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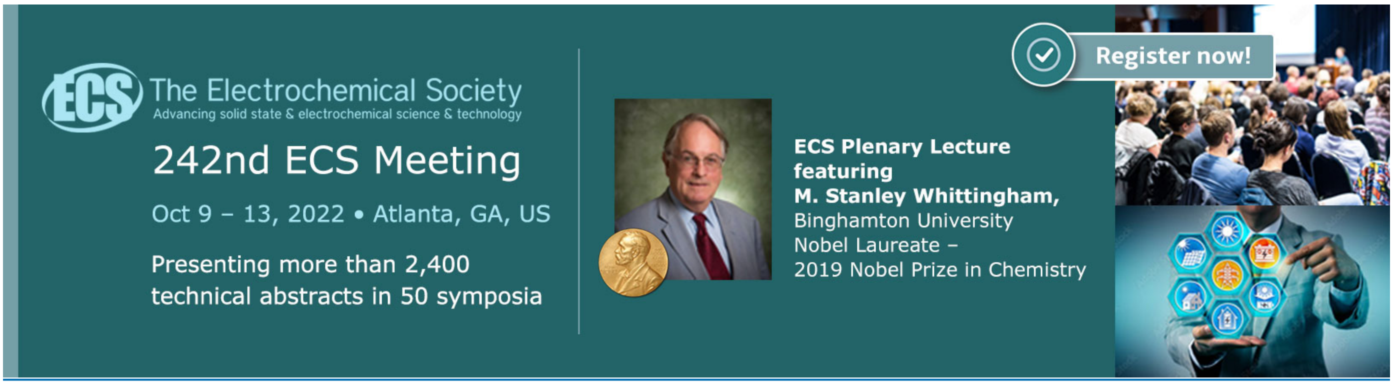

Impact of Energy Efficient Design Strategies on Users Comfort in Selected Mixed-Use Buildings in Lagos State, Nigeria

A. B. Sholanke[1], K. D. T. Alugah[2], J. A. Ademo[3] and O. S. Adisa[4]

Department of Architecture, Covenant University, Ota Ogun State, Nigeria.

Authors email: [1]anthony.sholanke@cu.edu.ng; [2]king-david.alugahpgs@stu.cu.edu.ng
[3]john.ademopgs@stu.cu.edu.ng; [4]ololade.adisapgs@stu.cu.edu.ng

Abstract. Human comfort is a major criterion for mixed-use buildings to be habitable, leading to the usage of technologies such as HVAC and artificial lighting. These devices demand high electricity, causing a 25% rise in building greenhouse gas emissions. It is important for architects to develop energy efficient design strategies in order to maintain and improve user comfort in mixed-use buildings. This study investigated the impact of energy efficiency design strategies on users' comfort in selected mixed-used building in Lagos State, Nigeria, with a view to identify areas for further improvements. The research adopted a quantitative approach. A structured questionnaire was used to obtain data. The Statistical Product & Service Solutions software was used to analyse the data. The result was presented with the aid of texts, tables and graphs. The findings indicated that building orientation was one of the most important techniques, affecting each dimension of human comfort. This revelation suggests that when adopting energy efficiency measures, a building's early design stage should focus on enhancing human comfort. The study recommended that professionals conduct critical analysis on buildings in the design stage to guarantee energy-efficient approaches used throughout the planning, design, and construction stages of mixed-use buildings. In order to create sustainable future designs, it is therefore necessary to recognise the significance of energy efficient design techniques on users' comfort.

Keywords: Energy Efficiency Design Strategies, Users' Comfort and Mixed-Use Building.

1. Introduction

The world is battling with several issues pertaining to global warming and climate change within the past three decades and Nigeria has only furthered this change as they have been recorded as one of the major emitters of greenhouse gases. The results of this climate change became a function of one of the major consumers of energy which is the land use and construction industry. These sectors accounted for about 38% and 32% of the country's total emissions respectively. The governments' pledge to reduce the emissions by 20% in 2030 has made architects and other professionals in the industry to become more innovative in developing building design concepts. Residential buildings are identified with high levels of energy consumption as special considerations for energy management have not been adequately thought of at the design and planning stages. 77.9% of energy consumption are associated with residential use [1]. Although some standards have been put in place to reduce energy consumption within buildings these strategies only help in regulating energy use within a building envelope while neglecting human comfort [2]. The implication is that sufficient precautions have not been taken to balance development objectives against the need to maintain desirable environmental quality. This problem brought about the adoption of energy efficient building techniques in order to reduce the carbon foot print of buildings. Some of the strategies such as the use of sustainable building materials should be implemented at the initial stage of a building project. As suggested in a previous study, good thermal comfort and indoor air quality played a significant role in ensuring human comfort, health and productivity in buildings [3]. Designing a mixed-use building is challenging as one of the major elements to achieve human comfort within the structure (Heating Ventilation and Cooling Systems) requires adequate energy to function efficiently.

