan template titled "Template 1" and "Survey Plan". These survey plans were drawn for the purpose of experimenting the transaction of land and landed property ownership on Web3 (see Figure 1).

instrument/land; the name of the previous owner; the name and address of the approved office that processed the document initially etc.) would be the required information to identify the Registrable instrument in question. This would be made available only to the buyer/benefactor.

To achieve the aim of the work, the survey plan template was sold and the survey plan was transferred to another account on the same blockchain. This is to consider the two occasions of buying and selling landed properties and the ownership transfer on the ground of gift tenure or devolution of landed property, lease, gift and so on.

RESULTS AND DISCUSSION

Core blockchain is a Web3 decentralized blockchain built to ensure security, scalability and decentralization with a minimum of three confirmations for a successful transaction (Liu, 2023). Minting the plans on Account1 and transacting them with Account2 on the Core blockchain can be traced using the wallet addresses of either the sender or the receiver and the transaction hash/ID. Account1 initially minted 4 plans (as can be viewed in the blockchain), sold out one and transferred one.

Selling "Template 1" from Account1 to Account2, the transaction hash/ID is 0xd6e373d94a116e55d84c93cdf978418e738f2bb4ed6a0e73ec18ef2beb3effcd (https://scan.coredao.org) (see Figure 2). The plan was sold out for 1.0 CORE and the gas fee of 0.00578274 CORE and a loyalty fee of 0.025 CORE were charged, making a total of 1.03078274 CORE (see Figure 3).

Also, transferring "Survey Plan" from Account1 to Account2, the transaction hash/ID is 0x7f773bdb2f05301ac22066a8cd50d6423768a18d2d5aac88d9f677b7821d8484 (https://scan.coredao.org). The transaction fee was charged at 0.00110232 CORE (see Figure 4).

The scan.coredao.org records (as presented in Figure 4) show that the two NFT transactions (sales and transfer) were successful. Details of the transactions show how old is the transaction, including time and cost of transaction between the involved parties. The ownership of the plans was initially recorded as Account1, but after the sale and transfer, it was automatically transferred to Account2. The main difference between the sale and transfer transaction is that the NFT was sold to the buyer at the cost of 1 CORE and 0.03078274 CORE transaction and loyalty fees, while the transferred NFT was at no cost to the receiver. All the records are kept intact on the blockchain.

A survey plan as one of Registrable instruments of land ownership, which is also recognized as a legal document by land administration system of each countries remains a sensitive document which should be treated with high level of security. The availability of transactions on blockchain ledger (as shown in this study) will provide an open, transparent, safe and secured transaction system that can be adopted for solving transaction (sales and transfer) problems relating to land ownership in developing countries.

The concept of land ownership transactions is to transfer the ownership of a land from one person to another (be it by sales, assignment, lease, transfer, gift etc) with all rights preserved in respect to the agreement between the parties. At a successful transaction, the instrument transaction ID will read the buyer as new owner but will still record the seller as the previous owner.

