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INFLUENCE OF CLIMATE CHANGE ON BUILDING DESIGN IN ENUGU SOUTH L.G.A OF NIGERIA

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ABSTRACT: *The effects of climate change on building design is a worrisome issue. Flooding, wind storm among others drastically affect buildings in the study area. This sometimes leads to building failures and in extreme cases, complete collapse. This research employed the use questionnaire and also sourced climate data from NIMET. The data collected were analyzed using percentages, Principle component analysis and regression analysis. The research found out that the respondents are knowledgeable about climate change and agree that it affects building designs, therefore must be factored into the design for proper ventilation and illumination as well as increased resilience and durability of the buildings in the study area. The likert table with a cluster means value of 4.01 > 3.0 and associated standard deviation of 0.65 indicates that the respondents perceived climate changes as contributing to changes in building designs. Bu ilding Designs in Enugu metropolis have changed over time. Component II recorded an eigen value of 1.486 and an additional variance of 16.512% bringing the cumulative explanation of respondents perception of climate influence on building designs to 88.183%. The research concluded that there are stages in the design of buildings whereby climate parameters are considered and that affects important decisions regarding the supposed building. The research recommends the need for building professionals to obtain basic climatic data from meteorological stations nearer to their proposed site and analyze such data for proper design of buildings.*

KEYWORDS: climate change, building design, Enugu south L.G.A , Nigeria

INTRODUCTION

The overwhelming influence of climate change ranging from increased temperature to flooding among other effects poses a threat to man's culture and even his very existence. The case is very pathetic as Enugu South Local Government Area of Nigeria has been greatly affected. The recorded incidence of flooding, the disappearance of indigenous pattern of building for which Enugu state is known can still be traced to some other local governments like Igboeze Local Government Area among others. Climate Change has effect on a lot of variables; fresh water availability, the productive capacity of soil and in the pattern of human settlement (Raleigh,

Clinodh, & Henrik, 2007). Climate Change to a great extent bear influence on human society and political system (Raleigh *et al*, 2007).

Buildings are usually designed to suit a specific climate, but their lifespan is often not more than a century. Buildings are vulnerable to climate change which in the future, can cause a higher risk of collapse, reduction in value resulting from the impact of climate change. All these most be factored into building design to reduce impending failures. According to Johns and Fedeski, (1994), climate agents play an important role in the deterioration of building fabric, and a change in climate is expected to have a significant effect on deterioration. Climate Change is defined as a change in the state of the climate that can be identified (e,g using statistical test) by changes seen mean and /or the variability of it's properties, which persists for an extended period typically decades or longer (Intergovernmental Panel on Climate Change 2007).

Aim of the Study

The study aims at analyzing the influence of climate change on building design so as mitigate future effects on the building fabrics.

Objectives

1. To understand the concept of building design.
2. To evaluate how climatic variables affect building design.
3. To access measures that can be employed to reduce future impact of climate change on building fabrics.

Hypothesis

H_o "there is no significant difference in the perception of the respondents on effects of climate variability on building design".

Significance of Study

This research will be of great help to the various stakeholders in the built environment. It will create awareness of impending effects of climate change on the building fabrics to the client as well as to the professionals in the system. This enables them to employ professionalism as required. It will be a guide to the government for policy making.

REVIEW OF RELATED LITERATURE

Concept of Climate Change

Climate change is defined as a change in the state of the climate that can be identified (e,g using statistical test) by changes seen mean and /or the variability of it's properties, which persists for an extended period typically decades or longer (Intergovernmental Panel on Climate Change 2007).Climate Change is evidenced by rise in temperature, fluctuations in rainfall, floods, drought and wind storm (IPCC, 2013). It is caused by both natural and anthropogenic activities like mining, construction, urbanization, agriculture and so on.Human activities bring about change as a result of urbanization, industrialization and change in the standard of living. This advances the normal traditional way of building to mechanized system involving the use of higher machinery. The

normal manual process of building production is gradually abandon for mechanization which increases the change in climate variables, (Iheama, 2017).