Human comfort and energy consumption are both being negatively impacted by the increasing warmth of the climate. The need to create a suitable liveable environment that increases productivity levels within a space has become a major focus as well as reducing energy consumption. The difficulty for designers today is to produce a mixed-use building design that is energy efficient while still maintaining high human comfort levels. Building holistically is tough because climatic boundary conditions have a major influence on both the comfort conditions and the energy efficiency requirements. Focus must be placed on creating an interior atmosphere that supports efficient working conditions in office buildings and comfortable living environments in residential structures [4]. In order to provide this level of comfort while utilising the least amount of fossil fuel feasible, architects strive to do this through architectural designs.

In order to create sustainable future designs, it is necessary to recognise the significance of energy efficient design techniques on user comfort. It is on this note that this study investigated energy efficiency design strategies on users' comfort in Lagos State, Nigeria, with a view to identify areas for further design emphasis and improvements on human comfort within mixed-use buildings. Consequently, the sole research question formulated for the study is: How effective do energy efficient strategies incorporated in existing mixed-use buildings meet user's comfort? The scope of this research was restricted to selected mixed-use buildings in Lagos State, Nigeria. The study scope was restricted to Lagos State because it has the highest number of mixed-use buildings in the country as well as adjudged as being energy efficient. The selected mixed-use buildings were those that granted the authors access to them as access was restricted to some of the buildings selected for the study. This study will be useful to architects as it provides useful information towards improving specific design areas. The research is also useful to stakeholders such as building professionals, students, researchers, educators and policymakers, in understanding and addressing issues relating to developing a comfortable, and sustainable environment, with regards to energy efficient buildings.

2. Literature Review

Buildings have been found to consume a significant amount of energy, contributing to global warming by increasing the amount of greenhouse gases in the atmosphere. Energy efficient techniques have become mandatory as a result. In order to achieve a zero-energy building, energy efficient techniques must be used to guarantee that the energy demand of the structure is minimised [5]. Through the optimisation of space and resources as well as materials and technologies, the efficiency, conformability, functionality, and stability of an energy efficient building are improved. This is accomplished by collaborating with the fields of telecommunications, building automation, system integration, and office automation to achieve the best results. Its aim is to assist in the establishment of a more environmentally friendly environment through improved energy efficiency and green construction [6].

Because appropriate and effective performance is reliant on energy consumption, it is essential to implement energy-efficient techniques in order to maintain enough performance and comfort without compromising on either. As a result, energy efficiency is directly connected to environmental comfort. The term "energy efficient" refers to a structure that provides its occupants with an acceptable degree of environmental comfort, while at the same time reducing its energy usage [7]. Passive and active techniques for energy conservation may be generally divided into two categories [5]. Passive methods, which reduce a building's energy demand from the beginning of the design process, are dependent on optimising the passive solutions that are implemented during the design phase. Natural energy sources such as water or wind power are used in conjunction with passive design strategies rather than standard energy sources such as fossil fuels or electricity. Sunlight and wind energy are captured and used for a variety of purposes, including building cooling, heating, natural lighting, and other applications, depending on the form of the structure. Passive building designs may reduce energy consumption by a significant amount, which can aid in increasing the energy efficiency of the structure [8]. Some researchers have stressed the necessity of using a passive energy design strategy when designing a mixed-use building that is both energy efficient and sustainable.

Building orientation has been shown to be important by researchers such as Altan et al. [9]; Adebisi et al. [10]; and Rattanongphisat & Rordprapat [11], who stated that in order to achieve energy efficiency, buildings should have their floor plans oriented in such a way that the majority of rooms have windows facing toward the equator. It was also revealed by them that the direction of buildings has an impact on the overall solar radiation gains that they get. Wind speed and direction are affected by the orientation of the structure; as a result, natural ventilation reduces the amount of heat lost by convection. According to Olsson [12], there is a direct link between the shape of a building and the total energy performance of the building since the shape of the building impacts the overall energy loss and gain of the building. To create energy efficient structures in hot and humid regions, Omrani et al. [13] advocated for the use of long and thin shapes. The long side of the building should be oriented in the direction of the prevailing winds in order to provide enough natural and cross ventilation.

A study by Yüksek & Karadayi [14] found that structural building envelopes, which typically account for 15% - 40% of total construction costs, serve as a thermal shield that connects the building and its conditioned interior spaces, and thus allow for the transmission of thermal energy to the surrounding environment. Bano & Arif Kamal [15] cautioned that the materials used in the components must be carefully chosen in accordance with the specific conditions, as the walls and windows of multi-story buildings are the primary source of heat gain in these structures. Building materials must be energy efficient, as demonstrated by the use of locally sourced and recycled materials, since this aids in the achievement of a low carbon footprint [9]. By intercepting incoming sunlight, shading devices can have an impact on the energy consumption of a building's construction. According to the proceedings of the 2011 annual conference, the employment of shading devices can aid in the promotion of energy savings as well as the improvement of thermal performance in office buildings [16].