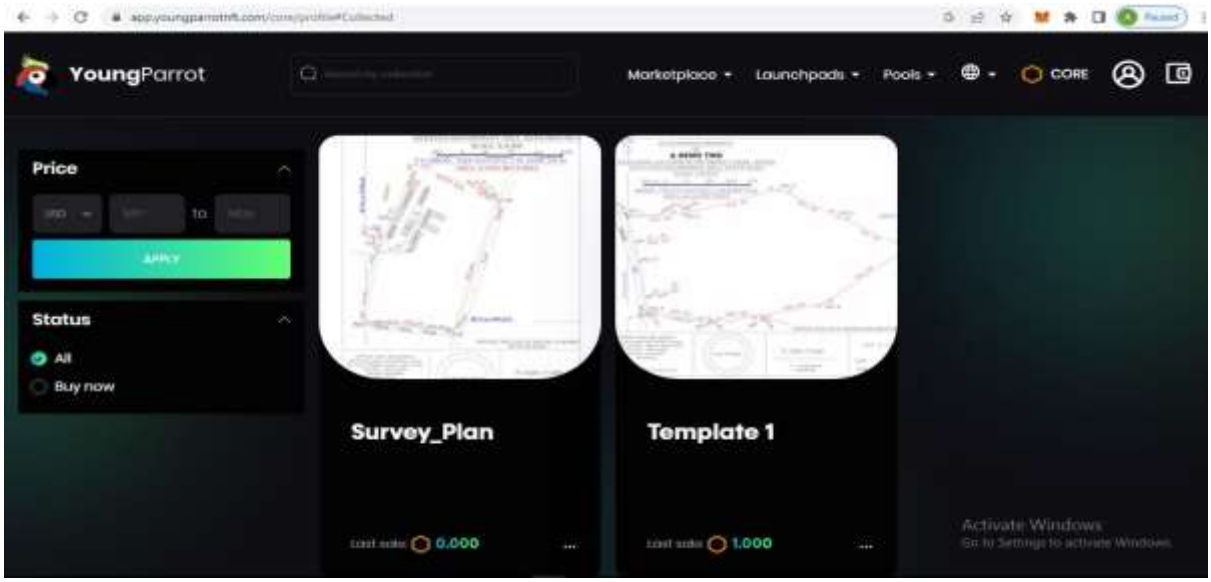

Figure 2: NFT Record on Account2

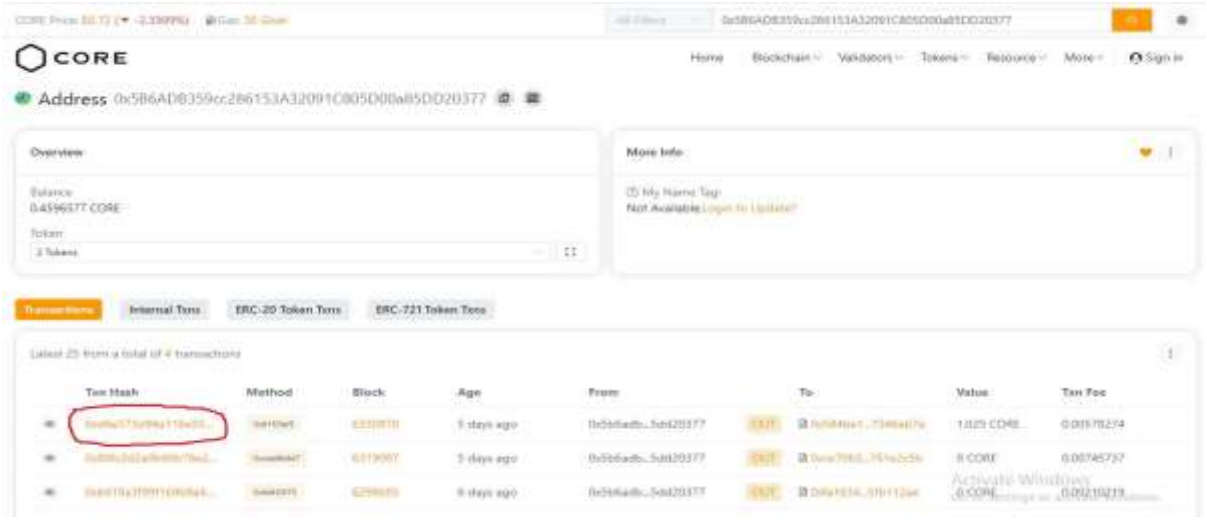

Figure 3: NFT Sales Transaction Details on Scan.coredao.org

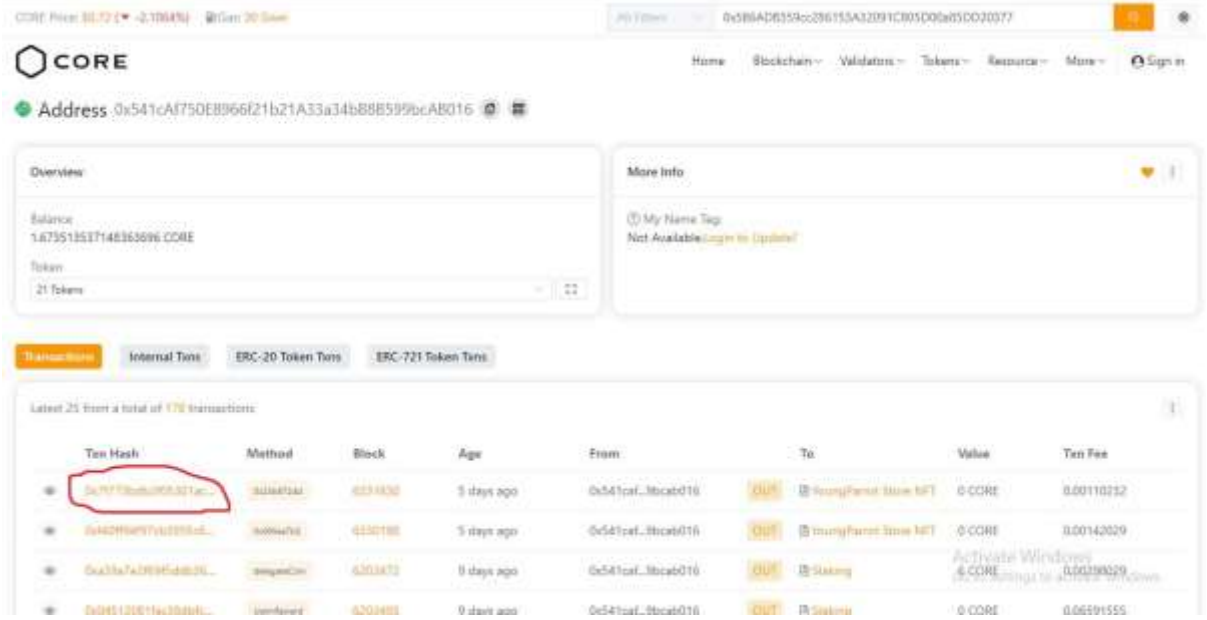

Figure 4: NFT Transfer Transaction Details on scan.coredao.org

To maintain a reliable and efficient adoption of the technology in the cadastre system for developing and underdeveloped countries, Nigeria for example, the first step would be to design a scalable Blockchain Ecosystem. For example (Figure 5), in the Ecosystem of land ownership transactions, SURCON (the professional governing body) would control the governance of the Decentralized Autonomous Organization (DAO) Blockchain (Busch, 2022); the SURCON State Committee on Ethics and Practice of the Surveying Profession (SSCE) and the Nigerian Institution of Surveyors (NIS) at the states level would be Transaction Validators in each state, while the approved offices (subsection 6, section 13, SURCON Enabling Act) would be the blockchain Nodes all over the country.

Recognized access into the blockchain to perform such transactions would be Registered Surveyors and all approved offices, thereby enforcing the laws of land ownership transactions and the rules and regulations of engagement within the ecosystem. With a hybrid DAO blockchain (where the general public will only be able to view and trace transaction, but will not be able to alter it), no land ownership transactions outside the blockchain would be recognized.

In this wise, the transactions on the blockchain should be considered as securing and confirming transactions within the surveying community ecosystem, other than the dark web) for the purpose of combatting insecurity, fraud and ensuring a well-structured database of land ownership transactions.

Since a survey plan is one of the Registrable instruments of land ownership, if a Survey plan template could be minted as art NFT and transacted on a cryptographic blockchain, so could other documents.

