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Influence of Architectural Design Variables on Cost of Energy Consumption in Office Buildings in Minna

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The prime objective of the study is to investigate the influence of architectural design variables on the cost of energy consumption in office buildings. The study is restricted to office buildings within Minna metropolis. Data was collected through field survey and computation from architectural plans. A random sample of 30 buildings form the basis of the study. Descriptive analysis was used to compute the mean, maximum, minimum and modes for all the variables. Partial correlation coefficient of the dependent and all the independent variables explored the strength of association between the variables and detected collinearity among the variables. Regression analysis determined the strength of the relationship between the dependent and independent variables. Multiple regression analysis using the 'stepwise' regression procedure determined the extent to which the design parameters acting together explained the variation of the dependent variable. It was established that design variables like floor areas, shape, height, perimeter, orientation, shading and extent of glazing have significant effect on cost of energy consumption in office buildings. The conclusion derived from the study is that the designer during the design stage will have control of about 62.6% of energy consumption cost of the building. Therefore, it is recommended that designers should control these parameters from inception in order to produce energy conscious buildings with minimal running costs.

Key words: Energy, Electricity, Design variables, Running Cost, Office buildings

Introduction

Energy has been described as a force multiplier that enhances man's ability to convert raw materials into useful products, providing varieties of useful services (Sorensen 2003). It is a basic necessity for domestic, commercial and industrial uses. According to Mulugeta, Nondo, Schaeffer, and Gebremedhin, (2010), energy consumption is an indispensable component in growth, directly or indirectly as a complement to capital and labour as an input in the production process. Basic form of energy used for domestic and industrial purposes in Nigeria is the electric power. It is used mostly in office buildings for lighting, heating, cooling, communication and powering of equipment and machines (Akomolafe and Danladi, 2014). As one of the common energy forms in Nigeria, it is insufficient to satisfy the needs of the highly increasing population. It currently contributes less than 1% to the country's GDP. (Base Line Power Report, 2015).

Nigeria's commercial sector which consists of both private and public buildings including small businesses, consume about 48% of the total electricity produced for all the sectors of the economy (Maxwell *et al*, 2014). Office buildings use about 21% of the total energy used in the commercial sector annually. It is generally used in lighting, heating and cooling, communication and running the equipment in the buildings. It is therefore quite clear that the proportion of energy consumed by office buildings in the commercial sector is high. This will consequently increase running cost. Hence, the need to embark on the design of energy efficient buildings from the onset, by paying attention to design parameters that significantly influence energy consumption patterns of office buildings. The proportion of subsequent running cost of office buildings is shown in Figure 1

The aim of the study is to evaluate the influence of architectural design variables on cost of energy consumption in office buildings in Minna, with a view to suggesting effective strategies for designing energy-efficient office buildings with minimal running costs.

This research considers only the running cost of electrical energy consumed by office buildings with respect to varying architectural design parameters associated with each building. These are the costs that are incurred to generally pay for the electricity charges that the offices use.

Literature Review

Energy consumption is simply defined as the amount of energy consumed in a process or system, or by an organization or society. Energy consumption in buildings has been a topic discussed in various forums. The aim has always been to reduce energy consumption in buildings through adoption of energy conservation measures and energy conscious designs.

Energy conservation refers to the steps taken to reduce energy use and increase efficiency in an existing stock of buildings. Energy conservation can achieve significant reduction in energy consumption. It has been shown that energy saving of about 25% or more can be achieved through the adoption of energy conservation measures (Leach and Desson, 2006). Energy conscious design on the other hand refers to attempts made at the design stage to produce a low energy consuming building. This is achieved by taking into account various design parameters that result to high levels of energy consumption in buildings.

Energy Use Determinants in Building

The objective of a building system is to provide the optimum internal environmental conditions to aid human activity. Mavers (2001) mentioned that to achieve the objective, the building system must contain a sub-system referred to as the services subsystem. Service system will include:
(1) Ventilation and air conditioning sub-systems (2) Lighting systems (3) Acoustic systems (4) Vertical transportation systems and (5) Drainage/water systems.

Energy Consumption and Energy Costs

Energy consumption of any building will ultimately result to an energy bill which is expressed as a cost to the consumer. Though the quantity of energy consumed might remain fairly constant over the years, energy cost will vary throughout the life of the building. Energy cost will be influenced by tariff regulations, inflationary factors and taxation among other factors (Stone 2009). Energy cost for any building will be highly significant if viewed as a life cycle cost of the building. Stone (2009) argues that over the life of a building running costs are usually greater than initial construction costs. Running costs account for over 55 - 60% of cost over the life of the office building in temperate climates.