By using daylighting strategies, it is possible to reduce the amount of energy required for cooling and heating [17]. Windows facing south should be built in such a manner that they allow direct sunlight to enter in the winter and give shaded space in the summer, if possible. It is possible to get good daylighting results by utilising high-performance glass, selecting the appropriate opening size, and installing shading devices. This approach has a significant impact on a building's energy consumption since these devices help to minimise solar heat gain into the building, which in turn helps to lower the cooling load in the building. Gupta, & Tiwari [18] discussed the advantages of passive cooling, which limit the passage of heat into or out of a building while requiring little or no mechanical energy on the part of the building owner. Passive energy efficiency strategies, in general, aid in the achievement of an energy efficient architectural design.

The passive techniques for reducing energy consumption and achieving a zero-energy building have an impact on the active solutions for energy efficiency. By implementing active energy management methods, which provide a systematic structure for energy efficiency, it is possible to save up to 30% on energy use. To achieve the highest possible level of energy efficiency, active energy controls energy-efficient equipment so that they consume just the amount of energy that is necessary in a given space, eliminating all extra energy and ensuring maximum energy efficiency [19]. Energy management through monitoring, measuring, and control ensures effectiveness and change. Energy control can also be implemented at a relatively low cost with a modest payback period, especially when compared to high energy prices, because most energy control solutions can be paid off within a few years, if implemented properly.

Building Management Systems (BMS) are among the active design systems that are used to monitor and run the technical systems and services of a building, such as air conditioning, ventilation, lighting, and hydraulics. Using Building Automation Systems (BAS), you may improve the efficiency and productivity of your workplace by optimising buildings, systems, services, and administration [20]. The system consists of centralised hardware and software that monitors and manages the facilities systems of a building (electricity, lighting, plumbing, Heating, Ventilation and Air Conditioning (HVAC), water supply, etc.). Renewable energy technology has shown to be effective in the development of energy-efficient buildings. It makes it possible to employ renewable energy sources to create electricity, heat, and fuel. Renewable energy technology reduces the dependency on fossil-fuel-generated energy, resulting in a reduction in carbon emissions as a result. Renewable energy technologies include wind turbines, building integrated photovoltaic (BIPV) systems, heat exchangers, solar collectors and photovoltaic (PV) panels, heat pipes, heat pumps, and solar water heating systems [21].

A mixed-use building is a type of infrastructure that incorporates a variety of commercial, residential, and maybe hotel purposes into a single structure [22]. The building is designed for all people and includes elements of a live-work-play environment. It is usually located in a pedestrian-friendly neighbourhood, among other things. A housing complex that includes essential necessities such as a house, a place of employment, a place to rest, and an area to shop is what it really is. According to the findings of Mirzaei et al. [23] and Ezema & Oluwatayo [24], these sorts of buildings are successful in lowering energy consumption when appropriate techniques are used in the building's construction, therefore making it more energy efficient. Given that energy efficiency is currently on trend and that the future holds enormous potential for growth, it is necessary to develop a pragmatic approach to developing a sustainable future in the form of a mixed-use building, which is a mixed-use building with a mix of commercial and residential uses. When living and working in poor office conditions such as thermal discomfort, inadequate lighting, poor indoor air quality, and so on, the health and productivity of occupants and employees are severely reduced. In these types of situations, the financial impact on an organization's bottom line might be significant.

In recent research, it has been discovered that increasing ventilation rates are associated with better levels of productivity [25]. It is possible to develop a sense of comfort in a mixed-use building as a consequence of being satisfied with the internal environmental quality of the structure. According to studies, people in developed areas of the globe spend up to 90 percent of their time indoors, and occupants' comfort and health are affected by their surroundings, including their living and working settings. It was discovered that when there is a lack of a suitable workplace, comfort, worker productivity, performance, and morale are all severely impacted, according to the research findings [26].

Poor visual, auditory, and thermal conditions in the building environment usually interfere with the functional activities of the building's residents, resulting in a reduction in productivity. Examples of this sort of behaviour include tardiness, inability to finish duties on time, and various other forms of disturbance in the work environment. Following the completion of several case studies, Mirzaei et al. [23] discovered a few advantages of mixed-use buildings, some of which are lowering energy consumption when appropriate techniques are used in the building's construction, reduction in vehicle journeys, decrease in fuel consumption, and less dependence on cars, resulting in it being more energy efficient. It can be seen from the above review that research Lawrence & Keime [2] focused on energy efficiency in buildings without taking into account human comfort, an aspect which is essential for building habitability. This research aims to evaluate energy-efficient strategies and their impact on human comfort to enable the development of ways to improve energy efficiency.

