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Assessing the Effect of Green Strategies on Indoor Thermal Comfort of Office Buildings in Enugu State

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Abstract
It is an undeniable fact that the average temperature is rising. This temperature increase is greatly being influenced by indisputable climate change. The bulk of the negative effects of this climatic change are felt more in the cities. These cities have some critical urban characteristics like unplanned, congested buildings lack of landscape features and reflective surfaces Thus giving rise to urban heat island effect, urban-dust-dome effect and radiation effects from reflective surfaces of roads and roofs. Indoor thermal stresses in these cities are equally increasing because both indoor and outdoor thermal comfort levels are negatively affected. Green strategy is the concept that focuses on using passive means to minimize these environmental problems and improving the indoor air quality IAQ and thermal comfort. When passive means of achieving indoor comfort is effectively implemented, it results in reducing the excessive use of non-renewable energy for mechanical means of achieving indoor comfort. The main highlight of green strategy is sustainability in the built environment in particular and the entire universe in general. This paper evaluates the efficient use of passive design techniques that will achieve indoor comfort and ensure energy efficient buildings and environmental sustainability. The researchers employed descriptive research methods with extensive literature review. Survey method and statistical regression analysis based on Software Package for Social Sciences (SPSS) standards, is used to establish the relationship between different green strategies and thermal comfort. The conclusion highlights the importance of green strategies in improving the indoor thermal comfort of occupants in office buildings
Keywords: Climate change, Green strategies, Green initiatives, Environmental Sustainability, Regression Analysis, Thermal comfort. Software Package for Social Sciences (SPSS).
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1.1 Introduction

In most countries within the tropical regions and subregions of hot climate areas, extreme heat has been a daunting problem. This problem is becoming more challenging because the indoor spaces where we spend about 90% of the time, is not properly designed to respond to the changing climate trends (Leech et al., 2002). Rather the designers pay more attention to aesthetic features ignoring the most important aspects of functionality, ventilation and thermal comfort of the occupants. With the increasing rise in average temperature, coupled with poor ventilation of the buildings, the occupants have no other alternative than to rely on artificial means for cooling and lighting. The frequent power disruption and load shedding in Nigeria, which last over eight hours a day amid hot dry conditions have made the life of city dwellers more miserable and has not helped matters (Akande, 2010). The immediate effect is uncomfortable indoor environment which may lead to poor productivity, health and psychological consequences (Parsons, 2003).

Green strategies are effective passive means of achieving indoor comfort in a more sustainable manner, which will also minimize adverse effect to the environment. Green strategies can be actualized through many frontiers, like efficient use of materials, energy efficiency in buildings and design strategies. All these are sustainable strategies that are recent means of averting the negative consequences of human-induced activities which then guarantee comfort in both indoor and outdoor environments. This research concentrates on green techniques that will facilitate energy efficiency because energy is a critical key element in the world economy today. Energy is a major cost component in building industry which influences both cost of construction and running buildings.

In this era of technological growth, energy is regarded as a scarce resource. Energy is specifically valued in architecture because virtually all materials and the technology of their production are driven by one form of energy or another (Atolagbe and Fadamiro, 2005). Energy is highly indispensable in sourcing, manufacturing, transportation, assemblage and in cooling, warming and cleaning of built spaces (Atolagbe and Ajayi, 2015). Several studies have confirmed that the building industry ranks highest in energy consumption worldwide. In some of those studies, it was stressed that buildings account for about 40% of the global energy consumption and contribute over 30% of the CO_2 emissions (Koranteng, Essel and Nkrumah, 2015; Akande, Fafiyi and Mark, 2015;

Oyedepo, 2014; Ohajuruka, 2013). Still narrowing it down, a large proportion of this energy is used for thermal comfort in buildings (Yang, Yan and Lam, 2012). The increased use of air-conditioners and lack of sustainable design approaches especially in public buildings like offices, have led to the present energy crisis (Koranteng, Essel and Nkrumah, 2015).

To address this issue several researches have been conducted in both temperate and tropical regions. In Greece, Nicosia Cyprus, London United Kingdom, Germany and Kuwait, different aspects of building envelope designs were evaluated against indoor thermal performance by different researchers (Konstantina, Eli, Christian, Efrosini and Agis, 2014;; Chu, Li, Lu, Hou and Wang, 2012; AI-Anzi, Seo and Kranti, 2009). In some tropical countries like Ghana and Indonesia, similar studies were investigated on the influence of building envelope design on indoor comfort (Rashdi, Suraya and Embi, 2016; Koranteng et al,. 2015). However, in Nigeria and particularly in south eastern region, few of such researches have been carried out. It is this knowledge gap that this research intends to address.

1.2 Problem Statement.

Most existing office buildings in Enugu urban were designed without adherence to standards in terms of window orientation, natural ventilation, shading devices and compact form. These are among some passive green strategies that ought to have given succour to the building occupants against the uncomfortable indoor environment. Building form, spacing and configuration affects both the solar and wind factors. They play a large role in determining the amount of solar radiation received by the building surface and air flow rate into the indoor space (Nayak and Prajapati, 2006). Building surface being the exposed components to the outdoor environment should be compact in terms of surface to volume (S/V) ratio to help maintain thermal performance and occupants' comfort.

Orientation particularly window orientation, affects positively the indoor thermal comfort by minimizing the direct solar radiation into the building envelope. It also facilitates air flow in form of natural ventilation into the indoor spaces. Architectural design strategies in respect of natural ventilation and sun shading devices increase indoor air velocity and body cooling mechanism. These are some passive green strategies that form the major design inputs that should be the bedrock of office buildings. But however, these were not properly articulated and implemented in most office buildings in Enugu metropolis. They are the main bane of indoor thermal discomfort which affects the occupants of office buildings in Enugu.