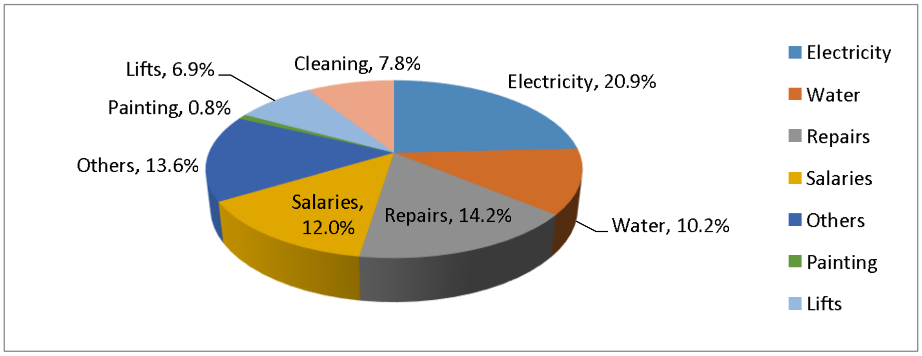

Figure 1: Proportion of subsequent running cost Source: Moirongo (2006)

Architectural Design Variables having Influence on Energy Consumption

The design variables in the conceptual design stage in building construction are defined as the variables that describe the building in the conceptual phase. Variables have to be synthetic, simple and meaningful either from thermal engineering or from architectural point of view, hence architects can take rational conclusions easily. These variables include: (1) Plan shape and Perimeter (2) Total Plinth area (3) Building height (4) Storey height (5) Orientation (6) Circulation space (7) Shading devices (8) Glazing area

Impact of Design Parameters on Energy Use in Buildings

Reference has been made to energy conscious design as a way of influencing energy use patterns in the building. It is only through design that energy use by air conditioning, lighting and vertical transportation can be controlled.

It is observed that energy consumption in any single building is due to the interaction of a large set of variables. This study separates these variables into four groups; climate-based parameters, parameters due to siting, occupancy parameters and the building design parameters. The first three groups cannot be influenced by the designer. Design variables associated with the building form, orientation, fenestration and thermal physical properties of the materials among others have significant impact on energy use in the building. Variables considered for detailed study are floor areas, perimeter/floor area ratio, glazed area, heights of buildings, shading, orientation and perimeter.

Cost Effective Strategies for Designing Energy Efficient Buildings with Minimal Running Costs

There is no one best design or construction technique for achieving the most desirable energy efficiency for any new home construction. Builders are now exposed to a wide variety of materials, components, appliances and construction techniques. Good work and quality materials have always been distinguishing characteristics of a well-built house but is essential to have an understanding of how a house operates as a complete system in building an energy efficient home. In order to produce a highly efficient home, knowledge of how to integrate all of the building components properly and understanding that they all act together is important. An Energy efficient home has tight ducts, proper ventilation, high insulation levels, highly effective windows, air-tight construction, and energy efficient heating and cooling appliances. The combination of these results in reduced utility bills, fresh indoor air, and less maintenance.

Research Methodology

This study is based on a survey of 35 office buildings. A sample size of 30 buildings forms the basis of the survey because there was restriction in getting information on the remaining 5 buildings due to security reasons relating to those buildings.

Primary data on energy consumption is obtained from the Abuja Electricity Distribution Company (AEDC) Niger Region Office in Minna. The data was extracted from 2012-2016 utility bills or consumption records. The design variables were measured and computed from architectural plans. These were compared with the existing building to take account of any modifications. The architectural drawings for both the private and public buildings were obtained from Niger State Urban Development Board (NUDB). The design variables obtained are the glazed areas, floor area, average perimeter, height of the building, circulation space and orientation.

Secondary data on energy demand and supply in Nigeria was obtained from the National Bureau of Statistics (NBS) and the Energy Commission of Nigeria (BLPR 2015). The data comprise of energy demand and supply statistics. Inferential analysis was carried out in various stages. First, the partial correlation coefficient of the dependent and all the independent variables was carried out. In the analysis the dependent variable is the mean annual energy consumption cost and the independent variables are the Architectural design parameters.

The purpose of computing the partial correlation coefficients is twofold:
i) To explore the strength of association between the variables.
ii) To detect collinearity among the variables.
The result of the partial correlation analysis is presented as a correlation matrix. Simple regression analysis was performed between the dependent variable, mean annual energy consumption cost and each of the seven design parameters (independent variables). Regression analysis was carried out to determine the strength of the relationship between the dependent and independent variables. The result of this analysis is presented in form of regression coefficients and scatter plots. Multiple regression analysis was carried out using the 'stepwise' regression procedure. The main aim is to determine the extent to which the design variables acting together could explain the variation of the dependent variable.

Results and Discussion

During the data collection process, the independent variables were measured and computed from architectural plans while the dependent variable was computed by calculating the mean of the annual consumption cost for the five-year period. The dependent variable is the mean annual energy consumption cost while the independent variables are floor area, glazed area, height, orientation, perimeter and shading.