3. Methodology

This study was carried out to evaluate the impact of energy efficiency design techniques on the comfort of users in a number of mixed-use buildings in Lagos, Nigeria. In order to do this, the researchers employed a quantitative technique using a questionnaire to gather data. The quantitative approach is considered appropriate for this survey because it gives a full description and evaluation of a research aim without restricting the scope of the study by relying on findings that cannot be quantified. In selecting the mixed-use buildings that were investigated for this study, the purposive sampling approach was used. This selection technique was used since the Lagos (Eko) district of Lagos has the largest number of mixed-use buildings in the state relating to this study. However, access to several mixed-use buildings were denied while searching for samples. Three mixed-use buildings namely; Kings Tower, Nestoil Tower, and Landmark Towers allowed access and were used for the study. Responses were gathered through the use of closed-ended questions. A total of 150 questionnaires were distributed to the users of the selected mixed-use buildings in which 121 questionnaires were retrieved for analysis. The data gathered from the questionnaire was analysed and interpreted using the Statistical Product and Service Solutions. Regression analysis was the statistical analysis used for analysis because the research made use of predictors and criterions to evaluate the impact energy efficient strategies on human comfort. Text and tables were used to present the result.

4. Results and Discussion

Three mixed used buildings were investigated in this study. Located on a prominent corner of Alfred Rewane Road in Ikoyi, Lagos, Nigeria, the Kingsway Tower is a landmark mixed-use building that serves as a gateway to the city, going north to the airport and south to the Victoria Island. Kingsway Tower is a 15-story building designed by South African architects, Stefan Antoni Olmesdahl Truen Architects (SAOTA). Besides the basement, it has two levels of retail spaces, a parking level, and twelve levels of office space. The second building is Nestoil Tower, a one-of-a-kind office development strategically located at the intersection of two major business districts; Akin Adesola Street and Saka Tinubu Street in Victoria Island, Lagos. It has a panoramic view of Eko Atlantic City and the Atlantic Ocean. The Nestoil Tower is part of the Nestoil Group of Companies. The Nestoil Tower, with its technologically advanced amenities and a land area of 3900 square metres and 10,000 square metres of leasable commercial space on 15 floors, is a perfect space for corporations aiming to be at the forefront of their industries. The third building is Land mark village. Landmark village is a state-of-the-art mixed-use development on a 38,000m2 plot along the Atlantic Ocean beachfront in Lagos, Nigeria. The landmark tower is situated on the grounds of the landmark village; it takes up a total floor area of about 8000sqm. A mixed-use commercial real-estate development with a main building of ten stories and a Grade A leisure facility. The structure has a high-ceiling retail floor with terraces, world-class restaurants, six stories of Grade A offices, and a 22-room luxury hotel.

Examining the effectiveness of energy efficient strategies on human comfort required the use of regression analysis by SPSS to obtain the results. The regression analysis was conducted for each smart building strategy indicated in the questionnaire. The independent variables were the smart building strategies, while the dependent variables included questions related to the different groups of human comfort, which include; thermal comfort, visual comfort, indoor air quality and noise comfort. The analysis showed different levels of significance between each human comfort question responded to by the questionnaire.

Table 4.1 shows the summary of the regression analysis conducted for the dependent variable; "I am comfortable with the indoor temperature of the building" which was significant. In order to test the hypothesis, the dependent variable was regressed to different independent variables. The R Square value (0.366) from the analysis explains 36.6% of the variance in the variable; "I am comfortable with the indoor temperature of the building." (R square = 0.366, p = 0.000).

Table 4.1. Summary of regression analysis for the variable "I am comfortable with the indoor temperature of the building"

Model	R Square	F	Beta Coefficient	t-value	p-value (Sig)
	0.366	3.752			0.00
Constant				3.730	0.00
Building Orientation			.148	1.399	.165
Building Shape			-.112	-1.059	.292
Building Envelope			-.048	-.422	.674
Choice of Materials			-.047	-.367	.714
Solar Shading			.051	.503	.616
Landscaping			-.207	-2.102	.038
Daylighting			.091	.977	.331
Space Conditioning			**.199**	2.035	**.044**
Energy efficient equipment			.086	.728	.469
Adaptive facades			**.268**	1.880	**.009**
Renewable energy technology			-.132	-1.202	.232
Smart Motion Sensors			-.024	-.273	.785
Smart Fire and smoke detectors			.129	1.518	.132
Smart meters			.181	1.635	.105
Smart security systems			-.061	-.472	.638
Smart network systems			-.001	-.014	.989

In table 4.1, the most effective strategy that influences comfort with the indoor temperature of the building is adaptive facades (Beta = 0.268, p = 0.009). Next to this strategy was the space conditioning (Beta = 0.199, p = 0.044).

Table 4.2 shows the summary of the regression analysis conducted for the dependent variable; "I will prefer if the building space is warmer" which appeared significant. In order to test the hypothesis, the dependent variable was regressed to different independent variables which were the smart building strategies. The R Square value (0.241) from the analysis explains 24.1% of the variance in the variable; "I will prefer if the building space is warmer." (R square = 0.241, p = 0.015).