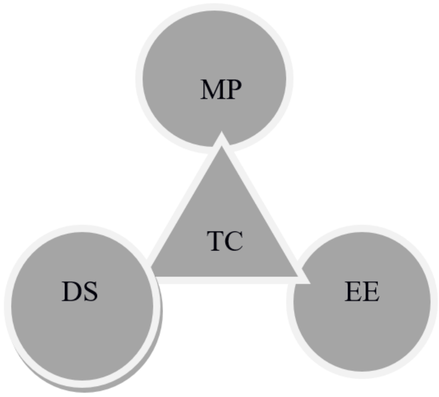
1.3 Aim and Objectives.

The aim of this research is to assess the influence of green strategies on indoor comfort in office buildings in Enugu state. Green strategy is highly connected to energy efficy and environmental sustainability.. These objectives are posited to achieve the aim,

(a) To evaluate through self- report of respondents on the extent to which design strategies (DS) can influence thermal comfort.
(b) To assess the likelihood of how energy efficiency (EE) can affect thermal comfort of office buildings in the tropics.
(c) To assess the impact of material properties (MP) on thermal comfort of office buildings in tropical region.

1.4 Conceptual Framework.

The conceptual framework that guides this research is to establish the relationships that exit among design strategies, energy efficiency, building material selection and thermal comfort. It is from the conceptual framework that the hypotheses are formulated. This conceptual framework is expressed diagrammatically in figure 1,1 below.
Figure 1.1 Showing the relationship among green techniques (design Strategies, energy efficiency and Material properties) to thermal comfort



Source; Researcher's concept.

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(a) **Hypothesis 1**; Design strategies cannot substantially influence indoor comfort in office buildings.
(b) **Hypothesis 2**; Energy Efficiency does not effectively influence indoor comfort of occupants in office buildings.
(c) **Hypothesis 3;** Material Properties cannot significantly influence indoor comfort in office buildings

2.0 Review of Related Literature.

Green strategies that affect indoor comfort of office buildings could be grouped into three categories namely, design strategies, energy efficient strategies and material selection.

2.1 Design strategies (DS)

These are passive design variables that are targeted towards harnessing the potentials of the immediate natural environment for the purpose of providing indoor comfort at minimum energy demand. Building envelope have great influence on both the indoor and outdoor space conditions (Goulding, Lewis and Steemers, 1992). The different elements of building envelope are the main components that affect the overall heat transfer coefficients. Research has verified that buildings account for 36%, 25% and 43% of the peak cooling load in Hongkong, Singapore and Saudi Arabia respectively (Al-Tamimi, Fadzil and Harun, 2010). Since Nigeria is within the tropical region like the countries mentioned above, the indoor environment could equally be influenced by the building envelope. Acoording to Appah and Koranteng (2012) many factors such as shape, orientation, absorption of solar radiation, window-to-wall ratio and material selection, are the various means in which buildings respond to the external environment. The individual elements of buildings envelope that moderate climatic potentials are discussed below.

2.1.1 Building Forms and Geometry.

Building form, its spacing and configuration within the neighbourhood affects both the solar and wind factors. They play a large role in determining the amount of solar radiation received by the building surface and also the quantity and speed of air flow through the building indoor spaces (Nayak and Prajapati, 2006). Compact forms such as cubes and lower surface-volume ratio (S/V), show lower heat gain than elongated forms (Federal Ministry of Power, Works and Housing, FMPWH, 2016). In related research, Wang, Rivard and Zmeureanu, (2006) stated that selecting the optimum shape, orientation and envelope configuration can reduce the energy consumption by about 40%. High energy demand for the provision of indoor comfort in built sector is ranked high among the major issues of sustainable environment. If about 40% of energy required in building sector can saved by shape factor and orientation, it suggests the effectiveness of the green strategy.

2.1.2 Building fenestration.

Window placement, size and orientation have a strong influence on the productivity and indoor comfort of building occupants (Appah and Koranteng, 2012). It was also reported by Al-Najem (2002) after a research on the effect of ventilation in the tropics, that heat gain through the exterior windows account for 25-28% of the total heat gain. However, Carmody,

Selkowitz, Arastch and Heschong, (2007) stipulated that high performance windows have benefits such as increased comfort, reduced condensation problems and heat gain control. A study carried out by Bokel (2007) on the effect of window position and window size on energy demand for heating, cooling and electric lighting, arrived at the following conclusions;
(a) that external facades should have a WWR of about 30% of the facade area.
(b) that WWR between 20% to 40% is also acceptable.
These results indicate that it is only the optimal window-to-wall ratio that will ensure adequate natural ventilation, reduction in solar heat gain and guarantee indoor comfort at minimum energy consumption. One of the major objectives of this study is to verify the relationship between percentage size of window as part of design techniques and thermal comfort.

2.1.3 Shading Devices.

The main purpose of shading devices is to protect and shade building facades from the direct effects of solar radiation. This will minimize the amount of heat gain from outdoor to indoor spaces. In a study conducted by Al-Tamimi, Fadzil,and Sharifah (2011), it was concluded that selecting the best shading devices can improve the number of comfortable hours. In the tropics, the percentage increase of these improvements is about 20% and 4.7% in unventilated and ventilated conditions respectively. Shading both transparent and opaque surfaces of the building envelope will minimize the amount of solar radiation that induces overheating in both indoor spaces and building structure.

2,1,4 Building Orientation.

Buildings that are well orientated on the site with reference to sun's path will provide better thermal comfort to the occupants (Muktar and Halil- Zafer, 2017). In the tropical regions, the alignment of the longer facade of buildings in the north and south axis will reduce solar heat gain and facilitate natural ventilation (Syed Fadzil and Sin Sheau, 2004). Selecting the most optimal building orientation is one of the critical energy efficient design decisions that could have great impact on building envelope energy performance (Nedhal- Ahmed and Sharifah-Fairuz, 2009). This can be used to minimize the direct sun radiation into the building windows, building openings as well as external opaque walls. Despite the positive impact of building orientation on indoor comfort, the required attention is given to it, but rather more regard is on the street and access-based orientation. The purpose of orientation is to turn the building to its most important side so that occupants will have the best living conditions even when the weather is not too conducive (Akande, 2010 in John and Lesado, 2017). An adequately oriented building can save a lot of money by cutting down heating and cooling costs (EcoWho 2017). Also Prianto et al,.2000 concluded that building orientation has a strong correlation with wind direction and sun radiation. These research findings are all pointing out the importance of orientation as a contributory factor to indoor comfort.