The above variables were measured in a sample of 30 buildings, both private and government owned. Each building is represented with a numerical code from 1-30. The data was then tabulated as shown in table 1 below.

Table 1: Data on measurement and energy consumption charge

BUILDING	X_1	X_2	X_3	X_4	X_5	X_6	X_7	C	T	E
1	350.23	0.17	43.20	5.75	0	0.25	59.39	3,560.00	27.45	97,722.00
2	842.00	0.13	42.09	9.80	0	0.25	110.00	10,080.00	34.48	347,558.40
3	1,296.00	0.09	56.78	10.62	1	0.22	122.73	12,407.00	34.48	427,793.36
4	1,178.19	0.09	34.90	9.65	0	0.50	107.80	9,892.23	34.48	341,084.09
5	967.00	0.10	38.00	10.34	0	0.60	97.50	8,608.35	34.48	296,815.91
6	522.63	0.23	67.97	5.90	1	0.45	118.17	5,451.02	27.45	149,630.50
7	876.54	0.12	55.67	10.45	0	0.26	108.51	13,076.15	34.48	450,865.65
8	778.00	0.12	32.48	9.95	0	0.26	94.89	10,876.00	34.48	375,004.48
9	1,215.30	0.11	85.02	7.23	0	1.00	139.33	9,434.56	37.76	356,248.99
10	1,356.90	0.11	65.05	8.67	1	1.00	155.12	9,870.00	34.48	340,317.60
11	987.09	0.11	47.00	10.21	0	0.26	108.50	8,508.30	34.48	293,366.18
12	430.98	0.23	21.60	5.78	0	0.25	99.42	5,460.00	27.45	149,877.00
13	2,400.67	0.10	102.80	9.60	1	1.00	236.00	4,678.98	37.76	176,678.28
14	2,350.00	0.10	90.76	9.60	1	1.00	225.39	5,040.00	37.76	190,310.40
15	2,500.89	0.10	89.93	9.60	1	1.00	241.95	3,989.08	37.76	150,627.66
16	2,420.00	0.10	95.05	9.60	1	1.00	237.60	3,693.44	37.76	139,464.29
17	1,987.67	0.10	78.00	9.23	0	0.09	193.78	4,015.87	37.76	151,639.25
18	2,175.00	0.09	116.54	8.98	1	0.27	197.50	11,342.15	34.48	391,077.33
19	634.95	0.22	45.00	5.95	1	0.25	138.44	9,763.33	27.45	268,003.41
20	564.00	0.22	39.55	6.95	1	0.27	121.77	5,798.02	27.45	159,155.65
21	450.23	0.23	29.65	7.15	0	0.26	105.35	8,845.31	34.48	304,986.29
22	786.06	0.27	48.63	7.65	0	0.25	210.47	9,667.45	34.48	333,333.68
23	674.78	0.30	45.07	7.42	0	0.25	200.62	9,393.00	34.48	323,870.64
24	345.00	0.17	38.78	6.20	0	0.24	59.45	4,630.55	27.45	127,108.60
25	267.05	0.24	29.46	6.15	0	0.23	62.84	4,231.42	27.45	116,152.48
26	267.05	0.25	31.66	6.15	0	0.23	65.50	4,579.00	27.45	125,693.55
27	1,318.00	0.14	50.23	8.63	1	0.24	190.03	7,800.90	34.48	268,975.03
28	679.60	0.21	40.02	8.21	0	0.26	143.78	6,540.22	34.48	225,506.79
29	467.98	0.20	35.00	7.60	1	0.26	92.82	4,691.13	27.45	128,771.52
30	1,879.00	0.11	65.98	8.65	1	0.24	206.89	5,078.86	37.76	191,777.75

Source: Measurement and field survey (2017).

Key: X1 - Floor area (m^2); X2 - Perimeter/floor area ratio; X3 - Glazed area (m^2); X4 - Height of building (m); X5 - Shading; X6 – Orientation; X7 - Perimeter (m); C - Mean annual energy consumption (kwh/year); T – Tariff; E - Mean annual energy Cost (₦/kwh/yr)

Descriptive Analysis

Mean Annual Energy use - Variable C

The results show that the maximum annual energy consumption is 19.65 KWH/yr/rm^2 and the minimum is 1.53 Kwh/yr/m2. The mean annual energy consumption is 9.51 KHW/yr/m^2.

KWH/yr/m2 and 13.34% of the buildings had mean annual energy use of 15.00 KWH/yr/m2 and above, see Figure 2.