In the past the pattern of buildings encouraged culture as people valued and used the materials in the environment like mud, timber, fibres down to an advanced level where these muds were fired (put under pressure to increase its strength and durability). Climate change is not just caused by natural factors, it is also triggered by other anthropogenic activities like agriculture, mining, industrialization as well as construction. Contingency in everyday life makes lasting behavioral change relatively rare, the time lag can be considerable even when there is such great desire to sustain culture, advancement in technology used in construction is very attractive and calls for effectiveness since the targeted time must be met. The natural material like mud consumes a lot of time both in preparation and placement and demands such great skill which has been lost by the present generation since they have never even seen it either prepared or witnessed its placement. This makes it difficult to produce the required number of housing units considering the fact that housing demands is on the increase as a result of urbanization.

The urbanized area has more risk of flooding due to excessive rainfall, construction works deter infiltration of water into the soil thereby causing more runoff (Satterthwaite, 2008). Excessive rainfall overwhelms the available drainage systems and the increase in demand or the pressure on the provision of more housing units.

Effects of Climate Change on Building Design

Claudia (2004), opined that flooding, coastal erosion, subsidence, drainage systems require new building techniques and materials in order to resist adverse weather conditions; influences the choice of site, cost of finance/insurance: as a result of this Insurance sector is beginning to factor impacts of climate change into premiums.

Kimmo (2005), in ECONO project report opined that climatic factors affect buildings. He buttressed this by saying that the intensity and direction of the wind affects the walls, roofs and groups of building. While, Wilby (2007), reviewed climate change impacts on the built environment, he collated evidence of effects in four main areas: urban ventilation and cooling, urban drainage and flood risk, water resources, and outdoor spaces (including air quality and biodiversity). He therefore, pointed out that built areas exert considerable influence over their local climate and environment, and that urban populations are already facing a range of weather-related risks such as heat waves, air pollution episodes and flooding. According to him, though climate change is expected to compound these problems, building designers and spatial planners are responding through improved building design and layout of cities and not considering the traditional building patterns. For example, green roofs and spaces provide multiple benefits for air quality, mitigating excessive heat and enhancing biodiversity which the thatch roof did not fall to provide except for interest in advanced innovation.

Patrick (2014), in his paper on climate change; implications for building, reported that Buildings face major risks of damage considering mostly the mud and thatch house from the projected impacts of climate change, having already experienced a big increase in extreme weather damage

in recent decades. According to him, there is likely to be significant regional variation in the intensity Enugu State being in the tropics and nature of such impacts.

METHOD OF DATA ANALYSIS AND PRESENTATION

The data collected from the questionnaire distributed was analyzed using simple percentages and descriptive analytical tool such as tables in analyzing and presenting the result. The data realized from NIMET was analyzed using time series analysis and presented in Tables and charts. The research questionnaires were designed with variables from the exploratory studies, this was supplied by the interviewees and the literature survey. The design obtained representative views of the respondents on the levels of importance or relative impact of climate change on the design of building, each attribute being rated. Likert scales were provided on a rating continuum (1-5) to measure the varying degrees of respondents' opinions about the relative worth of the attributes in the subsets. Likert scale is used in measuring opinions, beliefs and attitudes. In the field of organizational research, a range of response between 30 and 90 is acceptable according to Bryman and Bell (2003). The rest of the questionnaires were either not returned or improperly completed, therefore invalid. No specific reason was given by the respondents for the uncompleted questionnaires.

Regression Analysis

To investigate the relationship between the climatic parameters and their combined strength on variations in building design in the study area, multiple regression analysis was performed to determine the strength of these relationships. The dependent variables were regressed on the climatological variables (independent variables). From this multiple regression model, the rate of change (increase or decrease), as indicated by the regression coefficients of the independent variables, building design.

Principal Component Analysis

Other major statistical techniques employed were Principal Component Analysis and Correlation Analysis. Correlation analysis was used to examine the relationships between the perceptions of the respondents on effects of climate parameters on building designs. The Principal Component Analysis (PCA) was utilized to collapse the various nine variables indicating the respondents' opinion on effects of climate parameters on building designs. The PCA was used as a result of the severe autocorrelations noticed in the data. The largest amount of variation in the data set is called an 'eigen vector' and is regarded as the first principal component. Furthermore, a 'varimax rotation' is employed for interpretation of the components and eigen values greater than 1.00 are usually extracted and considered for interpretation (Anyadike, 2009). This statistical analysis was performed with the aid of Statistical Package for Social Sciences (SPSS) version 20 running on windows PC (Ezenwaji et al., 2013).