2. 2 Energy Efficiency (EE).

Energy efficiency is one of the passive cooling or heating initiatives that focusses on heat gain control and heat dissipation to improve indoor thermal comfort with low or no energy consumption (Leo Samuel, Shiva Nagendra and Maiya, 2013). Natural cooling techniques utilize the interaction between the energy available from immediate natural environment and building envelope design to dissipate heat (Niles and Kenneth, 1980). Attaining energy efficiency and conservation in the achievement of indoor comfort in the built environment, is one the targets of green strategies because of sustainability benefits involved. Building design is one of the key factors determining the building's energy efficiency besides occupant behaviour (Akande, Fabiyi and Mark, 2015). Some specific design passive techniques for actualizing indoor comfort with little or no energy requirement include but not limited to natural ventilation, Landscaping and installation of renewable energy resources.

2.2.1 Natural Ventilation.

Natural ventilation keeps the air moving within the indoor environment and therefore keeps the inhabitants cooler even without the use of energy. Some studies revealed that thermal comfort in naturally ventilated environments is much better than in mechanically controlled environments (Fanger and Toftus, 2002; Xia,Zhao and Jiang,.1999). Wong and Huang (2004) made a comparative study on the indoor air quality of naturally ventilated and air-conditioned bedrooms of residential buildings in Singapore (hot humid climate like Nigeria).

The finding of this research was that thermal comfort in an air- conditioned environments were usually overcooled, resulting in extremely high PPD (percentage People Dissatisfied)

2.2,2 Landscaping;

Landscaping of the immediate external environment of buildings can moderate the indoor temperature and improve thermal comfort of occupants. In a research on climate change and Architects' perspective towards achieving thermal comfort in buildings in south Eastern Nigeria, the importance of green areas on thermal comfort was emphasized. It was concluded that vegetation absorbs unwanted carbon dioxide, cleans the air, reduces the sun glare, absorbs solar radiation, and by transpiration cools the air, and help reduce overheating of the air (Alozie, Eze and Irouke, 2016).

2.2.3 Renewable Energy/Energy saving techniques.

The concept of energy efficient buildings has implications on regulations, economic energy demand and the environment (March, 2005). Energy efficient buildings are buildings which use design practices to take advantage of natural resources and minimize energy waste. This ensures drastic reduction of environmental pollution and sustainability of the ecosystem. Renewable energy resources commonly used for building applications include solar, wind geothermal, and biomass. Chwieduk, (2003) proposed three basic criteria for an energy efficient building and there are;

►the building should be equipped with efficient installations and materials appropriate for the location and conditions.

►the building should be provided with amenities and services appropriate to the buildings' intended use

►the building should be operated as much as possible to ensure low energy use when compared to other similar buildings.

These criteria for energy efficient buildings not only guarantee indoor thermal comfort but also ensure environmental sustainability.

2.3 Material Properties (MP).

The properties of building materials of various building components play very important role in controlling the processes of heat transfer which eventually influence indoor thermal performance. Heat transfer mechanisms between the outdoor and indoor environments affect the indoor temperature which is very fundamental to indoor thermal comfort. Though it is important to note that solar heat gain pass though window openings, but opaque walls also admit solar heat gain as explained below. The most important thermal properties that affect indoor thermal comfort are, surface qualities, thermal conductivity, thermal resistance, thermal transmittance and density.

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2.3.1 Surface qualities.
Absorptance/reflectance will strongly influence the solar heat input. To minimize indoor solar heat input, reflective surfaces are preferred.
2.3.2 Thermal conductivity λ
Thermal conductivity is a property of the material which represents the quantity of heat per unit time in watts, that flows through a 1m thick even layer of material with an area of 1m^2, across a temperature gradient of 1 K (Kelvin) in the direction of heat flow (CSR Hebel Technical Manual, 2006). The lower the value of thermal conductivity, the less the thermal heat transmitted (Mahia, Taufiq, Ismail and Masjuki, 2007). Building materials with low conductivity is preferable in terms of ensuring less solar heat gain through the opaque walls.
2.3.3 Thermal Resistance of materials R.
The thermal resistance of a material is the ability to obstruct the flow of heat between two surfaces of different temperatures. Resistance can be expressed as the R-value which is a function of the material thickness and the reciprocal of its thermal conductivity (CSR Hebel Technical Manual, 2006).
2.3.4 Thermal Transmittance, or U-value
This is the heat flow density (W/m^2) with 1K temperature difference (ΔT) between air inside and air outside in units of W/m^{2}K (Szokolay, 2004).

Thermal transmittance is a direct measure of the thermal insulating ability of a given building component air to air. It is inversely proportional to the measure of the total thermal resistance of the material component, R (given as U = 1/R) (CSR Hebel Technical Manual, 2006).Table 2.1 below indicates the U-values of some basic building components.

Table 2.1. Building Fabric materials and their U- values

Building Components	Materials Used	U- value (W/m^2 k
Roof	Aluminium roofing sheets	1.27
Wall	200mm sandcrete wall with plaster	1.14
Window pane	4mm single glazed reflective glass	5.80
Window frame	Aluminium frame	5.88
Door frame	25mm hardwood panel door	3.20
Door frame	50mm hardwood	2.84
Floor	150mm concrete slab with 50mm screed	0.82

Source; Koranteng and Nkrumah, (2015).
2.3.5 Density and Porosity.
The density ρ is the mass of a volume (Kg/m^3) of the material comprising the solid itself and gas-filled pores. Density plays major role in the thermal properties because the lighter the material, the more insulating and the heavier the more heat storing (Rosenlund, 2000). For insulating and minimum heat flow, lighter building materials are recommended. But these light materials lack structural stability which is required in most building components. In internal spaces where it is necessary to regulate temperature using passive means, composite elements made up of both light and dense materials could be used.