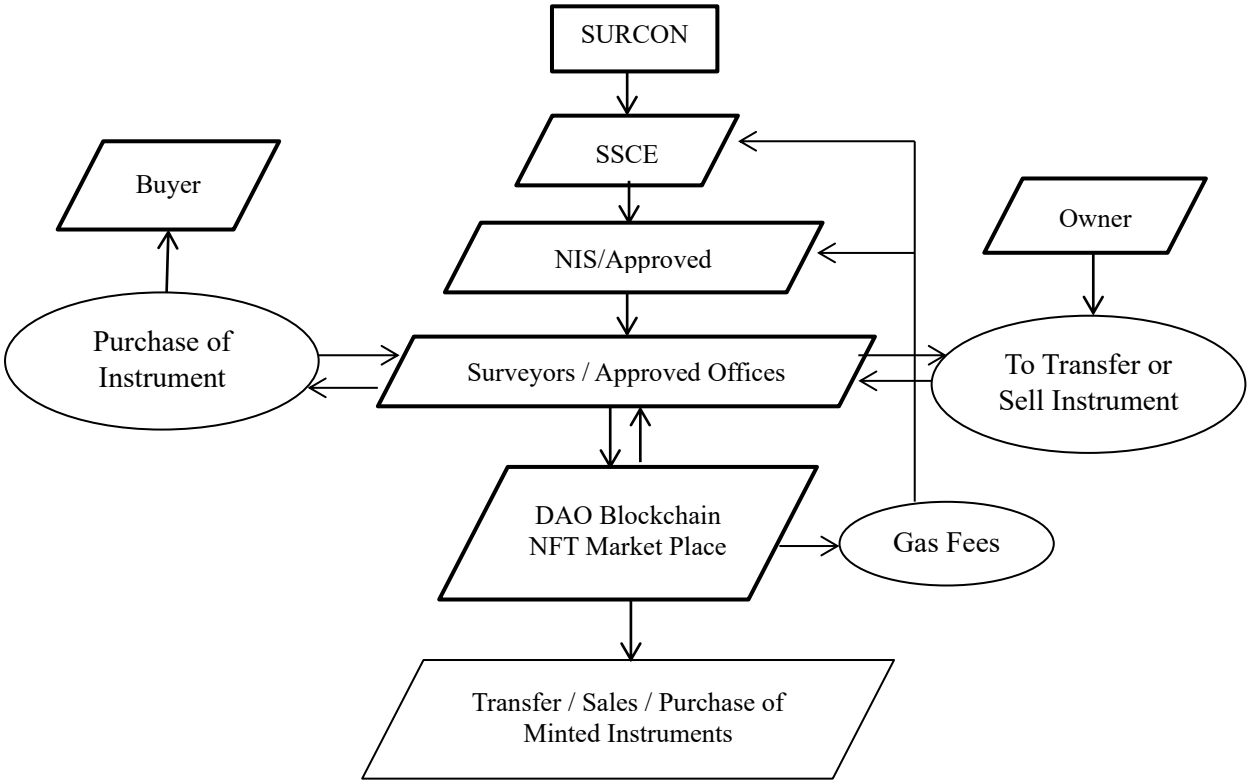

Figure 5: Proposed Structure of Blockchain Ecosystem

CONCLUSION

The possibility of transacting Survey plans on Web3 via a non-fungible token on a decentralized blockchain has been successfully carried out by preparing them as art NFTs on Core blockchain (a secure, scalable and decentralized blockchain) in the YoungParrot NFT marketplace. An NFT called "Template 1" was minted and sold while the "Survey Plan" NFT was minted and transferred. All the transaction details are recorded and detailed on the blockchain ledger and can be viewed anytime to promote security, transparency and a well-structured database of land transactions.

Transactions on Web3 (blockchain) is a promising technology not only to the cryptographic world but in the application of the technology in Land Ownership transactions, like in the professions of Surveying, Architecture, Urban and Regional Planning etc. This research work is not a financial advice, but an insight into what the Web3 technology has to offer to the Surveying profession in the constantly evolving world of technology. It is important to further look into the possibilities of adopting the technology for land administration and ownership transfer by other related professional fields. Further works could be done on the conversion of the minted art NFT back into actual Survey plan (instrument) that will maintain its original scale and properties.

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Are Holidays or Festive Periods to blame for Seasonal Spikes in Road Traffic Accidents in Nigeria?

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Over the years, citizens have characteristically viewed festive and holiday seasons in Nigeria as a period when there are spikes in traffic and road crashes. These spike in road crashes have been ascribed to some spiritual or mystical powers which often possess the road ways especially the intercity or highways within the country. The paper examined the impact of holiday and festive periods on the recorded road traffic accident cases in Nigeria for a period ten years (2012 – 2021) using weekly data obtained from the Federal Road Safety Corps Office, the research adopted exploratory data analysis conducted on the Road Traffic accidents data suggests that the data is not normally distributed (Shapiro-Wilk = 0.94, p = .002) hence Kruskal-Wallis test -a non-parametric statistics equivalent of Analysis of Variance (ANOVA) was adopted for test of difference. The aim was to isolate the actual period when road accidents occurred most between ordinary day, non-festive holiday and festive holiday periods. National holiday and festive dates were marked on the data sheet and a hypothesis was tested. A Kruskal-Wallis test was conducted to compare the median ranks of three groups: Festive Holiday, Non-holiday, and Non Festive Holiday. The test revealed a significant difference among the groups ($\chi2(2) = 11.02$, p = .004.). Post hoc tests using the Dunn-Bonferroni method showed that Festive Holiday (FH) and Non-holiday (NH) groups had a significantly different median rank (KW = 58.38, Mdn_FH = 220, Mdn_NH = 180, adj.p = .007). Similarly, the Festive Holiday and Non Festive Holiday (NFH) groups had a significantly different median rank (KW = 84.16, Mdn_FH = 220, Mdn_NFH = 177.5, adj. p = .017). However, there was no significant difference in median rank (Mdn) between Non-holiday and Non Festive Holiday groups (KW = 25.77, Mdn_NH = 180, Mdn_NFH = 177.5, adj. p = .948). The study concluded that most road traffic accidents occur during festive holidays.

Keywords: Road Traffic Accidents, Holiday, Non-Holiday, Festive holiday

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INTRODUCTION

Road traffic accidents represent a significant public health problem worldwide, resulting in injuries, deaths and economic losses. Studies have consistently shown that RTA rates are seasonal, with different accident patterns at certain times of the year. Understanding the factors that contribute to this seasonality and the impact of holidays on crash rates is critical to improving road safety measures and crash prevention strategies. Evidence of seasonality in RTA data is well documented in the literature. Alireza (2013) identified weather conditions, particularly those related to winter, as a significant factor in the seasonality of accidents. Winter weather, characterized by adverse conditions such as ice and snow, results in higher accident mortality rates. Iwok (2016) highlighted that behavioural factor, which are often overlooked in time series analyses, also play a role in the seasonality of RTAs.

A notable seasonal trend observed in the literature is the occurrence of accidents during ember months, which include September to December (Baloye & Palamuleni, 2017). Ojeniyi *et al*. (2015) reported that September in particular recorded the highest accident frequency. This trend is consistent with the idea that accidents are more common during this period (Baloye & Palamuleni, 2017). In addition to seasonality, studies have also examined the influence of weekends and holidays on RTA prices. Phil (1989) and Solanki and Mittal (2016) found that weekends, particularly Saturdays, were associated with higher accident rates. These results suggest that behavioural factors related to weekend leisure activities and relaxation contribute to increased accident rates. Holidays were also associated with increased RTA rates. Anowar (2012) reported that accidents resulting in death and personal injury are overrepresented during vacation. Celik and Oktay (2014) conducted a study in Turkey and found a statistically significant increase in the number of traffic accidents during official holidays. Similarly, Wiratama *et al*. (2021) found that road accidents on public holidays in the UK are more likely to result in death or serious injury compared to non-holiday days.