Data Presentation, Analysis and Results

Table 1.1 Population distribution of questionnaires and percentage responses.

Number Administered	Number Returned	Percentage
400	325	81.25

This deals with the analysis of the various data collected from the study area. From the questionnaire administered, collected and analyzed, the results obtained provided insight on the effects of climate change on buildings in Enugu south. A total of 400 copies of the questionnaires were distributed to the respondents in parts of Enugu South L.G.A. At retrieval, a total of 325 copies were completed, representing 81.25% response rate.

Table 1.2 Socio-Demographic Characteristics of the Respondents

Characteristics	Factors	Frequency	Percentage (%)
SEX	Male	181	55.7%
	Female	144	44.3%
	Total	**325**	**100.0%**
AGE	25 – 35	95	29.2%
	36 – 45	100	30.8%
	46 – 59	77	27.7%
	60 and above	53	16.3%
	Total	**325**	**100.0%**
DURATION OF STAY	0-5years	87	26.8%
	6-10 years	57	17.5%
	11-15 years	54	16.6%
	16-20 years	67	20.6%
	21 years and above	60	18.5%
	Total	**325**	**100.0%**
RESIDENT STATUS	House owners/ Landlords	41	12.6%
	Tenants	210	64.6%
	Family House Occupants or Attachment	74	22.8%
	Total	**325**	**100%**
EDUCATIONAL QUALIFICATION	HND	0	0.0%
	B.Sc.	154	47.4%
	M.Sc.	46	14.2%
	PhD	24	7.4%
	Others	101	31.1%
	Total	**325**	**100.0%**
OCCUPATION	Engineers	44	13.5%
	Builders	18	6.8%
	Architect	29	8.9%

	Quantity Surveyors	33	10.2%
	Others	197	60.6%
	Total	**325**	**100.0%**

The configuration of the respondents cuts across professionals in the building industry, practitioners in the environmental sector and then rest of the public. Amongst the respondents, it was evident, that there are more male respondents than females. This is so because in the course of the research, it was observed that lots of the men were willing to fill the questionnaire and more male were found as house owners, best fit tenants and a greater number of them were the professionals in the built environment.

From the result, the total number of sampled males in the study was 181 representing 55.7% of the population of the study while that of females constitute about 144 representing 44.3%. This indicates that there are more of males than females in the study.The age group of the respondents was also shown; out of 100% of the number of respondents, 29.2% of them were between age bracket of 25 – 35 years of age; 30.8% of the respondents were between the ages of 36 and 45years; 23.7% had ages ranging from 46 to 59 years; while about 16.3% of the respondents were in the age group of above 60 years of age. The result presented below also indicate that majority of the respondents are within the productive age group ranging from 18 to 55 years.

On the duration of stay, the result of the responses on how long they have lived in the study area. The questionnaire revealed that about 26.8% of the respondents have lived in the area for less than 5years. About 17.5% of the respondents have lived in Enugu between 6 to 10 years; 16.6% have stayed in the study area for 11 to 20 years, 20.6% of the respondents have equally stayed here for a period of 2 to 3 decades i.e. 21 to 30 years while the remaining 18.5% have stayed for more than 30 years. This confirms that information obtained in the study has both current and dated evaluation. Looking at the educational attainment of the respondents, the result indicates that all the respondents have varying levels of formal education. A large number of the respondents (47.4%) indicated that their highest level of education attainment is B.Sc; 14.2% of the respondents noted that they have acquired masters degrees or on the course of achieving that feat while about 7.4% of the respondents have obtained Ph.D. or is still in view. However, a good number of the respondents (31.1%) selected others have attended and completed primary education while none of the respondents reported are without any formal education. Also, it is impressive to know that the respondents had one form of formal education or the other and as such understood the contents of the questionnaire.The lickert table with a cluster means value of 4.01 > 3.0 and associated standard deviation of 0.65 indicates that the respondents perceived climate changes as contributing to changes in building designs. Particularly, the result shows that there are stages in the design of buildings whereby climate parameters are considered and affects important decision regarding the supposed buildings. In addition, since the sample size, N, was larger than 30, the normal distribution was used. This is because as N increases in size, the “Z” distribution approaches the normal distribution (Anyadike, 2009).