2.4 Thermal comfort.
Thermal comfort is defined as the condition of the mind which expresses satisfaction or dissatisfaction with the thermal environment (Malgwi and Musa, 2014). Thermal environment in this context is concerned with the immediate environment which could be an enclosed or open space. The environmental conditions of both indoor and outdoor spaces affect the level of human thermal comfort. But however, this research concentrates on the indoor environment because it is more defined and can be controlled by some design measures to suit human comfort. Since substantial amount of time is spent at indoor space either to work, rest and for leisure, it is imperative that indoor spaces should be conducive and comfortable for the occupants.

The use of mechanical means of ventilation requires high energy demand which is more expensive. But unfortunately, the economic and environmental costs of obtaining this indoor comfort through artificial means are becoming very expensive and unaffordable to the average citizenry. This has triggered many research studies on the use of building envelope design to achieve indoor comfort at minimal energy demand.

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3.0 Methodology.
3.1 Data Collection.
Descriptive research methodology design was considered adequate for this study because it is basically concerned

with possible causal relationship between phenomenon and variables. According to Kothari and Garg (2014) descriptive research methodology is all about specific prediction, narration of facts and characteristics concerning individuals, groups or situations Data for this research was through primary sources.

Subjective data collection techniques like questionnaires and interviews were adopted. This method is considered adequate because it is one of the most economical means of obtaining the occupants thermal comfort preferences and perceptions. The number of respondents is selected from a poll of Enugu State civil servants in the ministry who must have been in active service for not less than five years. This is to ensure that the respondents must have experienced afternoon indoor office conditions through the two major seasons (dry and rainy seasons) prevalent in the study area.

Purposive or judgemental sampling techniques are most appropriate for this research because the respondents should be the civil servants who meet the specified characteristics. A sample size of 150 respondents is randomly selected from civil servants who possess the above mentioned qualities. The subjective thermal preferences and acceptance of the respondents were obtained using the judgement of likelihood based on these inputs indicated by a five-tier lexicon consistent with everyday usage shown below.

very unlikely	unlikely	possible	likely	Very likely
1	2	3	4	5

3.2 Statistical Analysis of the subjective variables.

Multiple Regression analysis was adopted for analysis of the variables. This was considered adequate since we are interested in establishing the relationship between the output, response or dependent variable (TC which is quantitative) and input, independent or explanatory variables (DS, MP and EE which are also quantitative). Linear Regression analysis and one-way analysis of variance ANOVA were used to compare means of the dependent and independent variables. A software package known as Statistical Package for Social Science (SPSS) was used. The P-value represents the probabilities that the Null hypothesis is true. As stated in the hypothesis, it means that Material properties, Design strategies or Energy Efficiency do not significantly influence thermal comfort of office workers in Enugu State. P-values were calculated using parametric statistic of Regression Analysis. In this paper, P-value less than 5% ($P<0.05$) is considered to be statistically significant.

3.3 Results and Discussions.

3.3.1 Results

From table 3.2, the mean scores of EE, MP and DS indicated that DS has the highest mean score of 3.74. This signifies that DS has the highest influence on thermal comfort (TC). The frequency tables in figures 3.2, 3.3 and 3.4 showed that the frequencies for 'likely'are 36 for EE, 65 for DS and 17 for MP. These were further explained by the Bar charts in figures 3.1.1, 3.1.2 and 3.1.3 From figure 3.1.1, the highest frequency for EE is on 'possibility'The highest frequency for DS is on ' likely'and the highest frequency for MP is on very ' unlikely'.

Table 3.1 Showing the mean, median and mode of the subjective rating of respondents

Statistics

		Energy Efficiency	Material Properties	Design Strategies	Thermal Comfort
N	Valid	150	150	150	150
	Missing	0	0	0	0
Mean		3.56	2.61	3.74	2.6783
Median		3.00	2.00	4.00	2.5000
Mode		3	1	4	2.00

Table 3.2 Showing the frequency rating of the influence of Energy efficiency (EE) on thermal comfort.

Energy Efficiency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very unlikely	6	4.0	4.0	4.0
	unlikely	14	9.3	9.3	13.3
	possible	57	38.0	38.0	51.3
	likely	36	24.0	24.0	75.3
	very likely	37	24.7	24.7	100.0
	Total	150	100.0	100.0	

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Table 3.3 Showing the frequency rating of the influence of Design strategies (DS) on thermal comfort

Design Strategies

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very unlikely	4	2.7	2.7	2.7
	unlikely	4	2.7	2.7	5.3
	possible	48	32.0	32.0	37.3
	likely	65	43.3	43.3	80.7
	very likely	29	19.3	19.3	100.0
	Total	150	100.0	100.0	

Table 3.4 Showing the frequency rating of the influence of Material properties (MP) on thermal comfort

Material Properties

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very unlikely	53	35.3	35.3	35.3
	unlikely	37	24.7	24.7	60.0
	possible	9	6.0	6.0	66.0
	likely	17	11.3	11.3	77.3
	very likely	34	22.7	22.7	100.0
	Total	150	100.0	100.0	

Table 3.5 Frequency of the average impacts on thermal comfort (TC).

Thermal Comfort

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.25	3	2.0	2.0	2.0
	1.50	5	3.3	3.3	5.3
	1.75	19	12.7	12.7	18.0
	unlikely	30	20.0	20.0	38.0
	2.25	17	11.3	11.3	49.3
	2.50	12	8.0	8.0	57.3
	2.75	9	6.0	6.0	63.3
	possible	10	6.7	6.7	70.0
	3.25	4	2.7	2.7	72.7
	3.50	13	8.7	8.7	81.3
	3.75	5	3.3	3.3	84.7
	likely	10	6.7	6.7	91.3
	4.25	9	6.0	6.0	97.3
	4.50	1	.7	.7	98.0
	4.75	3	2.0	2.0	100.0
	Total	150	100.0	100.0	

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Figure 3.1.1 Bar chart showing the frequency of EE rating on TC.