However, there are conflicting reports in the literature. Bruce (2016) analysed Australian road fatality data and found no evidence of an increase in road fatalities during the Christmas or Easter periods. Anowar et al. (2010) examined holiday crashes in Alberta and found a decreasing trend in the risk of traffic fatalities during the holidays. While holidays appear to influence RTA rates, it is important to further investigate which specific

holidays have a greater impact. Arnold and Cerrelli (1987) conducted a study to identify specific holidays associated with increased traffic fatalities. A procedure was presented that is useful to forecast the expected fatality count for each upcoming holiday period. The number of fatalities to be expected on a particular holiday can be roughly forecast by using the averages observed during 1975-1985. The forecast is the product of three quantities: the average for that holiday relative to its weekday, the average for that weekday relative to all days of its month, and 11-year average. The experience of the l1-years shows that the average Memorial Day produces about 23% more fatalities than does the average other days in the month of May of the same year. However, research of this nature is limited in Nigeria.

The conflicting findings in the literature emphasize the need for further research, especially in the Nigerian context, to identify the types of holidays that have a more significant effect on RTA rates. Such investigations are crucial for developing targeted road safety measures and accident prevention strategies that can help reduce the burden of RTAs and save lives. Road traffic accident is one of the leading causes of injuries and deaths worldwide. In Nigeria, there are a lot of myths associated with it. Some believe that accidents are caused by bad luck or evil spirits especially at certain calendar period called “ember months”. The focus of this study is to determine the actual period when road accidents occurred the most, differentiating between ordinary days, non-festive holidays, and festive holidays. This present study is conducted in response to the need to identify the specific types of holidays that record the highest RTA. The objective is therefore to find out if there is any significant difference in the RTA between ordinary days, festive holidays and non-festive holidays with a view to isolating the holiday type recording highest RTA cases.

RESEARCH METHODOLOGY

For this study, a 10-year weekly secondary data (2012 - 2021) was extracted from the weekly RTA reports from the 36 States and the Federal Capital Territory from the database of the Federal Road Safety Corps (FRSC) Headquarters, Abuja. The focus of this study is to determine the actual period when road accidents occurred the most, differentiating between ordinary days, non-festive holidays, and festive holidays. The Organisation defined a week of seven days as that which starts on a Friday and ends on a Thursday. In identifying the week that a public holiday falls, two steps were followed. First, all the official public holiday dates were obtained and tabulated as shown in Table 1 and second, the week start and weekend days for weeks 1 – 53 for the 10 years period, resulting in 525 rows of data, were accordingly computed and properly tabulated. Consequently, the first week of 2012 starts on Friday, December 30, 2011, and ends on Thursday, January 5, 2012 while the last week of 2012 (Week 53) starts on Friday, December 28, 2012, and ends on Thursday, January 3, 2013.

In similar manner, the first week of 2013 begins on December 28, 2012 and ends on January 3, 2013, i.e. week 1 of 2013. The last week of 2013 begins on December 27, 2013 and ends on January 2, 2013 .2014, i.e. week 1 of 2014. The last week of 2019 (week 52) includes the last two days of 2019 and the first five days of 2020. The last week of 2020 (Week 52) includes the last four days of 2020 and the first three days of 2021, as the ISO weekly system allows up to three days of the following year to be included in the last week of the current year.