Floor Area (m^2) - Variable X_1

The floor area was distributed with a maximum of 2,500.89m^2 and a minimum of 267.05m^2. The mean floor area is 1,098.96m^2 with a standard deviation of 719.52m^2. About 37% of the buildings had floor areas between 501 and 1,000m^2 (Figure 3)

About 20% of the buildings in the sample have mean annual energy use of between 0 and 5.0

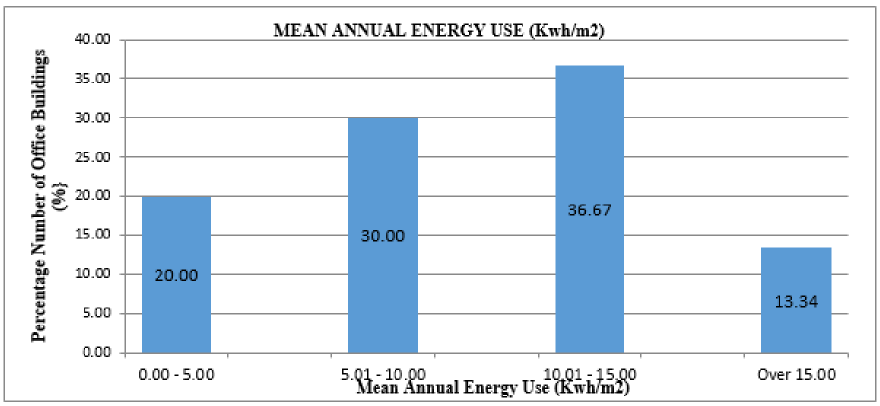

Figure 2: Distribution of the mean annual energy use

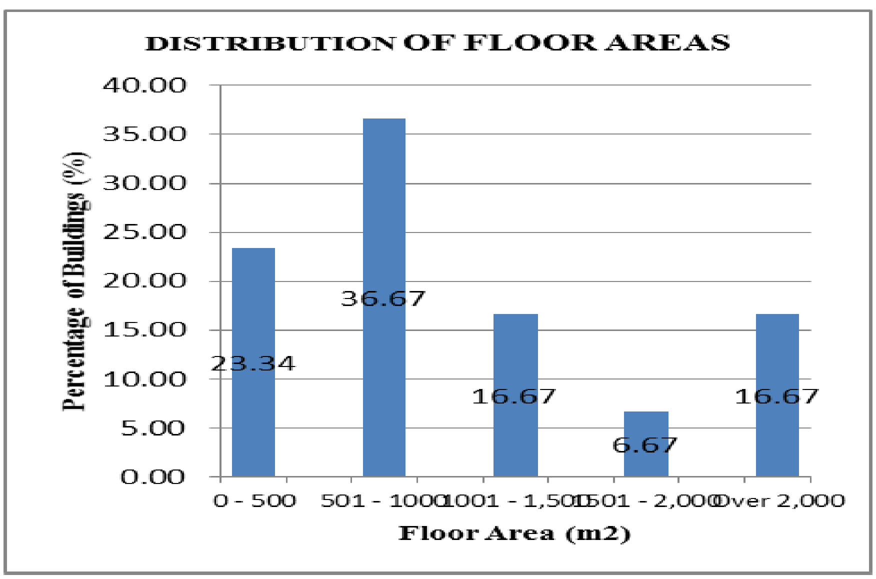

Figure3: Distribution of the floor areas (X1) in the sample

Source: Measurement and Computation from Architectural plan (2017)

Glazed areas - Variable X_3

The distribution of glazed areas in the sample had a maximum of 116.54m^2 and a minimum of 21.60m^2. The mean glazed area is 55.40m^2 with a standard deviation of 24.85m^2, see figure 4.

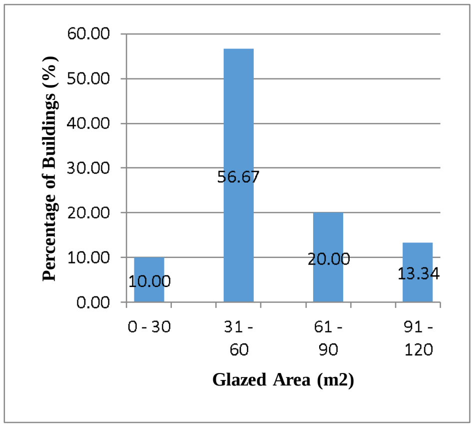

Figure 4: Distribution of the glazed areas (X3) in the sample.
Source: Measurement and Computation from Architectural plan (2017)

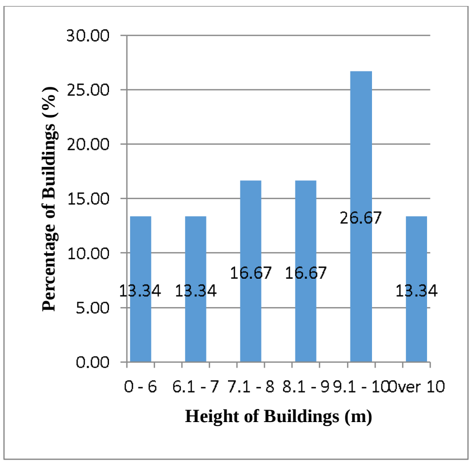

Figure 5: Distribution of the height of buildings (X4) in the sample
Source: Measurement and Computation from Architectural plan (2017)

Height of Buildings - Variable X_4

The internal heights of the buildings are distributed with a maximum of 10.62 meters and a minimum height of 5.75 meters. The mean height of the buildings in the sample is 8.26 meters.