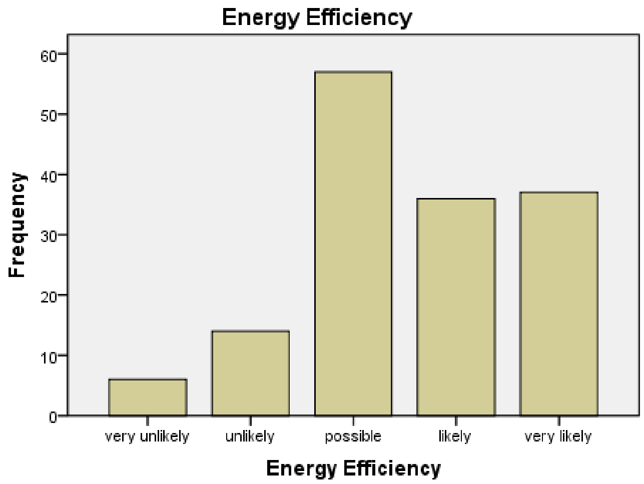


Figure 3.1.2 Bar chart relating the frequency of DS rating on TC.

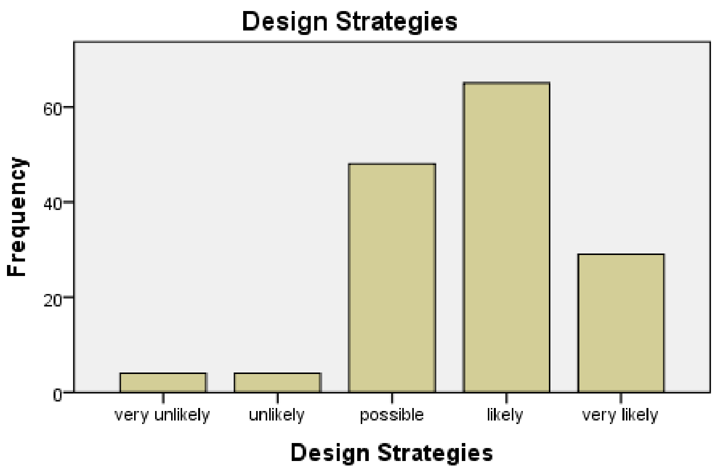
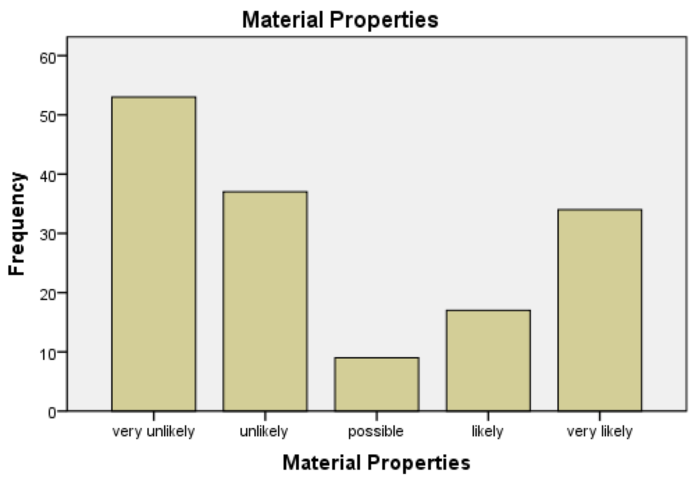
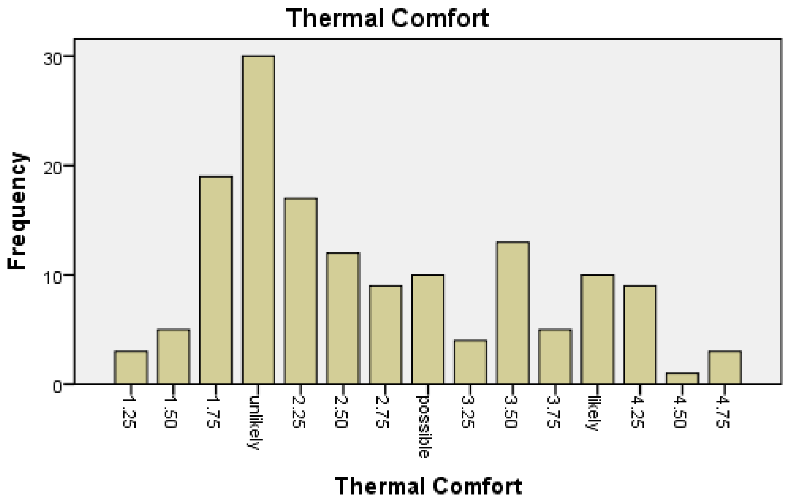


Figure 3.1.3 Bar chart relating the frequency of MP subjecting scores on TC.



Fgure 3.1.4 Bar chart showing the frequency of different ratings of Lexicon of TC



3.3.2 Discussion of Analysis.

From table 3.6 which is the model fit table, the value R-square is 0.507 and Adjusted R-value is 0.497, which means that the independent variables (Design strategies, Material properties and Energy efficiency) account for 50.7% of variance in the dependent variable (thermal comfort). The ANOVA table shown in table 3.3 clarifies the model fit by showing P-value of 0.00 which justifies the explanatory power of the model fit. Table 3.9a indicates the P-values of the independent variables

Table 3.9b shows the P-values of the independent variables and from the same table, the p-values for energy efficiency and material properties are 0.685 and 0.034 respectively. These values are greater than 0.05 (P=0.685 P=0.034; P>0.05) which implies that the risk level of rejecting the null hypothesis is very high and therefore, both energy efficiency and material properties do not significantly influence indoor comfort in office buildings. But for design strategies, the result shows that the p-value is less than 0.05 (0.00< 0.05). This implies that design strategies can significantly influence indoor comfort in office buildings.