Validation of Hypothesis

The Z test was used instead of the sampled t test to assess if there is any significant difference in the perception of the respondents on effects of climate variability and change on building design. At 0.05 level of confidence, from the table of the standard normal curve, the critical value of Z is 1.96. Since the calculated Z of 4.66 was found to be greater that the critical Z = 1.96, the null hypothesis which states that "there is no significant difference in the perception of the respondents on effects of climate variability and change on building design" was rejected. This implies that the alternative hypothesis, H_1 is accepted. Thus, there is a significant difference in the perception of the respondents on effects of climate variability and change on building design. And since the cluster means value of 4.01 > 3.0, the data fits the general opinion held by the respondents.

Table 1.3 Climate Contribution to Changes in Building Design

Question Items SA=5, A=4,UD=3,D=2,SD=1						Statistics	
	SA	**A**	**UD**	**D**	**SD**	**Mean**	**STD**
Building design has changed over the past five decades	196	111	9	9	0	**4.5**	**0.86**
Roofing has changed over the past five decades	208	100	17	-	-	**4.6**	**0.9**
There has been a continuous evolution of new window designs over the past five decades	199	99	18	9	-	**4.5**	**0.85**
The change is as a result technological innovation	62	125	27	71	40	**3.3**	**0.38**
The change is aimed at containing environmental condition and climate change	90	145	63	27	-	**3.9**	**0.56**
Building pattern in Enugu metropolis has changed over the past five decades due climate change	51	51	93	93	37	**3.0**	**0.26**
Climate parameters are put into consideration when designing	197	128	-	-	-	**4.6**	**0.92**
Climate parameters are considered when designing windows and other openings	86	149	31	31	8	**3.8**	**0.57**
The effect of new design can only be contain by critically considering climatic factors	83	150	58	25	9	**3.8**	**0.56**
Cluster Mean and Standard Deviation						**4.01**	**0.65**

PCA Analysis of Perceived Climate Contribution to Changes in Building Design.
The result of the correlation amongst the perceived responses on climate effects on designs is presented below

Table 1.4 Correlation Matrix of Perceived Climate Contribution to Changes in Building Design.

	X1	*X2*	*X3*	*X 4*	*X5*	*X6*	*X 7*	*X8*	*X9*
X 1	1								
X 2	0.994314	1							
X 3	0.996171	0.999195	1						
X 4	0.443445	0.347481	0.368148	1					
X5	0.690186	0.648823	0.655885	0.727635	1				
X6	-0.41975	-0.40666	-0.38505	-0.25103	-0.13045	1			
X7	0.995174	0.982343	0.98371	0.508091	0.729124	-0.47059	1		
X8	0.718717	0.657579	0.667431	0.869777	0.958929	-0.29794	0.769915	1	
X9	0.654375	0.606275	0.612007	0.770933	0.992754	-0.20455	0.703754	0.972818	1

The Table above reveals a high association between some variables as well as serial autocorrelation as many of the responses provided show strong and significant positive correlation with each order. For example, X1 is strongly and positively correlated with X_2, X_3, X_5, X_7,.Furthermore, X_2 is very highly correlated with X_3 and X_7. With these very serious autocorrelations that characterize the data, there was no other alternative than to subject the correlation results to PCA.

Table 1.5. Coding and Labelling of the 9 Question Items on Perceived Climate Contribution to Changes in Building Design

S/N	**Variable Description**	**Variable Code**
1	Building design has changed over the past five decades	X1
2	Roofing has changed over the past five decades	X2
3	There has been a continuous evolution of new window designs over the past five decades	X3
4	The change is as a result technological innovation	X4
5	The change is aimed at containing environmental condition and climate change	X5
6	Building pattern in Enugu metropolis has changed over the past five decades due climate change	X6
7	Climate parameters are put into consideration when designing	X7
8	Climate parameters are considered when designing windows and other openings	X8
9	The effect of new design can only be contain by critically considering climatic factors	X9

PCA, being a powerful multivariate statistical analytical technique which is often used in investigations to simplify the relationship between large bodies of variables, was able to collapse the 9 variables into significant and orthogonal components that can explain the variables in the observed responses. When PCA was transformed, the primacy of two components manifested in the table above.