Perimeter - Variable X_7

The maximum perimeter is 241.95 meters and minimum perimeter is 59.39 meters. The mean perimeter is 141.72 meters. (See figure 6)

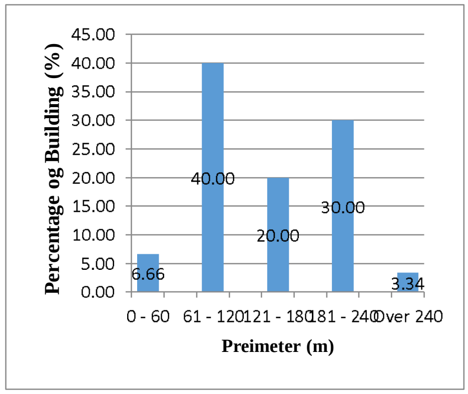

Figure 6: Distribution of the Perimeter (X7) in the sample.
Source: Measurement and Computation from Architectural plan (2017)

Energy Consumption Model

The model of this study is based on the hypothesis that energy consumption in office buildings is influenced by the various design variables. T h u s

$E = Xc + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \ldots\ldots\ldots\ldots\ldots\ldots \beta_7 X_7 + e$

Where E = mean annual energy cost (₦/KWH/yr); Xc = constant term; X_1 = floor area (m^2); X_2 = shape (perimeter/floor area); X_3 = glazed area (m2); X_4 = total height of buildings (m); X_5 = existence of shading; X_6 = orientation; X_7 = perimeter (m); $\beta_1 \ldots\ldots \beta_7$ Beta Coefficients; e = error term. This is a stochastic model with an infinite number of variables.

Assumptions: The above model is based on the following assumptions.

(i) The population is normal (ii) The variables are not significantly interacting with each other.

With regard to the data collected and the study model formulated, data was analysed statistically using the correlation and regression techniques.

Correlation Analysis of the Model

The partial correlation between all the variables in the model was computed. The resulting correlation matrix is illustrated in Table 2 below

The result in Table 2 above show the strength of relationship between the dependent variable (E) and the independent variables X_1 to X_7.

Floor Area (X1)
The correlation coefficient is 0.048 showing a positive relationship between energy consumption cost and floor area. The correlation coefficient is significant at 95% confidence level.

Perimeter/Floor Area Ratio (X2)
The correlation coefficient for the two variables is **-** 0.282 showing a negative relationship between the variables E and X_2. It is also probable that the relationship is curvilinear. This relationship will be explored further using regression analysis.

Glazed Area (X3)
The correlation coefficient between mean annual energy consumption cost and total glazed area is r = 0.042. This shows that there is a positive but very weak relationship between the two variables. The correlation coefficient was significant at a 95% confidence level. This shows that there is little or no relationship between the two variables. .

Total Height (X4)
The correlation coefficient between mean annual energy consumption cost (E) and total height of buildings in the sample r = 0.529. This shows that there is a positive relationship between the two variables.
The correlation coefficient is significant at 95%. This implies that the chance of getting no relationship given a correlation coefficient of 0.529 is less than 0.03. It is highly probable that a relationship exists.

Shading (X5)
The correlation coefficient for the two variables r = **-** 0.145. This illustrates a negative relationship between the two variables. The relationship is not significant at 95% of confidence level. It is likely that there is curvilinear relationship or a high likelihood of chance variation due to inadequate measurement of the parameter.

Orientation (X6)
The correlation coefficient between the two variables is r = **-** 0.056 showing a weak negative relationship between mean energy consumption cost and orientation. The relationship is probably curvilinear hence linear approximation is inadequate. The likelihood of chance variation also exists.

Perimeter X7
The correlation coefficient is 0.044 showing a positive but weak relationship between the two variables. The relationship is probably curvilinear or there is a possibility of chance variation. This is explored further in regression analysis.