The result on design strategies agrees with what many researchers had earlier reported .from the literature on building orientation, building form, fenestration and shading devices. The influence of these components on thermal comfort were rated very high (FMPWH, 2016; Appah and Koranteng, 2012; Carmody et al,. 2007; Ai-Tamimi, et al,.2011; Muktar and Halil-Zafer, 2017). The significant influence of design strategies on indoor comfort of office buildings is likely to be as a result of open form of the buildings which might have enabled optimum window ratio and natural ventilation.

The result of the subjective analysis of energy efficiency and material properties on thermal comfort was at variance with results of earlier studies. According to some researchers, energy efficiency buildings could reasonably improve indoor comfort of occupants (March, 2015; Chwieduk, 2003; Alozie, Eze and Irouke, 2016). Also research results had shown that the properties of some building materials influence the rate of heat transmitted into the indoor space which ultimately affects human comfort (Mahia, Taufiq, Ismail and Masjuki, 2007). It could be that the physical and chemical properties of some building material components may have been modified during construction stages and also by interaction with the environment. This could account for insignificant contribution of material properties to remarkable improvement of indoor comfort in the office buildings.

Table; 3.6 Showing both the dependent and independent variables entered.

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Energy Efficiency, Material Properties, Design Strategies[b]	.	Enter

a. Dependent Variable: Thermal Comfort
b. All requested variables entered.

Table; 3.7 Showing the model fit

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	.712[a]	.507	.497	.63523

a. Predictors: (Constant), Energy Efficiency, Material Properties, Design Strategies

Table 3.8 ANOVA table

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	60.628	3	20.209	50.083	.000[b]
	Residual	58.914	146	.404		
	Total	119.542	149			

a. Dependent Variable: Thermal Comfort
b. Predictors: (Constant), Energy Efficiency, Material Properties, Design Strategies

Table 3.9a Showing the P-values of the independent variables.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.073	.300		3.575	.000
	Material Properties	.127	.059	.127	2.140	.034
	Design Strategies	.405	.034	.721	11.988	.000
	Energy Efficiency	.020	.050	.025	.407	.685

a. Dependent Variable: Thermal Comfort

Table 3.9b showing the relationship between Design envelope factors and thermal comfort.

Variables	Unstandardised Coefficients	Standardised Coefficients	T	P	α sig	Comment
Constant	1.073		3.575	.000	< 0.05	significant
Material Properties	0.127	0.127	2.140	0.034	>0.05	Not significant
Design Strategies	0.405	0.721	11.988	.000	< 0.05	Significant
Energy Efficiency	0.020	0.025	0.407	0.685	>0.05	Not significant

3.4 Conclusion and Recommendations

The subjective study of the influence of green strategies on indoor comfort of office buildings in Enugu revealed that design strategies has great influence on indoor comfort of office workers. The result however indicated that the other aspects of green strategies (energy efficiency and properties of material components) do not significantly influence comfort of occupants. This do not mean that energy efficiency and material components have no influence on thermal comfort but in comparative terms, design strategy has greater influence. Again the disposition of the respondents may also contribute to their individual responses that affect the result.

One of the major highlights of this study is that the key stakeholders in building industry (architects, engineers, builders, developers and end-users) should understand the urgent need to adopt green initiatives in the design and construction of buildings. Special attention should be paid to orientation, optimum window ratio shading devices and compact form articulation, all of which encourage natural ventilation that guarantee comfort at minimum energy demand, Main target should always be to utilize the potentials of specific building locations to optimize natural means of achieving indoor comfort. These requirements should be enshrined in National Building Code for the country.

References

Akande, O. K; Fabiyi, O and Mark, C. I (2015), Sustainable Approach to Developing Energy Efficient Buildings for Resilient Future of the Built Environment in Nigeria. *American Journal of Civil Engineering and Architecture, 3 (4) 144-152.*

Al-Anzi, A. Seo, D. & Krati, M. (2009, Impact of building shape on thermal performance of office building in Kuwait. *Energy conservation and management. 50. (23). 822-828.*

Alozie, G. C. Eze, M.U. and Trouke, V. N. (2016), A Review of Climate Change and the Architect's Perspective towards Achieving Thermal Comfort in Buildings in South-Eastern, Nigeria. *International Journal of Advanced Studies in Ecology Development and Sustainability 4 (1) 2364-4260.,*

Al-Tamimi, N. Fadzil, S. and Harun, W.(2010), he effect of Orientation, Ventilation and Varied WWR on the

Thermal Performance of Residential Rooms in the Tropics, *Journal of Sustainable Development 4(2) 142-149.*

Al-Najem, A. A. (2002), The Architectural Category and its importance to measure the Electrical energy demand and to identify effective conservation measures The first Symposium on Energy Conservation and Management in Buildings Conference SAK, (1) 99-110.

Al-Tamimi, Wan-Mariah, W.H.l and Sharifah, F. (2011), The potential of shading devices for temperature reduction in high rise residential buildings in the tropics, International Conference on Green Buildings and Sustainable Cities, Procedia Engineering 21, 273-282.

African Development Bank (ADB), (2006), Forum on African Statistics Development FASDEV- Progress on the Implementation of the Bank's Statistical Capacity Building Activities in Africa in the Context of of the International Comparison Program for Africa African Development Bank Group Statistics Division, Addis Ababa, 6-10 February ,1-19.

Adebamowo, M.A. and Akande, O. K. (201), Indoor Thermal Comfort for Residential Buildings in Hot-Dry Climate of Nigeria.

Akande, O.K, (2010), Passive design strategies for residential buildings in a hot dry climate in Nigeria. WIT Press, www, witpress.com ISSN 1743-3541.

