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Technological Innovation and Building Design Considerations on Sustainable Urbanism in Lagos State, Nigeria

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ABSTRACT

Creating cities that are economically, environmentally and socially sustainable will be one of the biggest tasks of this century in the face of current fast urbanization, environmental degradation and natural resource depletion. Based on this assertion, this study investigated the role played by building designers in ensuring sustainable human settlement and communities (sustainable urbanism). The study adopts a survey research technique which involves the use of well-structured questionnaire to elicit information from the respondents. Simple random sampling technique was used to distribute 220 copies of questionnaire among the residence of three selected estates namely, County Estate (Agege), Unity Estate (Ikorodu) and Arowojobe Estate (Victoria Island) across the three senatorial districts in Lagos State, Nigeria. The survey data was analysed using SmartPLS3.0 and SPSS version 23. Findings revealed that two (2) out the five (5) hypothesized relationships between sustainable building design and sustainable urbanism are insignificant. P-values of 0.216 and 0.91 at 95% significant level for energy conservation and optimization of site potential respectively indicates that energy efficient designs and the exploitation of nature to the benefits of built environment are not of utmost priority to building professionals in the design and construction of residential buildings in the study area. However, the study found statistical significance but negative beta value [P = 0.002; (β) = -1.122] and [P = 0.001; (β) = -0.582] for water conservation and indoor environmental quality respectively. The study likewise established from positive beta value (β) of 0.307 and significant P-value 0.02 for collaborative design approach that built environment will be more enhanced if construction professionals brainstorm and work hand-in-hand to address other grey areas militating against the preservation of the ecosystem in the study area. A statistical significant value of 0.000 at 95 % significance level shows that sustainable building design is significant to the model. Hence, the null hypothesis stated above is rejected. However, the study observed lack of mediating effect on technological innovation from the indirect effect between sustainable building design and sustainable urbanism via role of technological innovation is statistically insignificant (P-value of 0.67 and 0.326) at 95% significant level. Therefore, the sustainable development of man and his environment in emerging cities largely depend on adoption of technological innovation and the sustainable practices in building construction projects. The study recommends that building construction professionals should take concerted efforts towards sustainable building construction practices to minimise the level of environmental degradation and resource depletion in the interest of man in the nearest future

Key words: built environment, sustainable urbanism, sustainable building, urbanization, environment degradation

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INTRODUCTION

One of the major reasons for induced pressure on natural resources recently in most developing cities result from high demand for buildings either for commercial or residential purposes [1]. This upsurge increases in building construction in the 21st century due to immense economic activities and quest of man to own at least a home undoubtedly has produced cities that are not just notorious and monotonous in appearance, but posing serious threats to social, economic and environmental sustainability of the ecosystem [2]. [3] noted that creating cities, towns and communities that are economically, environmentally and socially sustainable, which meet the

challenges of population growth, natural resource depletion and climate change will be one of the biggest tasks of this century. This is attributed to the fact that most emerging cities in developing countries have not been supplied with sustainable urban infrastructures especially buildings, hence compromising the comfort of urban populace and a bane in ensuring conservation of natural resources [4].

Sizeable number of literature upheld that the construction industry have been the main consumers of resources, energy and materials globally. It is estimated that buildings and their associated functions are responsible for 40% of the world energy consumption. They generate 30% of the carbon (iv)oxide (CO_2) emission and approximately 40% of all manmade waste, hence a formidable contributor to degraded ecosystem in urban centres [4, 5, 6, 7, 8, 9, 10]. As such, [6] affirm that buildings have a major impact upon the physical environment and the resources therein, due to the materials and techniques used to design and construct them.