Table 4.2. Summary of regression analysis for the variable "I will prefer if the building space is warmer"

Model	R Square	F	Beta Coefficient	t-value	p-value (Sig)
	0.241	2.065			0.15
Constant				0.977	0.331
Building Orientation			.132	1.147	.254
Building Shape			-.115	-1.011	.315
Building Envelope			**.267**	2.174	**.032**
Choice of Materials			-.030	-.231	.818
Solar Shading			.033	.304	.762
Landscaping			-.118	-1.095	.276
Daylighting			.059	.603	.548
Space Conditioning			-.113	-1.024	.308
Energy efficient equipment			**.282**	2.062	**.042**
Adaptive facades			.070	.634	.528

Renewable energy technology	**.314**	2.445	**.016**
Smart Motion Sensors	-.094	-.570	.570
Smart Fire and smoke detectors	.083	.693	.490
Smart meters	.005	.042	.966
Smart security systems	-.041	-.289	.773
Smart network systems	-.147	-.986	.326

In table 4.2, the most effective strategy that influences the warmth of the interior of the building is the renewable energy technology (Beta = 0.314, p = 0.016). Next to this strategy was the energy efficient equipment (Beta = 0.282, p = 0.02) and the building envelope (Beta = 0.267, p = 0.032).

Table 4.3 shows the summary of the regression analysis conducted for the dependent variable; "Staying outside is preferable due to the indoor temperature" which appeared significant. In order to test the hypothesis, the dependent variable was regressed to different independent variables which were the smart building strategies. The R Square value (0.232) from the analysis explains 23.2% of the variance in the variable; "Staying outside is preferable due to the indoor temperature." (R square = 0.232, p = 0.22).

Table 4.3. Summary of regression analysis for the variable "Staying outside is preferable due to the indoor temperature"

Model	**R Square**	**F**	**Beta Coefficient**	**t-value**	**p-value (Sig)**
	0.232	1.968			0.022
Constant				3.925	0.00
Building Orientation			-.023	-.208	.836
Building Shape			-.135	-1.211	.229
Building Envelope			.017	.142	.888
Choice of Materials			-.051	-.376	.708
Solar Shading			.153	1.423	.158
Landscaping			**.296**	2.842	**.005**
Daylighting			**-.285**	-2.908	**.004**
Space Conditioning			.114	1.108	.270
Energy efficient equipment			-.172	-1.372	.173
Adaptive facades			.011	.104	.918
Renewable energy technology			**.242**	2.085	**.040**
Smart Motion Sensors			-.011	-.123	.903
Smart Fire and smoke detectors			.033	.369	.713
Smart meters			-.160	-1.363	.176
Smart security systems			.082	.866	.388
Smart network systems			.084	.900	.370

In table 4.3, the most effective strategy that influences occupants' comfort of the interior of the building in relation to staying outside due to heat landscaping (Beta = -0.296, p = 0.005). Next to this strategy was daylighting (Beta = -0.285, p = 0.004) and renewable energy technology (Beta = 0.242, p = 0.040).

Table 4.4 shows the summary of the regression analysis conducted for the dependent variable; "The building lighting is satisfactory" which indicated significant. In order to test the hypothesis, the dependent variable was regressed to different independent variables which were the smart building strategies. The R

Square value (0.321) from the analysis explains 32.1% of the variance in the variable; "The building lighting is satisfactory." (R square = 0.321, p = 0.00).

Table 4.4. Summary of regression analysis for the variable "The building lighting is satisfactory"

Model	R Square	F	Beta Coefficient	t-value	p-value (Sig)
	0.321	3.069			0.00
Constant				2.828	0.00
Building Orientation			**.321**	2.935	**.004**
Building Shape			.099	.921	.359
Building Envelope			-.048	-.413	.681
Choice of Materials			.024	.192	.848
Solar Shading			.001	.006	.995
Landscaping			-.035	-.340	.734
Daylighting			-.086	-.926	.357
Space Conditioning			-.008	-.075	.941
Energy efficient equipment			.116	.893	.374
Adaptive facades			.082	.786	.434
Renewable energy technology			.037	.307	.759
Smart Motion Sensors			-.188	-1.204	.231
Smart Fire and smoke detectors			.110	.966	.336
Smart meters			-.137	-1.120	.265
Smart security systems			.068	.505	.614
Smart network systems			.000	2.253	.996

In table 4.4, the most effective strategy that influences occupants' comfort of the daylighting of the building interior space is the building orientation (Beta = 0.321, p = 0.004).

The variables "I experience glare as a result of sunlight" (Sig = 0.233) and "The building has adequate artificial light supply" (Sig = 0.168) appeared insignificant as the Significant values were greater than 0.05.

Table 4.5 shows the summary of the regression analysis conducted for the dependent variable; "The building spaces are well ventilated" which indicated significant. In order to test the hypothesis, the dependent variable was regressed to different independent variables which were the smart building strategies. The R Square value (0.291) from the analysis accounts for 29.1% of the variance in the variable; "The building spaces are well ventilated." (R square = 0.291, p = 0.002).