Anup S. (2004), UN Framework Convention on Climate Change. *Http;/www,globalissues.Org article/521.*

Anup S.(2015), Climate Change and Global Warming Introduction. *Http;/www.globalssues.org/article/233/climate-change-and-global-warming; Introduction*

Atolagbe, A.M.O. and Ajayi, O. O. (2015), Natural Ventilation and Body Heat; An Evaluation of Residents Satisfaction in Ogbomoso, Nigeria. I*nternational Journal of Civil Engineering, Construction and Estate Management, 3 (2) 7-15*

Atolagbe, A.M.O. and Fadamiro, J. A. (2005), Energy policy for Building Materials Technology. A global Imperative for Sustainable Architecture. Journal Saints *Dan Technology 15(3) 45-58.*

Appah, D.J. and Koranteng, C. (2012), A thermal comfort evaluation of a junior high school building in Accra, Ghana. *Journal of Construction Project Management and Innovation, 2(2) 403-423.*

Babatunde J.A, Ayobami T.S and Mark T. (2011) Climate Change Scenarios for Nigeria; *A report published by the Building Nigeria's Response to Climate Change (BNRCC)Project 144-152.*

Bokel, R.M.J. (2007), The effect of window position and window size on the Energy demand for heating, cooling and electric lighting, *Proceeding, Building Simulation.*

Carmody, J. Selkowitz, S Arastch, D and Heschong, L. (2007), Residential windows, Third Edition, W. W. Norton Company, Inc. 500 Filth Avenue, New York

Chauchan, K. and Shah, N. (2008), A study on sustainable urban Environment with climatic consideration in Housing Planning. Glob. J. Environ. Res. 2(1) 12-17

Chwied uk, D. A. (2003), Towards sustainable energy building, *Journal of applied energy 76,(13), 211-217*

Chu, M; lu, X; Hou, X and Wang, X. (2012), Comparative study of heat transfer in double skin facade on high-rise office building in jakanta, Applied Mechanics and Materials 170-173.

CSR Hebel Technical Manual, (2006), Version1. De-Nardo, J.C, Jarret A.R, Manbeck, H.B, Beattie D.J, & Berghage, R.D (2005), Storm water mitigation and Surface temperature reduction by green roofs. *Trans ASAE 48 1491-1496.*

Draguna, D, Predrag, Z. Mladen, T. (2015), Environmental Sustainability and Thermal Comfort with Green Roof Implementation in the Building Envelope. 17th Symposium on *Thermal Science and Engineering of Serbia. 438-443*

Eco-Who, (2017), The importance of Building Orientation, Eco Friendly and Sustainable Living,, received 12.07, 2017 from www. Echowho.com.

Emeka N, Eric E, and Noble J. N, (2015), Status and trend of deforestation; An insight and lessons from Enugu State, Nigeria. J*ournal of Agricultural Science, 3(1), 23-31 ISSN; 2315-9766.*

Fanger, P. O. and Toftum, J. (2002), Extension of the PMV model to non-air conditioned buildings in warm climates, *Energy and Buildings 34, 533-536*

Federal Ministry of Power, Works and Housing, FMPWH (2016), Building Energy *Efficiency Guideline for Nigeria. Shehu Yaradua Way, Mabushi. Abuja Nigeria.*

Frith M & Gedge, D, (2005), The wild roof Renaissance, p. 117-120. In Earth Pledge Green Roofs; Ecological Design and Construction, *Publisher,Schiffer Books London.*

Getter K. L. and Rowe, D. B (2006), The Role of Extensive Green roofs in sustainable Development. *Journal of Hort Science, 41 (5); 1276-1285.*

Goulding, J. Lewis, O. and Steemers, T. (1992), Energy in Architecture; The European Passive Solar Handbook, B.T. Batsford for the Commission of the European Communities, Directorate General XII for Science, Research and Development London.

Howe J.C, (2010), Overview of green buildings. National Wetlands *Newsletter, 33(1)*