Table 2: Correlation matrix

	X1	X2	X3	X4	X5	X6	X7	E
X1	1							
X2	-0.715**	1						
X3	0.873**	-0.564**	1					
X4	0.624**	-0.769**	0.375*	1				
X5	0.532**	-0.265	0.552**	0.127	1			
X6	0.617**	-0.453*	0.613**	0.281	0.383*	1		
X7	0.840**	-0.288	0.757**	0.393*	0.523**	0.492**	1	
E	0.048	-0.282	0.042	0.529**	-0.145	-0.056	0.044	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Computation from partial correlation

Regression Analysis of the Model

The energy consumption cost function is represented as

$E = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + B_6 X_6 + \beta_7 X_7 + e_1$

To ascertain the influence of the independent variables on energy consumption cost, regression analysis is used. The procedure adopted in the development of the model is to perform a test between the dependent variable and each of the seven independent variables. Then the second stage is multiple regression analysis to determine the effect of all the variables acting together. Each partial correlation will be discussed below.

Floor Area (X_1)

Regression analysis on the two variables with E as the dependent variables reveals that the best line of fit has a slope (β_i) of 6.9786 and an intercept (β_o) of 238977.9805 thus the equation of line can be expressed as

$E = 238977.9805 + 6.9786 X_1$

Table 3 shows that the coefficient of determination is $R^2 = 0.002$, showing a positive but weak relationship between the two variables. The standard error of the slope of β_1 is 27.730 at 95% confidence level and standard error of intercept (β_0) is 36242.759 at 95% confidence level. The hypothesis test is done to determine whether the relationship exists.

The hypothesis in this case is that there is no relationship between the two variables and the

slope $\beta_1 = 0$. It was revealed that $t_{calculated} = 0.252$ and $t_{significant} = 0.803$. Thus $t_{calculated} < t_{significant}$ which confirms the above hypothesis.

The ANOVA test reveal that $F_{calculated} = 0.063$ and $F_{significant} = 0.803$ thus $F_{calculated} < F_{significant}$, this shows that $R^2 < 0$, thus the independent variable has no explanatory characteristics for the dependent variable.

Perimeter/Floor Area ratio (X_2)

Regression analysis between the dependent and independent variable reveals that the correlation coefficient is 0.282 and coefficient of determination $R^2 = 0.080$. The coefficients are relatively low.

The regression line has an intercept of 319260.738 and a slope of - 457648.191 (see Table 4). The standard errors of (β_0) and β_1 were 50321.049 and 294079.092 respectively. The regression line is estimated as

$E = 319260.7411 - 457648.2088 X_2$

(50321.049) (294079.092)

The $t_{calculated} = -1.556$ and the $t_{significant} = 0.131$ thus $t_{calculated} < t_{significant}$ which shows that there might be no linear relationship between the two variables.

The ANOVA-test is done to determine the variability between the two variables thus $F_{calculated} = 2.422$ and $F_{significant} = 0.131$. $F_{calculated} > F_{significant}$. The hypothesis $R^2 > 0$ hence there is a linear relationship between the two variables. The large size of the standard error of the slope, reveal the possibility of a curvilinear relationship between the two variables.

Glazed Area (X3)

The correlation coefficient between the two variables is R = 0.042 and the coefficient of determination $R^2 = 0.002$ (see Table 5). This reveals that a positive but weak linear relationship exists between the two variables.

The slope is 178.7801 and the intercept is 236743.5799. The standard errors of intercept and slope are 48625.321 and 803.139 respectively thus the regression equation is

$E = 236743.5799 + 178.7801 X_3$

(48625.321) (803.139)

The $t_{calculated} = 0.223$ and the $t_{significant} = 0.825$ thus $t_{calculated} < t_{significant}$ showing that there is no significant linear relationship between the two variables.

The ANOVA-test show that the $F_{calculated} = 0.050$ and the $F_{significant} = 0.825$. This shows that $R^2 > 0$, thus there is a relationship between the two variables. The standard error of estimate of the slope is reasonable which shows a possible significant effect of chance variation.

Height of Building (X4)

The correlation coefficient is r = 0.529 and coefficient of determination $R^2 = 0.280$ see

regression output Table 6. This shows a positive relationship between the dependent and independent variables.
The regression line has a slope (β_1) of 34352.6529 and the intercept (β_o) is -36956.8261 thus the regression line is

$$E = -36956.821 + 34352.652\ X_4$$
$$(87616.118)\quad (10419.022)$$

The standard errors of estimates of intercept and slope are 87616.118 and 10419.022 respectively.
The $t_{calculated} = 3.297$ and the $t_{significant} = 0.603$ thus $t_{calculated} > t_{significant}$. The hypothesis that slope = 0 is rejected proving that a relationship exists between the two variables.
A further ANOVA test reveal that the $F_{calculated} = 10.871$ and the $F_{significant} = 0.03$ thus $F_{calculated} > F_{significant}$ the hypothesis that $R^2 > 0$ is accepted. This proofs existence of a linear relationship between the dependent and the independent variable.