According to [11], 98% of large emerging cities do not meet WHO air quality guidelines. Moreso, there is a greater demand for water resources than any other time in history due to climatic downturn, increasing population and urbanization. About 40% of the world's people lived in regions that directly compete for shared water resources [12]. The challenges faced in public water supply in most cities and developing countries are majorly due to increasing population size and poor operational efficiency of existing waterworks. Under a largely urbanized city like Lagos State, critical water shortage in the nearest future is imminent if pragmatic steps are not taken to bridge the public water supply-demand gap [13]. [14] opined that *"it is in emerging cities like Bogota (Columbia), Lagos (Nigeria), Mumbai (India) that the battle for a sustainable future will likely be lost or won".* Consequently, at a time of uncontrolled globalization and increasing world population which has placed heavy tow on already diminishing natural resources, there is an urgent need for a radical shift towards a holistic strategy for sustainable urban planning/design, with respect to environmental and social-economic sustainability, herein referred to as sustainable urbanism. This implies maintaining a "harmonious balance" between buildings, man and his environment [15]. Sustainable Urbanism hinges on high-performance buildings and high-performance infrastructure where human access to nature are core values, and aspects of sustainability, functionality and interconnectivity are more important than mere designs [7]. There is growing consensus and commitment among building practitioners in developed countries that to create a sustainable urban environment (cities), a move for eco-friendly building designs with utmost regards for natural resources conservation such as optimal land use, water and energy efficiency and as well as pollution control will be of utmost priority [16, 17]. Nevertheless "We can't solve problems by using the same kind of thinking we used when we created them. In view of this assertion, a synergistic integration of people, process and technology is imminent by any industry to develop in the 21st century. The backbone of effective urbanization is the incorporation of 21st Century technologies (otherwise called 4th Industrial revolution, 4IR) in new and existing infrastructures in order to achieve United Nations' Sustainable Development Goal 11 of Sustainable Cities and Communities by 2030. Digital technological disruption caused by rapid development has driven positive changes in the practices of many industries such as manufacturing, automobile and banking industry. However, the construction companies in Africa have been reluctant about plenarily embracing the newly emerging technological innovations of this century [18]

Hence, in view of global socio-environmental sustainability drive of United Nation's Sustainable Development Goals (SDGs) 11 to enhance inclusive urbanization and capacity for participatory, integrated and sustainable human settlement in emerging cities called for the scrutiny between building design considerations and sustainable urban development in Lagos State Nigeria. Therefore, the study assessed the role played thus far by building designers in Nigeria construction industry in ensuring the preservation of the ecosystem and conservation of diminishing natural resources. Using new urbanism theory (which involves creating streets and buildings with sense of place focusing on preservation of ecosystem) as the underpinning theory, the study examined the effect of building design considerations on sustainable urbanism in Lagos State, Nigeria.

MATERIALS AND METHODS

Study Area

The study area is Lagos State, Nigeria. Lagos State is located in Southwest of Nigeria on the narrow coastal flood plain of the Bight of Benin. It lies approximately between longitude 2o 42'E and 3o 22'E and between latitude 6o 22'N and 6o 42' N. It is bounded in the North and East by Ogun State of Nigeria, in the West by the Republic of Benin, and in the South by the Atlantic Ocean. Lagos State has a coastline 180 km long. Water

bodies and wetlands cover over 40% of the total land area of the State with lagoons and creeks consisting 22 % of its area. An additional 12% is subject to seasonal flooding. Lagos State has a total land area of 3,577km^2 and a total population of over 21million

Population of the Study

The study population comprises building owners in three selected residential estates namely Arowojobe Estate in Victoria Island (Lagos Island LG) with 102 houses, Counting Estate, in Old Abeokuta road (Agege) with 116 houses and Unity Estate, in Ikorodu (Ikorodu LG) with 105 houses totaling 323. These LGAs have been strategically selected from the three senatorial districts; Lagos East, Lagos Central and Lagos West of Lagos State due to high number of recently constructed housing estates in these areas within the past ten years relative to other Local Government Areas in Lagos State.