Table 4.5. Summary of regression analysis for the variable "The building spaces are well ventilated"

Model	R Square	F	Beta Coefficient	t-value	p-value (Sig)
	0.291	2.663			0.002
Constant				3.358	0.000
Building Orientation			**.371**	3.446	**.001**
Building Shape			.111	1.032	.305
Building Envelope			-.010	-.088	.930
Choice of Materials			.128	.978	.330
Solar Shading			-.011	-.110	.913
Landscaping			-.167	-1.670	.098
Daylighting			.117	1.237	.219

Space Conditioning	-.116	-1.164	.247
Energy efficient equipment	-.162	-1.350	.180
Adaptive facades	**.287**	2.778	**.006**
Renewable energy technology	.057	.508	.613
Smart Motion Sensors	-.001	-.007	.995
Smart Fire and smoke detectors	-.072	-.834	.406
Smart meters	-.137	-1.213	.228
Smart security systems	-.029	-.323	.747
Smart network systems	-.009	-.095	.925

In table 4.5, the most effective strategy that influences the occupant's comfort level of interior ventilation is the building orientation (Beta = 0.371, p = 0.001). Next to this strategy was the adaptive facades (Beta = 0.287, p = 0.006).

Table 4.6 shows the summary of the regression analysis conducted for the dependent variable; "I sometimes experience nausea as a result of the quality of indoor air" which indicated significant. In order to test the hypothesis, the dependent variable was regressed to different independent variables which were the smart building strategies. The R Square value (0.322) from the analysis accounts for 32.2% of the variance in the variable; "I sometimes experience nausea as a result of the quality of indoor air." (R square = 0.223, p = 0.032).

Table 4.6. Summary of regression analysis for the variable; "I sometimes experience nausea as a result of the quality of indoor air"

Model	R Square	F	Beta Coefficient	t-value	p-value (Sig)
	0.264	2.329			0.032
Constant				2.368	0.02
Building Orientation			.103	.914	.363
Building Shape			.089	.788	.432
Building Envelope			.041	.339	.735
Choice of Materials			-.203	-1.482	.141
Solar Shading			.128	1.180	.241
Landscaping			**.227**	2.170	**.032**
Daylighting			-.024	-.241	.810
Space Conditioning			-.028	-.268	.789
Energy efficient equipment			.024	.191	.849
Adaptive facades			-.049	-.451	.653
Renewable energy technology			**.351**	3.003	**.003**
Smart Motion Sensors			.083	.890	.376
Smart Fire and smoke detectors			.010	.109	.913
Smart meters			-.185	-1.566	.120
Smart security systems			-.061	-.643	.521
Smart network systems			.024	.259	.796

In table 4.6, the most effective strategy that influences occupants' experience of the quality of indoor air is the renewable energy technology (Beta = 0.351, p = 0.003). Next to this strategy was landscaping (Beta = 0.227, p = 0.032).

Table 4.7 shows the summary of the regression analysis conducted for the dependent variable; "I am content with the air quality in my indoor space" which indicated significant. In order to test the hypothesis, the dependent variable was regressed to different independent variables which were the smart building strategies. The R Square value (0.296) from the analysis accounts for 29.6% of the variance in the variable; "I am content with the air quality in my indoor space." (R square = 0.296, p = 0.001).

Table 4.7. Summary of regression analysis for the variable "I am content with the air quality in my indoor space"

Model	R Square	F	Beta Coefficient	t-value	p-value (Sig)
	0.296	2.739			0.001
Constant				2.159	0.33
Building Orientation			**.223**	2.080	**.040**
Building Shape			.077	.722	.472
Building Envelope			**.253**	-2.280	**.025**
Choice of Materials			.147	1.128	.262
Solar Shading			-.010	-.098	.922
Landscaping			.053	.533	.595
Daylighting			**.222**	2.368	**.020**
Space Conditioning			-.039	-.392	.696
Energy efficient equipment			**-.309**	-2.501	**.014**
Adaptive facades			-.110	-1.065	.289
Renewable energy technology			-.095	-.852	.396
Smart Motion Sensors			.145	1.640	.104
Smart Fire and smoke detectors			.014	.164	.870
Smart meters			.318	2.828	.189
Smart security systems			.004	.045	.964
Smart network systems			.003	.036	.971

In table 4.7, the most effective strategy that influences the occupant's comfort level with the building air quality is the energy efficient equipment (Beta = 0.309, p = 0.014). Next to this strategy was building envelope (Beta = 0.253, p = 0.025), building orientation (Beta = 0.223, p = 0.040) and daylighting (Beta = 0.222, p = 0.020).

Table 4.8 shows the summary of the regression analysis conducted for the dependent variable; "The noise levels are low within my indoor space" which indicated significant. In order to test the hypothesis, the dependent variable was regressed to different independent variables which were the smart building strategies. The R Square value (0.307) from the analysis accounts for 30.7% of the variance in the variable; "The noise levels are low within my indoor space." (R square = 0.307, p = 0.001).