(http/web/ebscohost.com.ibdb. Njit. Edu.8888.
Hegazy, T (2009), Life-cycle stages of projects. Computer-Based Construction Project Management.8
Jamaludin, N. Khamidi, M. F. Wahab, S. N.A. and Klufallah, M.M.A. (2014),Indoor Thermal Environment in Tropical Climate. Residential Building, F3S Web of conference 3, 01026 DOI 10.105
John, J.A and Lesado, A. (2017), Building Orientation; Enhancing Nature with Nature. *Journal of Applied Sciences and Environmental Sustainability, 3 (7) 29-35*
Kothari, C. R. and Garg, G. (2014), Research methodology, Methods and Techniques (3rd edition) New Age International Publishers New Delhi India.
Koranteng, C. Essel, C. and Nkrumah, J. (2015), Passive Analysis of the Effect of Window Size and Position on Indoor Comfort for Residential Rooms in Kumasi, Ghana. I*nternational Advanced Research in Science, Engineering and Technology, 2(10). 114-121*
Konstantina, L.; Elli, K; Christina; Efrosini and Agis, M. (2014). Thermal performance of office building envelopes; the role of window-to-wall ratio and thermal mass in Mediterranean and Oceanic climates. *Journal of Power Technologies 94 (2) 1-10*
Lauber W. (2005), Tropical Architecture, Sustainable and humane building in Africa, Latin America and South-East ASIA, New York, Prestel Publishing.
Leech, J.A; Nelson, W.C; Bumett,R.T; Aaron, S. and Raizenne,M.E;(2002),It is about Time, A comparison of Canadian and American Time-Activity Patterns. *Journal of Exposure Analysis and Environmental Epidemiology. 12(6); 427-432.*
Leo S.D.G; Shiva N.S.M; Malya M. P. (2013), Passive alternatives to mechanical air conditioning of buildings; A review, *Building and Environment. 66; 54-64.*
Mahia, T. M. I.Taufiq, B. N. Ismail, Masjuki, H. H. (2007), Correlation between thermal conductivity and the thickness of selected insulation materials for *building wall. Energy and Building, 39, 182-187.*
Mehran, S.S. (2014), Integrated Green Roofs and its Role of Achieving Sustainability in Residential Buildings in Urban Areas in Athens. *Int. Journal of Engineering Research and Applications 4. 104-112.*
Malgwi M. E. and Musa L. S. (2014), An Evaluation of Thermal Comfort conditions in an Urban Entertainment Centre in Hot- Dry Climate of Nigeria. *International Journal of Energy and Environmental Research..2(1) 55-74*
Mao, Xiaoping, Lu, Huimin, Li, Qiming (2009), A Comparison Study of Mainstream Sustainable/Green Building Rating Tools in the World. I*nternational conference on Management and Science 1*
March, G. (2005), Zero energy buildings. Key role for RE at UK housing development refocus. 3(3) 58-61
Nayak, J. K. and Prajapati, J. A. (2006), Handbook on energy conscious buildings. Indian Institute of Technology, Bombay and Solar energy centre, Ministry of non-conventional energy sources, Government of India.
Muktar, I. and Halil-Zafer, A. (2017), Application of Passive Cooling Techniques in Residential Buildings; A Case Study of Northern Nigeria *Journal of Engineering Research and Application. 7, 24-30*
Nedhal- Ahmed M.and Sharifah-Fairuz, S.F. (2009), The effect of glazed fenestration area and natural ventilation on thermal performance in residential buildings in tropical region. *Internal Symposium in Developing Economies*
Niles, P. and Kenneth, H.(1980), Passive solar handbook, California Energy Resources Conservation. ASIN B001UYRTMM (https/www.amazon.com/db/B001UYRTMM)
Oberndorfer, E, Lundholm,J,Bass, B, Coffman, R.R & Doshi,H. (2007), Green roofs as urban ecosystem ecological structure, function and service. *Architectural Science publications and Research, 57 (10).*
Odebiyi S.O, Subramanian S and Braimoh A.K. (2010), Green Architecture; Merits for Africa Nigerian Case Study). *Journal of Alternative Perspective in Social Science 2 (2) 746-767*
Ohajuruka, C. A. (2013), Green Building Retrofitting; Challenges and Opportunities For Nigeria, Architects Colloquium 2013, Held at Shehu Musa Yar'Adua Centre, Abuja
Okwo A. (2008), Can Renewable Energy Meet Africa's Development Needs? In Proceedings of the IEEE International Symposium on Electronic and the Environment 1 1- 2.
Ojo O. (1987), Rainfall trends in West Africa 1901-1985. The influence of Climate Change and Climatic Variability on the Hydrologic Regime and Water Resources. *Proceedings of the Vancouver Symposium August 1987. IAHS Publication, 168,37-43*
Oyedepo, S.O, (2014), Towards achieving energy for sustainable development in Nigeria. *Renewable and sustainable energy reviews, 34; 225-272.*
Parsons k.. (2003), Human thermal environment. The effects of hot, cold and moderate environment on human health, comfort and performance, *Second edition,Taylor and Francis, London.*
Prianto, E. Bonneaud, F. Depecker, P. and Peneau, J-P. (2000), Tropical-Humid Architecture in Natural Ventilation Efficient Point of View; A reference of Traditional Architecture in Indonesia. *International Journal on Architectural Science, 1 (2) 80-95*
Pushkar S, Becker, R & Katz, A (2005), A methodology for design of environmentally optimal buildings by

ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online) DOI: 10.7176/ISDE
Vol.10, No.7, 2019

variable grouping. *Building and Environment. 40(8) 11-26*

Rashdi, W. M; Suraya, W.S & Mmbi, R.M. (2016), Analysing Optimum Building Form In Relation to Lower Cooling Load. *Social and Behavioural Sciences 222,782-790*

Rosenlund, H. (2000), Climatic Design of Buildings using Passive Technologies. *Building Issues, 10 (1) 3-26.*

Stephen Emmitt (2002) Architectural Technology Publishes by Blackwell Science Ltd. 25 John Street, London.18-23

Susan J. H. (20*04), Impacts of a Warming Arctic. Published by Cambridge University Press 40 West 20th Street, New York USA.*

Syed Fadzil, S.F and Sin Sheau, J. (2004), Sunlight control and daylight distribution analysis; the KOMTAR case study, *Building and Environment 39(6) 713-717*

Sylvie L. (2007), Building and Climate Change; Summary for Decision-Makers.*UNEP SBCC Sustainable Buildings and Climate Initiative.*

Szokolay, V.S. (2004), Introduction to Architectural Science. The Basis of Sustainable Design, First Edition, Architectural Press, Oxford, UK.

United Nations Millennium Development Goal (UNMDG), 2008),Report of the Secretary-General on the Work of the Organization 2007, New York .United Nations Development of Economics and Social Affairs

U.S Environmental Protection Agency (2009), Green Building Basic Information. *Retrieved December 10 2009 from http /wwwe epa gov/greenbuilding/pubs/about.htm.*

Uyanga (2012).The plantation economy in the Calabar region; a preliminary analysis in Calabar and Environs. Geographic Studies (Inyang PEB, Usoro E.J Abassiekong E M, Sule RAQ, eds.). Dept. of Geography, University of Calabar.

Xia, Y.Z. Zhao, R.Y. and Jiang, Y. (1999), Thermal comfort in naturally ventilated houses in Beijing, *Journal on heat ventilated air conditioned Refrig. 1-5*

Wang, W. Rivard, H. and Zmeureanu, R. (2006), Floor shape optimization for green building design. Advanced Engineering Informatics, I (20). 363-378.

Wong, N.H, Chen, Y, Ong, C.L & Sia, S. (2003), Investigation of thermal benefits of Rooftop garden in the Tropical environment. *Building and Environment 38 261-270*

Wong, N. K. and Huang, B. (2004), Comparative study of the Indoor Air Quality of Naturally Ventilated and Air-Conditioned Bedrooms of Residential Buildings In Singapore, *Building and Environment, 39(9); 115-1123.*

WBDG Sustainable Committee (2009), Sustainable *Retrieved from http/www.Wbdg.org/designsustainable.php.*

Yau and Stellios (2006), Design for sustainability. Beijing, *China Architecture and Building press ISNB 7-112-08390-7*

Yang, L. Yan, H. Lam, J. C. (2012), Applied Energy. 115, 164-173.