Sample Size

The study used a sample size of 178 determined from a population of 323 using Yamane [19] formula

$n = N/[1+N (e^2)]$

n= corrected sample size, N = population size, and e = Margin of error (Moe), e = 0.05 based on the research condition.

Sampling Technique

Probabilistic sampling technique which was conducted in multiple stages was used for the study. The first stage involved use of Bourley's proportional allocation formula [19] to determine the minimum copies of questionnaire to be shared to each residential estates across the three senatorial districts in Lagos State.

Bourley's proportional allocation = n_h x S

Where n_h = population sample size (178)

N= total population (323)

S = Number of houses in each location

Table 1: Distribution of the sample size of the study

Location	Number of Houses	Minimum copies of Questionnaire distribution per location
Arowojobe Estate (Victoria Island)	102	56
County Estate (Agege)	116	64
Unity Estate (Ikorudu)	105	58
Total	**323**	**178**

The second stage involves the use of simple random sampling technique in selecting respondents whose opinion was sought in this study.

Data collection

The study made use of primary source of data through a well-structured closed-ended questionnaire which was self-administered to the respondents. The choice of adopting the data collection technique is its ability to provide an efficient use of time, energy and cost [20]. It also affords physical interaction with the respondents which help in seeking appropriate information on the subject matter.

Data Coding

Table 2 shows the codes used to represent the constructs of exogenous variable, sustainable building design captured with optimization of site potentials (OS), collaborative building design (CD), energy conservation (EC), water conservation (WC) and indoor environmental quality (ID). The endogenous variable, sustainable urbanism measured in terms of sustainability dimension (SS), compactness (CP) and connectivity (CT).

Table 2- Data Coding

Constructs	Codes
BUILDING DESIGN CONSIDERATIONS	
Optimisation of Site Potential	OS
Collaborative building design	CD
Energy conservation	EC
Water conservation	WC
Indoor environmental quality	ID
SUSTAINABLE URBANISM	
Sustainability dimension	SS
Compactness	CP
Connectivity	CT

Data Analysis

The data collected was analysed using both descriptive and inferential statistics with the aid of SPSS version 23 and SmartPLS3.0 respectively. Firstly, SPSS version 23 was used to carry data screening to ensure the suitability of data collected for inferential statistics and likewise to compute response rate of questionnaire and demographic information of the respondents. SmartPLS3.0 was used to determine the standard path coefficient of constructs of sustainable building design on sustainable urbanism in the study area. Also, study's hypothesis was assessed from the result of bootstrapped structural model of the study variables, sustainable building design (exogenous variable) and sustainable urbanism (endogenous variables).

RESULTS AND DISCUSSION

Response Rate

A total of 220 copies of questionnaire were distributed among residents of three selected across three senatorial districts namely, Lagos West, Lagos Central and Lagos East. Table 3 shows that out of a total of 220 copies of questionnaire distributed, 195 copies were retrieved from the respondents. Upon assessing the collected questionnaire for missing value through frequency count, it was observed that 183 representing 83.2% of the distributed quantity of questionnaire were duly and completely answered by the respondents, hence used for analysis. The result of a survey could be adjudged significant if the response rate is not lower than 30-40%. Hence, 83.2% response rate is considered significant for data analysis [21].

Table 3: Response rate of the study

Copies of Questionnaire	Frequency	Percent
Quantity Distributed	220	100.0
Quantity Retrieved	195	88.6
Quantity Analysed after data sorting	183	83.2