Table 4.8. Summary of regression analysis for the variable "The noise levels are low within my indoor space"

Model	R Square	F	Beta Coefficient	t-value	p-value (Sig)
	0.307	2.880			0.001
Constant				5.041	0.000
Building Orientation			**.322**	3.025	**.003**
Building Shape			-.129	-1.212	.228
Building Envelope			.002	.022	.983

Choice of Materials	.172	1.330	.186
Solar Shading	.059	.575	.567
Landscaping	-.315	-3.185	.502
Daylighting	-.127	-1.360	.177
Space Conditioning	.107	1.091	.278
Energy efficient equipment	.140	1.178	.241
Adaptive facades	-.118	-1.158	.249
Renewable energy technology	-.008	-.068	.946
Smart Motion Sensors	.088	1.008	.316
Smart Fire and smoke detectors	.155	1.822	.071
Smart meters	.038	.341	.734
Smart security systems	.048	.534	.594
Smart network systems	-.098	-1.106	.271

In table 4.8, the most effective strategy that influences the occupant's comfort level with low noise levels within the interior space are the building orientation (Beta = 0.332, p = 0.003).

Table 4.9 shows the summary of the regression analysis conducted for the dependent variable; "I am not disturbed by traffic noise from the exterior environment" which indicated significant. In order to test the hypothesis, the dependent variable was regressed to different independent variables which were the smart building strategies. The R Square value (0.427) from the analysis accounts for 42.7% of the variance in the variable; "I am not disturbed by traffic noise from the exterior environment." (R square = 0.427, p = 0.000).

Table 4.9. Summary of regression analysis for the variable "I am not disturbed by traffic noise from the exterior environment"

Model	R Square	F	Beta Coefficient	t-value	p-value (Sig)
	0.427	4.846			0.000
Constant				2.154	0.034
Building Orientation			**.385**	3.973	**.000**
Building Shape			.013	.133	.894
Building Envelope			-.130	-1.256	.212
Choice of Materials			.209	1.778	.078
Solar Shading			-.036	-.391	.697
Landscaping			-.141	-1.569	.120
Daylighting			.093	1.102	.273
Space Conditioning			.145	1.622	.108
Energy efficient equipment			-.049	-.456	.649
Adaptive facades			.069	.743	.459
Renewable energy technology			.041	.411	.682
Smart Motion Sensors			-.008	-.098	.922
Smart Fire and smoke detectors			.044	.562	.575
Smart meters			.133	1.310	.193
Smart security systems			.015	.180	.857
Smart network systems			-.080	-.987	.326

In table 4.9, the most effective strategy that influences the occupant's comfort level with the noise levels perceived from the exterior within the interior space is the building orientation (Beta = 0.385, p = 0.000).

Table 4.10 shows the summary of the regression analysis conducted for the dependent variable; "I am satisfied with the noised levels within indoor space" which indicated significant. In order to test the hypothesis, the dependent variable was regressed to different independent variables which were the smart building strategies. The R Square value (0.423) from the analysis accounts for 42.3% of the variance in the variable; "I am satisfied with the noised levels within indoor space." (R square = 0.423, p = 0.000).

Table 4.10. Summary of regression analysis conducted for the dependent variable "I am satisfied with the noised levels within indoor space"

Model	R Square	F	Beta Coefficient	t-value	p-value (Sig)
	0.423	4.758			0.000
Constant				2.383	0.019
Building Orientation			**.395**	4.063	**.000**
Building Shape			-.018	-.190	.850
Building Envelope			-.091	-.879	.382
Choice of Materials			-.029	-.243	.809
Solar Shading			.140	1.503	.136
Landscaping			-.114	-1.259	.211
Daylighting			.024	.285	.776
Space Conditioning			.111	1.241	.217
Energy efficient equipment			-.013	-.120	.905
Adaptive facades			**-.256**	-2.747	**.007**
Renewable energy technology			.257	2.546	.012
Smart Motion Sensors			.081	1.017	.311
Smart Fire and smoke detectors			.158	2.026	.722
Smart meters			.146	1.433	.155
Smart security systems			.006	.070	.944
Smart network systems			-.028	-.348	.729

In table 4.10, the most effective strategy that influences the occupant's comfort level with the noise levels within the interior space is building orientation (Beta = 0.395, p = 0.00). Next to this strategy is adaptive facades (Beta = -0.256, p = 0.007).

Table 4.11 shows the summary of the regression analysis conducted for the dependent variable; "I am very productive as a result of the indoor environment" which indicated significant. In order to test the hypothesis, the dependent variable was regressed to different independent variables which were the smart building strategies. The R Square value (0.329) from the analysis accounts for 32.9% of the variance in the variable; "I am very productive as a result of the indoor environment." (R square = 0.329, p = 0.000).