Shading Area (X5)
Regression analysis shows that the correlation coefficient r = - 0.145 and coefficient of determination $R^2 = 0.021$ (see Table 7). The adjusted $R^2 = -0.014$ showing the possibility of a negative or curvilinear relationship

The regression analysis shows that the slope = 30384.3172 and the intercept = 259813.7628. Thus the regression equation is

$$E = 259813.764 - 30384.319\ X_5$$
$$(25814.140)\quad (39214.494)$$

The $t_{calculated} = -0.715$ $t_{significant} = 0.445$ thus $t_{calculated} < t_{sigmficant}$. The hypothesis states that there is no slope, thus there is no relationship between the two variables.
The ANOVA test for the hypothesis that $R_2 = 0$ shows that $F_{calculated} = 0.600$ and $F_{significant} = 0.445$ thus $F_{calculated} > F_{significant}$ The hypothesis that $R^2 = 0$ is rejected, indicating that there is a linear relationship between the two variables. The relationship is probably curvilinear or there is a greater possibility of chance variation. This is illustrated by the large standard errors of the slope.

Orientation (X_6)
The regression analysis output Table 8 shows that the correlation coefficient r = 0.056 and coefficient of determination R^2 = 0.03. The r is positive which implies a linear relationship between orientation and the mean annual energy cost.

The slope was - 19091.689 and the intercept = 254691.190. The regression equation was

$$E = 25469.190 - 19091.689\ X_6$$
$$(33609.678)\quad (64785.916)$$

The $t_{calculated} = -0.295$ and $t_{significant} = 0.777$ thus $t_{calculated} < t_{significant}$ showing the possibility of positive slope.
The ANOVA test showed that $F_{calculated} = 0.087$ thus $F_{calculaed} < F_{significant}$ the hypothesis $R^2 = 0$ is accepted revealing a negative relationship between orientation and mean annual energy cost.

The high standard error of estimate for the slope implies that the relationship is possibly curvilinear or a high possibility of chance variation exists.

Perimeter (X7)
The correlation coefficient was r = 0.044 and the coefficient of determination R^2 = 0.002. This is shown in Table 9.
The slope is 80.095 and the intercept is 235296.317 thus the regression equation.

$$E = 235296.317 + 80.095\ X_7$$
$$(52728.709)\quad (345.350)$$

The $t_{calculated} = 0.232$ and $t_{significant} = 0.818$ thus $t_{calculated} < t_{significant}$ which indicates the possibility of a negative slope.

The ANOVA test reveal that $F_{calculated} = 0.054$ and $F_{significant} = 0.818$, thus $F_{calculated} < F_{significant}$. The hypothesis R2 = 0 is upheld confirming that a negative relationship exists between energy cost and perimeter of the building. The standard error of estimate of the slope (β_1) is large showing a possibility of chance variation.

Table 3: Regression analysis output for floor area versus mean annual energy cost

CORRELATION COEFFICIENT					
Multiple R	0.048				
R Square	0.002				
Adjusted R Square	0.033				
Standard Error	107447.9633				
ANALYSIS OF VARIANCE					
	DF	**Sum of Squares**	**Mean Squares**	F_C	F_S
Regression	1	7311810342	7311810342	0.063	0.803
Residual	28	3.233E + 11	11545064812		
VARIABLE IN THE EQUATION	**B**	**SE B**	**BETA**	T_C	T_S
X_1	6.9786	27.730	0.048	0.252	0.803
(Constant)	238977.98705	36242.759		6.594	0.000

Table 4: Regression analysis output for Perimeter/Floor ratio versus mean annual energy cost

CORRELATION COEFFICIENT					
Multiple R	0.282				
R Square	0.080				
Adjusted R Square	0.047				
Standard Error	103198.9978				
ANALYSIS OF VARIANCE					
	DF	**Sum of Squares**	**Mean Squares**	F_C	F_S
Regression	1	25792067802	25792067802	2.422	0.131
Residual	28	2.982E + 11	10650033142		
VARIABLE IN THE EQUATION	**B**	**SE B**	**BETA**	T_C	T_S
X_2	- 457648.191	294079.092	- 0.282	- 1.556	0.131
(Constant)	319260.738	50321.049		6.344	0.000

Table 5: Regression analysis output of Glazed area versus mean annual energy cost

CORRELATION COEFFICIENT					
Multiple R	0.042				
R Square	0.002				
Adjusted R Square	- 0.034				
Standard Error	107474.3556				
ANALYSIS OF VARIANCE					
	DF	**Sum of Squares**	**Mean Squares**	F_C	F_S
Regression	1	572356607.0	572356607.0	0.050	0.825
Residual	28	3.234E + 11	11550737113		
VARIABLE IN THE EQUATION	**B**	**SE B**	**BETA**	T_C	T_S
X_3	178.7801	803.139	0.042	0.223	0.825
(Constant)	236743.5799	48625.321		4.869	0.000