Demographic Information of Respondents

Table 4 consists of the frequency distribution of demographic information of respondents. Statistics show that the females were the highest respondents with 53.1% while the male is 46.9%. The study likewise observed that 65.6% of the respondents participated in this survey are entrepreneur followed by public servant with 6.0%, civil servant with 28.4%. Also, figures from Table 4 show that large number of the respondents captured are located in Agege with 35.5%, then Ikorodu with 33.3% and lastly Victoria Island with 31.2%. The modal figure for number of years of residence is 33.9% for 4-6years spent in the study area with least percentage of 8.1% represented by respondents who are stayed for just 1-3years. This means that majority of respondents whose opinion were sampled have handful foresight of the information required for the study. Lastly, the status of apartment occupied by the respondents was also considered. 52.5% of the respondents stay in personally developed buildings, 24.0% occupy purchased buildings while 13.1% and 10.3% occupy leased and rented apartments respectively. The considerable number of respondents staying in personally-developed and purchased buildings from their income/earnings further upholds the validity of the information provided on the building design considerations that may be influenced by the clients.

Table 4: Demographic Information of Respondents

Characteristics	Residents	
Gender		
Male	86	46.9
Female	97	53.1
Total	**183**	**100.0**
Number of Years of Residence		
1-3 Years	15	8.1
4-6 Years	62	33.9
7-10 Years	51	27.9
11 & above	55	30.1
Total	**183**	**100.0**
Profession		
Civil Servant	52	28.4
Entrepreneur	120	65.6
Public Servant	11	6.0
Total	**183**	**100.0**

Location of Respondents		
Ikorodu	61	33.3
Agege	65	35.5
Victoria Island	57	31.2
Total	**183**	**100**
Status of Apartment		
Rented	19	10.4
Leased	24	13.1
Purchased	44	24.0
Self Developed	96	52.5
Total	**183**	**100.0**

Effect of Sustainable Building Design on Sustainable Urbanism

Preliminary analysis to determine the suitability of measurement of the study variables is performed. The measurement or quality assessment model tests the internal consistency, convergent and discriminant validity and reliability of the constructs. Thereafter, structural model bootstrapping to establish the path coefficient, P-values, t-statistic of the constructs and variables under study is performed to evaluate the effect of sustainable building design on sustainable urbanism in the study area. The composite reliability values ranged for constructs of sustainable building design ranges 0.866 and 0.939 while the constructs for sustainable urbanism ranged from 0.836 and 0.906 after the deletion of six (6) items having cross-loadings making all other items have higher value above reliability threshold value of 0.7 as shown in figure 4.1 (PLS Algorithm for measurement model). This indicates that adequate internal consistency among items both variables under assessment [19]. Hence the measurements used for this study were within the acceptable levels to support the reliability of the constructs. The result of the quality assessment model of the constructs is presented in Table 5

Table 5: Quality Assessment Model

Construct Code	Cronbach's Alpha	Composite Reliability (rho_c)	Average Variance Extracted (AVE)
OS	0.762	0.842	0.521
CD	0.925	0.939	0.658
EC	0.907	0.929	0.686
ID	0.794	0.865	0.617
WC	0.845	0.895	0.682
SUS	0.754	0.835	0.512
COM	0.806	0.872	0.631
CON	0.870	0.906	0.659