1.6 Varimax Rotated Component Matrix of the Variables

	Components	
Variable	I	II
Building design has changed over the past five decades	.899	.414
Roofing has changed over the past five decades	.926	.339
There has been a continuous evolution of new window designs over the past five decades	.916	.355
The change is as a result technological innovation	.095	.888
The change is aimed at containing environmental condition and climate change	.350	.905
Building pattern in Enugu metropolis has changed over the past five decades due climate change	-.582	-.009
Climate parameters are put into consideration when designing	.879	.472
Climate parameters are considered when designing windows and other openings	.388	.918
The effect of new design can only be contain by critically considering climatic factors	.318	.924
Eigen value	**6.45**	**1.486**
% of variance explained	**71.671**	**16.512**
Cumulative % explained	**71.671**	**88.183**

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

The varimax rotation however maximizes the covariance loadings on each component in order to achieve as many high and as many low loadings as possible while maintaining the orthogonality (i.e. the uncorrelation) of the original components. It is clear that the two components explained 88.2% of the variance while all they had eigen values greater than 1.00.

Table 1.7. Variables with high loadings on Component I

VARIABLES	LOADINGS	VARIABLE NAME
X1	0.899	Building design has changed over the past five decades
X2	0.926	Roofing has changed over the past five decades
X3	0.916	There has been a continuous evolution of new window designs over the past five decades
X7	0.879	Climate parameters are put into consideration when designing

1.7b. Variables with high loadings on Component II

VARIABLES	LOADINGS	VARIABLE NAME
X4	0.888	The change is as a result technological innovation
X5	0.905	The change is aimed at containing environmental condition and climate change
X8	0.918	Climate parameters are considered when designing windows and other openings
X9	0.924	The effect of new design can only be contain by critically considering climatic factors

From above Tables, the rotated Principal Components produced 2 significant components. The limiting of the number of components to two for interpretation is based on the level of their Eigen values. As a rule, components that are chosen are those with eigen value greater than 1, which the first three components adequately satisfied.

Component I has on an integrated basis, produced an eigen value of 6.45 with percentage variance and cumulative percentage variance of 71.671%. This component loads significantly on X_1 *(*Building design has changed over the past five decades, 0.899), X_2 (Roofing has changed over the past five decades, 0.926), X_3 (There has been a continuous evolution of new window designs over the past five decades, 0.916) and X_7(Climate parameters are put into consideration when designing, 0.879). The above is a reflection of the fact that Building Designs in Enugu metropolis has changed over time. Component II recorded an eigen value of 1.486 and an additional variance of 16.512% bringing the cumulative explanation of respondents perception of climate influence on building designs to 88.183%. It had significant loading on X_4 (The change is as a result technological innovation, 0.888), X_5 (The change is aimed at containing environmental condition and climate change, 0.905), X_8(Climate parameters are considered when designing windows and other openings, 0.918) and X_9 (The effect of new design can only be contain by critically considering climatic factors, 0.924). The high loadings on these four variables depict that climate conditioning is driving the changes in building designs in Enugu. Thus the 9 items to which the respondents provided answers which constitute the variables in PCA were reduced to the following two perceptions namely; that:

(a) ***Building Designs in Enugu metropolis has changed over time***
(b) ***Climate conditioning is driving the changes in building designs in Enugu.***

Recommendations

1. There is need for building professionals to obtain basic climatic data from meteorological stations nearer to their proposed site and analyze such data for proper design of buildings.

2. Climatic site analysis should be carried out which will provide design guidelines for layout, orientation, spacing, cross ventilation, treatment of spaces between buildings, shade trees, courtyards, shape and height of the buildings as well as house form. The site climate deals with ground cover and the topography which differs from that obtained from the meteorological stations.

CONCLUSION

Based on the responses, it was clear that the respondents are quite aware of the contributions of climate change to the observed changes in building designs in the study area. The respondents agreed that these changes in the designs of buildings in Enugu South L.G.A manifest in the obvious changes in openings in these buildings such as in the designs of windows, roof designs, doors etc. Similarly, for the consideration of climatic parameters in building designs, all the respondents agreed that climate change affect building design in the study area. This follows from the fact that in one way or the other, the persons involved in construction would make decisions regarding the positions of the building, positioning of openings such as windows and doors to ensure maximum illumination of the indoors of such buildings by sunshine during the day while trying to maintain maximum ventilation putting the effects of climate change into consideration. Finally, they believed that the climate parameters have caused deteriorations in buildings and reduction of the life span of these buildings.

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