Table 6: Regression analysis output for Height versus mean annual energy cost

CORRELATION COEFFICIENT					
Multiple R	0.529				
R Square	0.280				
Adjusted R Square	0.254				
Standard Error	91296.75754				
ANALYSIS OF VARIANCE					
	DF	**Sum of Squares**	**Mean Squares**	F_C	F_S
Regression	1	90610253532	90610253532	10.871	0.03
Residual	28	2.334E + 11	8335097937		

VARIABLE IN THE EQUATION	B	SE B	BETA	T_C	T_S
X_4	34352.652	10419.022	0.529	3.297	0.603
(Constant)	- 36956.821	87616.118		- 0.422	0.676

Table 7: Regression analysis output of Shading versus mean annual energy cost

CORRELATION COEFFICIENT					
Multiple R	0.145				
R Square	0.021				
Adjusted R Square	- 0.014				
Standard Error	106434.4263				
ANALYSIS OF VARIANCE	**DF**	**Sum of Squares**	**Mean Squares**	**F_C**	**F_S**
Regression	1	6800957024	6800957024	0.600	0.445
Residual	28	3.172E + 11	11328287098		
VARIABLE IN THE EQUATION	**B**	**SE B**	**BETA**	**T_C**	**T_S**
X_5	- 30384.319	39214.494	- 0.145	- 0.715	0.445
(Constant)	259813.764	25814.140		10.065	0.000

Table 8: Regression analysis output of Orientation versus mean annual energy cost

CORRELATION COEFFICIENT					
Multiple R	0.056				
R Square	0.03				
Adjusted R Square	- 0.033				
Standard Error	107402.9868				
ANALYSIS OF VARIANCE	**DF**	**Sum of Squares**	**Mean Squares**	**F_C**	**F_S**
Regression	1	1001751949	1001751949	0.087	0.770
Residual	28	3.230E + 11	11535401565		
VARIABLE IN THE EQUATION	**B**	**SE B**	**BETA**	**T_C**	**T_S**
X_6	- 19091.689	64785.916	- 0.056	- 0.295	0.777
(Constant)	254691.190	33609.678		7.578	0.000

Table 9: Regression analysis output of Perimeter versus mean annual energy cost

CORRELATION COEFFICIENT					
Multiple R	0.044				
R Square	0.002				
Adjusted R Square	- 0.034				
Standard Error	107466.2387				
ANALYSIS OF VARIANCE	**DF**	**Sum of Squares**	**Mean Squares**	**F_C**	**F_S**
Regression	1	621206948.6	621206948.6	0.054	0.818
Residual	28	3.234E + 11	11548992458		
VARIABLE IN THE EQUATION	**B**	**SE B**	**BETA**	**T_C**	**T_S**
X_7	80.095	345.350	0.044	0.232	0.818
(Constant)	235296.317	52728.709		4.462	0.000

Conclusion

The study has shown that architectural design variables such as floor area, perimeter/floor area ratio, glazing, height of building, shading, orientation and perimeter influence energy consumption cost in office buildings. It was also revealed that there is significant relationship between the architectural design variables and energy consumption cost. All the variables explain over 62.6% of the variation in energy consumption cost.

The conclusion derived from the model is that the designer during the design stage will have control of about 62.6% of energy consumption cost of the building. This percentage would however increase as more information on how buildings use energy is acquired. Consequently, this will result in a significant reduction in the cost of utility services in office buildings, hence a reduction in the running cost.

Recommendations

The development of energy conscious building designs so as to reduce energy consumption cost in new buildings can basically be achieved by paying more attention to architectural design variables that influence the cost of energy consumption and the adoption of cost-effective strategies for designing energy-efficient office buildings with minimal running costs.

(1) The designer is seriously constrained as far as floor area is concerned. It is recommended that even if the designers cannot control the floor area, they should avoid deep plan buildings, which would significantly rely on artificial lighting and ventilation. Buildings with extensive floor areas should adopt other principles of passive design to ensure energy efficient buildings.

(2) The designers should carefully control the shape of the building; complex shapes result to higher energy costs. Complex shapes are however useful where natural lighting and ventilation is being maximised.

(3) It is important to pay attention to the efficiency of shading to be used in buildings. This is important to avoid cases where shading is only effective for shorter periods in the year. The shading elements should also be able to dissipate heat away from the building.

Finally, to reduce energy consumption in buildings there is need to adopt energy conscious design principles from inception. Winch and Burt (2010) suggest that a co-ordinated design concept whereby the design of the building fabric, the functions of various spaces, required environmental conditions and external environmental factors should be incorporated to produce energy saving design. To achieve energy conscious design there should be general awareness on the need to conserve energy use in the built environment considering the inadequate power supply situation experienced in the country. The Government should lead on this by providing detailed energy use policies that should set energy use standards. These would provide energy use yardsticks to the clients and the designers, thus promoting energy conscious design.

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