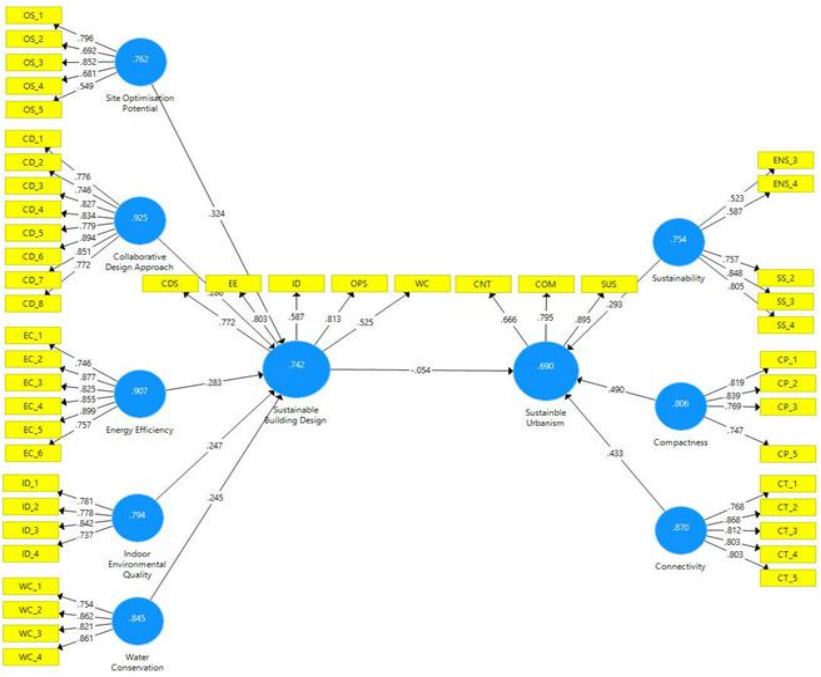


Figure 1: PLS Algorithm for Measurement Model of Sustainable Building Design and Sustainable Urbanism

Upon the establishment of the suitability study variables, Table 6 shows the path coefficient of the effect of sustainable building design on sustainable urbanism. Result reveals that two constructs of sustainable building design, namely energy (conservation) efficiency and site optimization potential with P-values 0.216 and 0.91respectively are statistically insignificant at 95% significance level as their P-values are greater than 0.05 while others are statistically significant due to P-value less than 0.05. This indicates that energy conservation techniques and optimization of site potential aspects in building design considerations have not been critically considered by designers in ensuring a healthy built environment for man and the ecosystem. Hence, energy efficient designs and the exploitation of nature to the benefits of built environment are not duly taken into consideration in the design and construction of residential buildings in the study. The insignificance of energy conservation owes to the fact that orientation and positioning of buildings relative to sunshine and energy-conscious landscape design are rarely considered in buildings requiring more energy supply for cooling purpose in the study area. Furthermore, while the purpose of a sustainable city is to reduce waste, lower emission and increase housing density, the insignificance of optimization of site potential to sustainable urbanism in this study depicts that buildings in the study area have negative environmental impact resulting from increased emission from frequent use of cars to short distances attributed to poor road connectivity in the study area. The above finding is contrasts with [22] in paper reviews on Planning and Design Strategies for Sustainable Urban Development in modern city development to produce green and sustainable cities in the UK, Hong Kong and America. The study found out that building façade, systems design and operation; efficient energy demand and supply; transit-oriented systems; water supply and use; and wastes/pollution issues are the underlying strategies to be adopted to ensure sustainable urban development. Also, the standard beta values in Table 6 shows the relative contribution of the constructs to sustainable urbanism in the study area. Figures reveal that collaborative design approach has the highest contribution with beta value (β) of 0.307 with P-value 0.02. This connotes that the built environment will be more enhanced if construction professionals brainstorm and work hand-in-hand to ensure the preservation of the ecosystem. Conversely, it is statistically observed from Table 6 that water conversation has a negative beta value of -1.122 though significant P-value of 0.002. This interprets that although there is consideration for water conservation in building designs in regards with rain water storage facility. However the negative beta value suggests that rain water only has immediate and limited usefulness suggesting the need to be put in place water recycling features in buildings to guarantee continuous availability of clean and portable water for coming generations in the study area. In the same vein, indoor environmental quality has negative -0.582 beta value and significant P-value of 0.001. This connotes that indoor environmental quality of buildings in the study has in a way contributed to sustaining the man and his environment. Although comfort is derived from adequate room ventilation and natural light but more is expected to be done by harnessing efficacy of existing natural vegetation to enhance the social and psychological condition of residents in the study area. Thus, these results attest to [23] who opined that certain design considerations should be incorporated for sustaining the urban environment. ‘‘Land Use Planning’’, ‘‘Quality of Life’’, ‘‘Conservation & Preservation of natural resources’’, ‘‘Integrated Design’’, ‘‘Provision of Welfare Facilities’’, and ‘‘Conservation of Existing Properties’’ were believed to be the significant underlying criteria for achieving sustainability of local urban renewal projects in Hong Kong, high density development area sharing similar geographical and demographic characteristics like as Lagos State, the study area.