Table 4.11. Summary of regression analysis for the variable "I am very productive as a result of the indoor environment"

Model	R Square	F	Beta Coefficient	t-value	p-value (Sig)
	0.329	3.183			0.000
Constant				3.779	0.000
Building Orientation			**.226**	2.158	**.033**
Building Shape			.050	.477	.634
Building Envelope			**-.267**	-1.667	**.021**
Choice of Materials			.134	1.054	.294
Solar Shading			.074	.738	.462
Landscaping			-.139	-1.430	.156
Daylighting			.163	1.783	.078
Space Conditioning			-.013	-.135	.893
Energy efficient equipment			-.146	-1.248	.215
Adaptive facades			.018	.182	.856
Renewable energy technology			-.058	-.537	.592
Smart Motion Sensors			.131	1.520	.132
Smart Fire and smoke detectors			.110	1.311	.193
Smart meters			.274	2.493	.014
Smart security systems			.046	.521	.603
Smart network systems			-.026	-.299	.765

In table 4.11, the most effective strategy that influences the occupant's productive level within the interior space is the building orientation (Beta = -0.226, p = 0.033). Next to this strategy is the building envelope (Beta = -0.267, p = 0.021).

4.1 Discussion

This evaluation of the energy efficient strategies that affect user's comfort in mixed-use buildings made use of three mixed-use buildings. For the evaluation of each of the human comfort groups, questions were asked regarding each comfort group. Thermal comfort of the users of the building was greatly affected by the building envelope, space conditioning and the use of adaptive façades in the building. The results showed that an increase in the use of these techniques to achieve thermal comfort within the space, the higher levels of comfort one would achieve within the building space. Daylighting factor also showed an effect on human thermal comfort within the space as the results stated by the regression analysis table showed that the more daylight admitted into the interior space the more likely one would feel a level of discomfort due to heat admitted into the building envelope. For the evaluation of visual comfort, it was noticed that the use of building orientation had the most effect on user's visual comfort. The results proved that the relationship between the building orientation energy efficient strategy and its effect on users' visual comfort levels was directly proportional. The results indicated that an increase in the use of building orientation in the design stage of a building will greatly affect the quality of light within that interior space which in turn will affect the visual quality of the interior space.

For indoor air quality the most effective strategies as shown by the results were the building orientation, the use of adaptive facades, landscaping, renewable energy technology, and the building envelope. These energy efficient strategies appeared to be the most effective in achieving an optimum level of indoor air quality. The passive energy efficient strategies that appeared to be the most effective in achieving indoor air quality was building orientation which agreed with the findings of Altan et al. [9] as their work showed a positive impact of the buildings orientation on the air conditioning levels within an interior space may either make or mar the air quality within the building space. The noise comfort level as experience by the users were the building orientation, landscaping and the use of adaptive facades. Noise from external forces didn't seem formidable in this building types due to the orientation of the building as well as adaptive facades used for the buildings. These features helped in sound insulation from the exterior noise caused from traffic and other external elements. The discussion above explained the energy efficient strategies that affected users' comfort levels within a mixed-use building space which creates a need to implement these strategies maximally in order to improve users' comfort within a mixed-use building space.

5. Conclusion

The effectiveness of energy-efficient strategies on human comfort in mixed-use buildings in Lagos State, Nigeria was investigated in this paper. The results demonstrated that a more passive energy efficient strategy proved to be beneficial in promoting human comfort in a mixed-use building. The building orientation was one of the most prominent of these methods, since it was shown to have an impact on each dimension of human comfort (Indoor air quality, thermal comfort, visual comfort and noise comfort). The findings suggest that when applying energy efficiency measures, greater focus should be placed on improving human comfort during the early design stage of a building. This is in line with previous research by [9]. Also, it was shown that some methods such as building orientation and form of buildings were not integrated into the design of these mixed-use buildings, which provided the extent to which energy efficient approaches have been used in such structures. However, the findings of the study are particularly important because they can be used to guide built-environment professionals in making decisions about the most appropriate energy-efficient strategies to implement during the planning, design, and construction stages of the development of mixed-use buildings. The main purpose of a building is to provide people with a comfortable environment; therefore, this article contributes to knowledge by providing empirical evidence on energy-efficient techniques applied in the selected mixed-use buildings on the comfort level of individuals within the space. In the context of mixed-use buildings, this will help to improve understanding of the level of impact of the implemented available strategies, which will further assist in guiding designers and other stakeholders on the most effective strategies and those that should be incorporated into the design of buildings.

The scope of this study was constrained by the fact that data collection from mixed-use buildings could only be accomplished if access to the buildings was permitted. As a consequence, it is advised that comparable studies be done to cover a larger number of mixed-use buildings in order to offer a conclusion that can be more broadly generalised in terms of the study objective. Further investigation would be required to establish whether increasing the level of environmental control available to occupants may enhance their sense of comfort without necessarily increasing energy usage.

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