Table 1: National Holidays from 2012 – 2021

Holiday	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
New Year Day	01-Jan	01-Jan	01-Jan	01-Jan	01-Jan	01-Jan	01-Jan	01-Jan	01-Jan	01-Jan
President Buhari Re-Election Campaign								21-Jan		
Election Day								22-Feb		
Id el Maulud	05-Feb	24-Jan	13-Jan	02-Jan	12-Dec	01-Dec	20-Nov	09-Nov	29-Oct	19-Oct
Id el Maulud holiday							21-Nov	11-Nov		
Good Friday	06-Apr	29-Mar	18-Apr	03-Apr	25-Mar	14-Apr	30-Mar	19-Apr	10-Apr	02-Apr
Holy Saturday	07-Apr	30-Mar	19-Apr	04-Apr	26-Mar	15-Apr	31-Mar	20-Apr	11-Apr	03-Apr
Easter Sunday	08-Apr	31-Mar	20-Apr	05-Apr	27-Mar	16-Apr	01-Apr	21-Apr	12-Apr	04-Apr
Easter Monday	09-Apr	01-Apr	21-Apr	06-Apr	28-Mar	17-Apr	02-Apr	22-Apr	13-Apr	05-Apr
Workers' Day	01-May	01-May	01-May	01-May	01-May	01-May	01-May	01-May	01-May	01-May
Swearing in	29-May	29-May	29-May	29-May	29-May	29-May	29-May	29-May	29-May	29-May
Democracy Day	12-Jun	12-Jun	12-Jun	12-Jun	12-Jun	12-Jun	12-Jun	12-Jun	12-Jun	12-Jun
*Eid el Fitr	20-Aug	08-Aug	28-Jul	17-Jul	05-Jul	26-Jun	15-Jun	04-Jun	24-May	12-May
*Eid el Fitr				18-Jul	06-Jul	27-Jun	16-Jun	05-Jun	25-May	13-May
*Eid el Fitr holiday	21-Aug	09-Aug	29-Jul	19-Jul			17-Jun		26-May	
*Eid el Fitr holiday							18-Jun			
Independence Day	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct
Eid el Kabr	20-Oct	15-Oct	06-Oct	24-Sep	12-Sep	02-Sep	21-Aug	12-Aug	30-Jul	20-Jul
Eid el Kabr holiday		09-Aug	07-Oct	25-Sep	13-Sep	03-Sep	22-Aug	13-Aug	31-Jul	21-Jul
Christmas eve	24-Dec	24-Dec	24-Dec	24-Dec	24-Dec	24-Dec	24-Dec	24-Dec	24-Dec	24-Dec
Christmas Day	25-Dec	25-Dec	25-Dec	25-Dec	25-Dec	25-Dec	25-Dec	25-Dec	25-Dec	25-Dec
Boxing day	26-Dec	26-Dec	26-Dec	26-Dec	26-Dec	26-Dec	26-Dec	26-Dec	26-Dec	26-Dec
Christmas Day off										27-Dec
Boxing Day off										28-Dec
New Year Eve	31-Dec	31-Dec	31-Dec	31-Dec	31-Dec	31-Dec	31-Dec	31-Dec	31-Dec	31-Dec

***It should be noted that particular days of religious festivals vary from year to year, holidays are usually declared for more than one day. If the day falls on a weekend, government often declares next two working days as holidays. Hence, such holidays like Eid, Easter and Christmas holidays occur in more rows in the Table unlike fixed holidays like Workers' (May 1), and Independence (October 1) days*

Thus, the New Year (January 1, 2012) falls in Week 1 that lies within December 30, 2011 - January 5, 2012 (Table 2). Similar Tables were constructed for the other years. Thus, we found that January 1 of 2015 fell within Week 53: December 26, 2014 - January 1, 2015 and so on. As a result of this system of dating, some years have 52 weeks while others have 53 weeks. In the data table, a variable "festive week" was created in which Weeks 1 – 53 were identified as festive holiday week, non-festive holiday week and non-holiday week.

It was assumed that people do not travel on the exact days of the holiday, but they do so few days to the holiday from their bases and few days after the holiday to return to their bases, especially the non-civil servants. Hence, if a holiday falls within a week, that week is marked as holiday week. A preliminary exploratory data analysis conducted on the Road Traffic accidents data suggests that the data is not normally distributed (Shapiro-Wilk = 0.94, p = .002) hence Kruskal-Wallis test -a non-parametric statistics equivalent of Analysis

of Variance (ANOVA) was adopted for test of difference.

Table 2: Days that fall within each of Week 1 to Week 52 in 2012

- Week 1: **December 30, 2011 - January 5, 2012**	- Week 20: May 11 - May 17	- Week 39: September 21 - September 27
- Week 2: January 6 - January 12	- Week 21: May 18 - May 24	- **Week 40: September 28 - October 4**
- Week 3: January 13 - January 19	- **Week 22: May 25 - May 31**	- Week 41: October 5 - October 11
- Week 4: January 20 - January 26	- Week 23: June 1 - June 7	- Week 42: October 12 - October 18
- Week 5: January 27 - February 2	- **Week 24: June 8 - June 14**	- **Week 43: October 19 - October 25**
- Week 6: **February 3 - February 9**	- Week 25: June 15 - June 21	- Week 44: October 26 - November 1
- Week 7: February 10 - February 16	- Week 26: June 22 - June 28	- Week 45: November 2 - November 8
- Week 8: February 17 - February 23	- Week 27: June 29 - July 5	- Week 46: November 9 - November 15
- Week 9: February 24 - March 1	- Week 28: July 6 - July 12	- Week 47: November 16 - November 22
- Week 10: March 2 - March 8	- Week 29: July 13 - July 19	- Week 48: November 23 - November 29
- Week 11: March 9 - March 15	- Week 30: July 20 - July 26	- Week 49: November 30 - December 6
- Week 12: March 16 - March 22	- Week 31: July 27 - August 2	- Week 50: December 7 - December 13
- Week 13: March 23 - March 29	- Week 32: August 3 - August 9	- Week 51: December 14 - December 20
- Week 14: March 30 - April 5	- Week 33: August 10 - August 16	- **Week 52: December 21 - December 27**
- Week 15: April 6 - April 12	- **Week 34: August 17 - August 23**	- **Week 53: December 28, 2012 - January 3, 2013**
- Week 16: April 13 - April 19	- Week 35: August 24 - August 30	
- Week 17: April 20 - April 26	- Week 36: August 31 - September 6	
- **Week 18: April 27 - May 3**	- Week 37: September 7 - September 13	
- Week 19: May 4 - May 10	- Week 38: September 14 - September 20	