Table 6: Bootstrapping Result of Constructs of Sustainable Building Design on Sustainable Urbanism

Path Coefficient Sample (O)	Standardized beta (O)	T Statistics (|O/STDEV|)	P Values	Decision
Collaborative Design Approach -> Sustainable Urbanism	0.307	2.321	0.02	Significant
Energy Efficiency -> Sustainable Urbanism	0.106	1.237	0.216	Non-significant
Indoor Environmental Quality -> Sustainable Urbanism	-0.582	3.203	0.001	Significant
Site Optimisation Potential -> Sustainable Urbanism	0.008	0.113	0.91	Non-significant
Water Conservation -> Sustainable Urbanism	-1.122	3.118	0.002	Significant

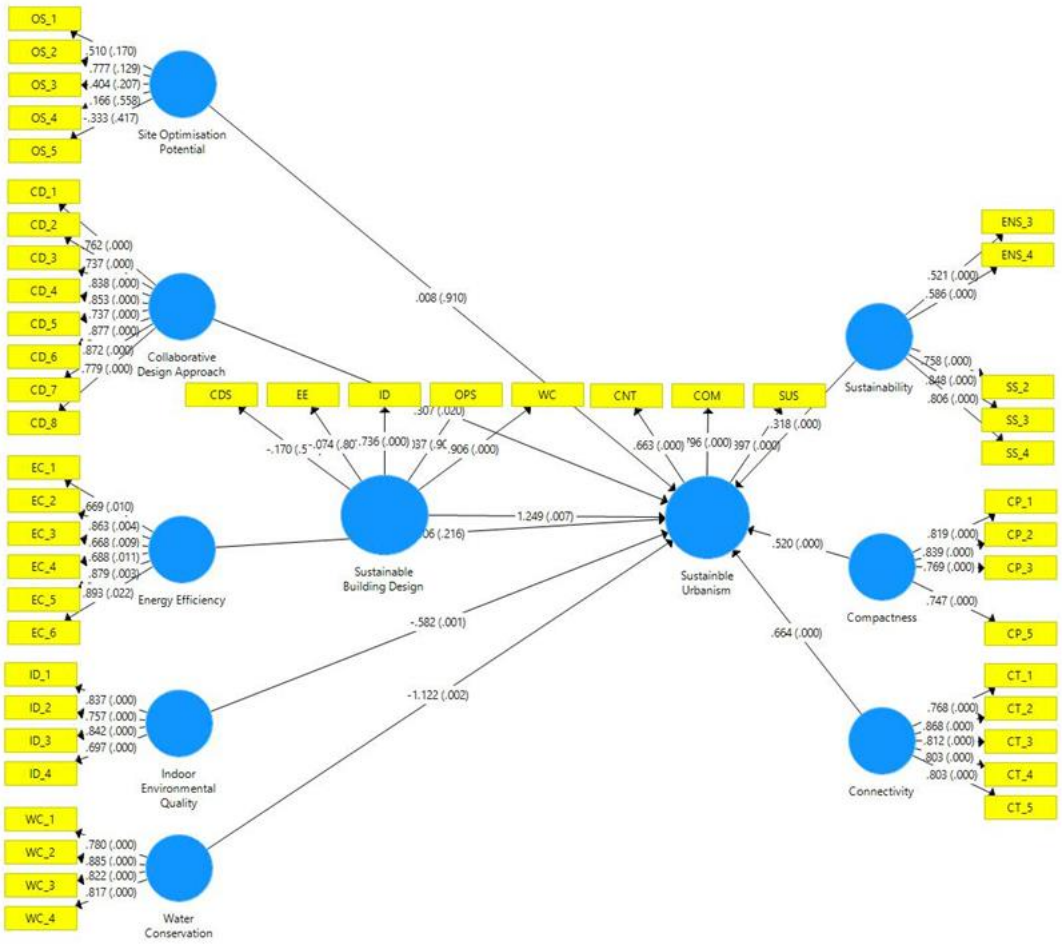


Figure 2: Structural Model Bootstrapping of Constructs of Sustainable Building Design on Sustainable Urbanism