National public holidays are in bold face

RESULTS AND DISCUSSION

Annual RTA trend (2012 – 2021)

A total of 106,789 RTA cases were recorded during the 10-year study period of 2012 to 2021. The annual trend reveals a high incidence of RTA from 2012 to 2014, a downward trend from 2015 to 2018 and a spike from 2019 to 2021.

Table 3: Descriptive Statistics of the Annual RTA Rates (2012 – 2022)

Year	Median	Mean	Std. Deviation	Minimum	Maximum	Sum
2012	365	365	77	162	718	19004
2013	256	256	29	207	367	13319
2014	197	196	34	121	336	10203
2015	164	165	27	87	237	8767
2016	161	161	28	36	248	8559
2017	154	153	25	101	223	7931
2018	156	155	36	14	280	8218
2019	186	188	43	18	299	9955
2020	198	199	56	73	317	10531
2021	197	198	30	147	279	10302

Weekly Trend

A downward trend in RTA can be noticed between Week 1 and around Week 316 where the trend starts a gradual upward movement.

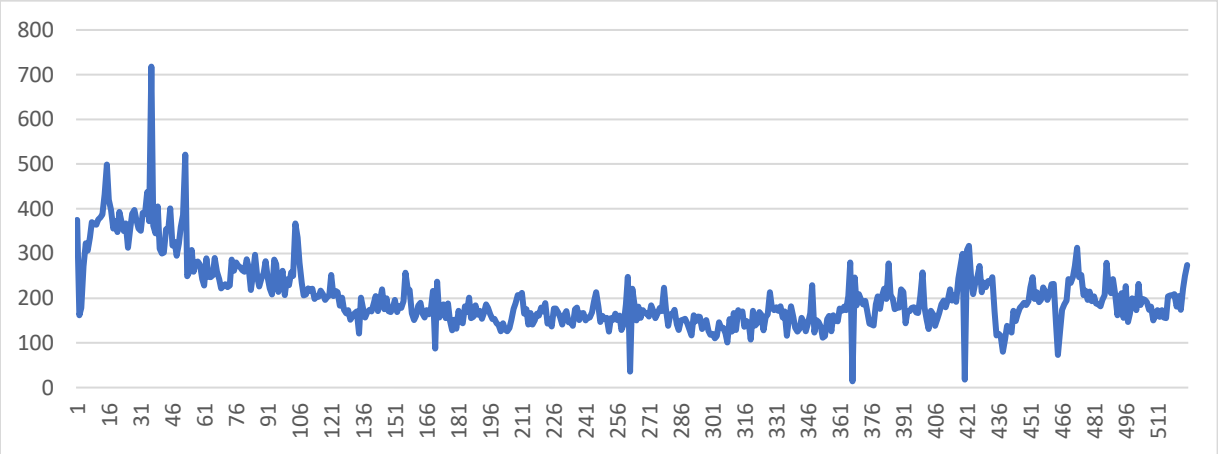

Figure 1: Weekly RTA trend from 2012 – 2021

Distribution Pattern of the RTA Data

When partitioned into festive holiday, non-festive holiday and non-holiday weeks, the distribution pattern of RTA shows the presence of outliers in the data. However, the festive holiday week's data is fairly normally distributed with mean almost equal to median compared to the non-festive holiday and non-holiday weeks as shown in Figure 2.