Test of Hypothesis

H_{O1}: There is no significant difference between sustainable building design and sustainable urbanism in the study area.

Table 7 shows the bootstrapped result consisting of the path coefficient, t-statistic, P-values, R-square root and effect size (f^2) for the hypothesis stated above. The value of the path coefficient, (otherwise called standardized beta value) between the endogenous and exogenous variables shows the strength and direction of the relationship between them. Result reveals that the R^2 value is .726. This indicates the model relationship is substantial agreeing with [24] that R^2 value > 0.26 would indicate a substantial model with R^2 values of 0.25, 0.50 and 0.75 represent a weak, moderate and substantial effect size respectively. This means that the exogenous variable (sustainable building design) explains 72.6% of variance in the level of endogenous variable (sustainable urbanism). The remaining 27.4% is to be explained by other variables not captured in this study, (that is outside the context of this study). This connotes that the "well-being" of man and his natural habitat (the earth) is determined by sustainable building construction practices as high as 72.6%. Invariably, this likewise means the possibility of achieving UN's SDG 11 is certain by 72.6% if buildings can be designed and constructed to minimise natural resources depletion, reduce environmental degradation and encourage recycling and reuse of materials. Going further, a positive beta value (β) of 0.852 signifies that sustainable building design makes considerable relative contribution in ensuring sustainability of the built environment in the study area. Also, P-Value less than 0.05 at 95% significant level is considered significant, however, a P-Value greater than 0.05 is considered non-significant. For this study, a statistical significant value of 0.000 at 95 % significance level shows that sustainable building design is significant to the model. Hence, the null hypothesis stated above is rejected.

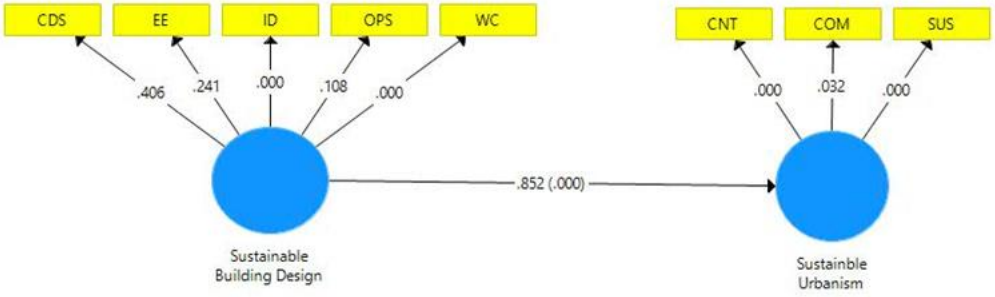
Furthermore, the effect size (f^2) shows the magnitude of the effect of the exogenous variable on the endogenous variable. A f^2 value of 2.655 signifies a large effect on the endogenous variable. This finding upholds the study

of [25] study on theories of Sustainable Urbanism and Green Rating System of 10th of Ramadan city Cairo, Eygpt. The study showed that there is strong interrelation between adopting Sustainable Urbanism principles and achieving high environmental performance in building construction which adds in favour of compact growth to urban sprawling or dispersed growth.

Hence the study upholds that building construction industry is making remarkable efforts in building design and construction to ensure sustainable urban settlement in the study area.

Table 7: Test of Hypothesis

Hypothesis Testing	Path Coefficient	T Statistics (|O/STDEV|)	P Values	R-Square	Effect size (f^2)
Sustainable Building Design -> Sustainable Urbanism	0.852	1.498	0.000	.726	2.655

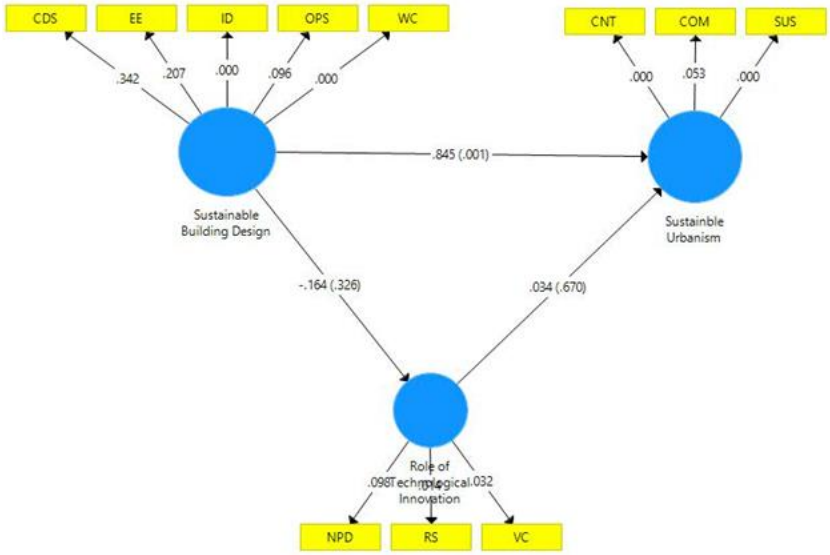


H$_{O2}$: Role of Technological innovation does not mediate the relationship between sustainable building design and sustainable urbanism in the study area

The result of bootstrapping in Table 8 shows the path coefficient of the mediating effect of technological innovation on the relationship between the endogenous and exogenous variables. The above stated hypothesis is tested by assessing indirect effect of technological innovation on the endogenous variable through the exogenous variables. Table 8 also shows statistical significance between endogenous and exogenous variables. However, the indirect effect between sustainable building design and sustainable urbanism via role of technological innovation is statistically insignificant (P-value of 0.67 and 0.326) at 95% significant level. Hence the above stated hypothesis is retained. This connotes that the technological potentials in building design, construction and operations have not been harnessed to the benefit of man and his immediate environment (ecosystem) in the study area

Table 8: Bootstrapping result for mediating role of technological innovation on sustainable Building design

Path Coefficient	Standardized beta (O)	T Statistics (|O/STDEV|)	P Values	Confidence interval 2.50%	Confidence interval 97.50%
Sustainable Building Design -> Sustainable Urbanism	0.845	3.354	0.001	0.787	0.907
Role of Technological Innovation -> Sustainable Urbanism	0.034	0.427	0.670	-0.12	0.186
Sustainable Building Design -> Role of Technological Innovation	-0.164	0.982	0.326	-0.326	0.344



CONCLUSION

This study affirmed through non-mediating role of technological innovation on the relationship between exogenous and endogenous variables that building designers in the study area over the years paid lip service to various technological innovations in building design and construction of the 21st century. More so, the study concluded from the statistical insignificance of energy conservation and optimization of site potentials to the model that energy efficient designs and the exploitation of nature to the benefits of built environment are not of utmost priority to building designers in construction of residential buildings in the study. It was also established that a negative beta value but significance P-value of water conservation in the study area portrays the fact that more is required especially in water recycling to ensure continuous availability of clean and portable water for future generations in the study area. Conclusively, the study affirmed that for a sustainable urban settlement with preserved natural resources in the study area to a large extent depend on the building professionals in providing sustainable design and construction of residential homes. Based on the outcome of this research, the study recommends for further studies, the energy management system (model) in residential buildings and as well biophilic design initiatives in the study area.

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