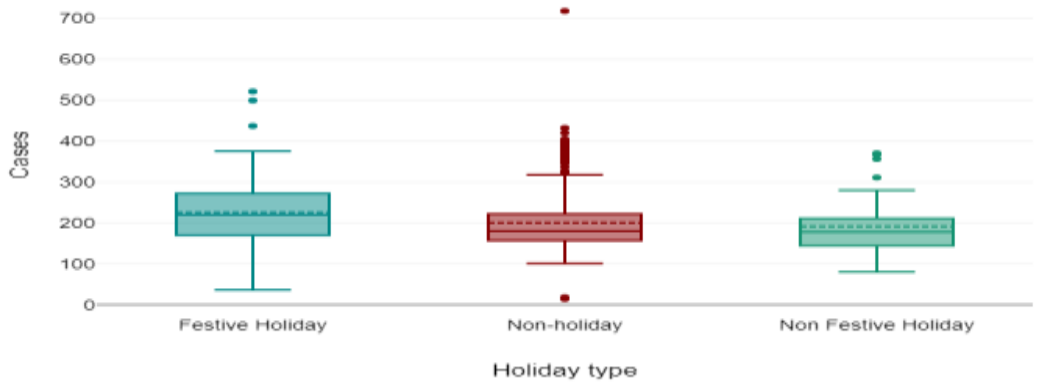

Figure 2: Distribution of RTA cases for time periods (2012 – 2021)

Relationship between RTA during Holiday and Non-Holiday Periods

The weeks in the study time period (2012 – 2021) were partitioned into three periods: Non-Holiday, Festive Holiday and Non-Festive Holiday and a hypothesis was set up to test for significant difference in the RTA cases in the three periods.

Hypothesis testing

Ho: There is no statistically significant difference in the road traffic accident cases among the three categories of periods.

Descriptive statistics yielded by the Kruskal-Wallis analysis shows that the festive holiday weeks have a higher median value (220) than non-holiday (180) and non-festive holiday (177.5) periods.

Table 4: RTA rates in the three periods

Groups	n	Median	Mean Rank
Festive Holiday	73	220	315.13
Non-holiday	414	180	256.75
Non-Festive Holiday	38	177.5	230.97
Total	525	182	

A Kruskal-Wallis test was conducted to compare the median ranks of three groups: Festive Holiday, Non-holiday, and Non Festive Holiday. The test revealed a significant difference among the groups ($\chi 2(2) = 11.02$, $p = .004$).

Post hoc tests using the Dunn-Bonferroni method were then conducted to determine which pairs of means were significantly different from each other after the Kruskal-Wallis test (KW). The results showed that Festive Holiday (FH) and Non-holiday (NH) groups had a significantly different median rank (KW = 58.38, Mdn_FH = 220, Mdn_NH = 180, adj.p = .007). Similarly, the Festive Holiday and Non-Festive Holiday (NFH) groups had a significantly different median rank (KW = 84.16, Mdn_FH = 220, Mdn_NFH = 177.5, adj. p = .017). However, there was no significant difference in median rank (Mdn) between Non-holiday and Non-Festive Holiday groups (KW = 25.77, Mdn_NH = 180, Mdn_NFH = 177.5, adj. p = .948).

Previous studies have identified "Ember months", that is, the last four months of the year (Ukibe *et al*., 2011; Omobowale *et al.,* 2011) as the most critical period while other studies pointed out to holiday periods (Anowar *et al.,* 2021) while others argued in favour of holiday periods (National Safety Council (2023) or specifically festive periods (Oyenuga *et al.,* 2006). This paper considered all the suggested periods and tested for the difference in the RTA cases during Festive Holiday, Non-holiday, and Non-Festive Holiday and found a statistically significant difference.

The results showed that there was a significant difference between festive holidays (FH) and non-holidays (NH). Likewise, the "Festive Holidays" and "Non-Festive Holidays" (NFH) groups had a significantly different median but no significant difference between non-holiday and non- festive holiday periods. This conclusion has thus pinpointed festivities as the undisputable factor responsible for high cases of RTA in Nigeria. The rise in RTA cases during the festive holiday season, as noted by Omobowale *et al.* (2011) is connected to the desire by merchants and transporters to earn additional money resulting from increase in economic activities.

Table 5: Dunn-Bonferroni test

	Test Statistic	Std. Error	Std. Test Statistic	p	Adj. p
Festive Holiday - Non-holiday	58.38	19.26	3.03	0.002	0.007
Festive Holiday - Non-Festive Holiday	84.16	30.34	2.77	0.006	0.017
Non-holiday - Non-Festive Holiday	25.77	25.71	1	0.316	0.948

Adj. p: Values adjusted with Bonferroni correction

CONCLUSION

The study provided empirical evidence to support the notion that festive holidays in Nigeria are associated with a higher frequency of road traffic accidents. Despite the significant finding, a daily rather than weekly data that would have allowed the specific accidents rates few days before, during and after a festive day would have been more useful. It should be noted that, apart from the drivers' discipline or indiscipline, weather condition and state of the roads are crucial factors that also play a role. Therefore, it is important for drivers to be cautious, reducing speed, maintaining a safe distance from other vehicles, and being prepared for unexpected obstacles. By taking these precautions, accidents can be minimized during the festive period. For future studies, a comprehensive accident record indicating the day, weather and road condition should be explored. The results of this study also point to the need for increased awareness, enforcement, and targeted interventions during these peak periods to mitigate the risks associated with road accidents.

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