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Analysis of the major factors that effect power consumption: A multiple regression analysis approach

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Abstract

The erratic power supply in recent times has been a matter of great concern not only to the consumers but also to the Power Holding Company of Nigeria (PHCN) organization itself. The nagging problem is compounded by the spasmodic nature of the phenomenon and hence calls for a special scientific investigation. The paper uses a multiple regression analysis technique to investigate the major factors that affect power Consumption in Jos Metropolis – traditionally tin-mining Camp. On the initial assumption that erratic power supply can only be due to the disparity between supply and demand. The paper sets out to answer the following two questions; i) what factors have been responsible for such increase in demand and the behaviour of the relationship that exist between these factors; ii) what likely measures are to be taken to restore the balance between demand and supply. We were able to identify the major factors as Residential Industrial and Commercial. Some interesting relationships were established.

Keywords: Power consumption, multiple regressions

Introduction

It is appropriate to note that investigation of the problem of power consumption has to be made against the backdrop of the historical development of electricity in the area under study. The development of electric power in Nigeria started in 1895, when the first 60 kilowatts generator was mainly characterized by uncoordinated electricity undertaking on individual basis in various towns and this period correspond with the time during which Government participation in electric power development was through the Public Works Departments (PWD). The Nigerian Electricity Supply Company (NESCO) played leading role in power development in Nigeria. By 1929 NESCO introduced Hydro-electricity supply to the tin-mining companies and to the inhabitants in parts of Plateau State in Nigeria.

In 1950, due to rapid growth in power consumption, the electricity expansion scheme could no longer be effectively handled by the PWD and management of electricity was separated from it. The Electricity cooperation of Nigeria (ECN) ordinance No. 15 was passed in 1950, which vested powers of electricity activities and functions of the Federal Government until 1972. At the introduction of National Electricity in Nigeria, coal alone was harnessed as one of the best sources, which seemed to meet the electricity demand of that time.

Following this were a number of other development efforts, such as the construction of the Kanji Dam (Nigeria's Premier Hydro-Power Station), the merging of the electricity cooperation of Nigeria and the Niger Dam Authority in 1972. Turning the search light on Jos, we note that, PHCN, though the legitimate organization charged with supply of Electricity in Jos, but purchases electric power from NESCO (table 8). This corporation NESCO, which has its headquarters at Bukuru was formed in 1929 to supply the Plateau Mines Fields with electric power. It started with only one power station of 8,000 kilowatt capacity at Kura falls. Today she has many power stations, some of which are sited in series down the escarpment from Kura falls.

Assumption

1. On the initial assumption that erratic power supply can only be a result of disparity between demand and supply, we set out to identify:
   - The major factors affecting consumption within Jos metropolis;
   - The statistical interpretation of the empirical results
2. On assumption that there has been a steady increase in the rate of power

3. Power consumption in Jos metropolis in recent years, we shall determine quantitatively the various parameters of the growth.
4. It is assumed that such increase in power Ý' is likely to depend on such factors as high rate of urbanization 'X'$_1$, with the consequent growth in commercial activities, 'X'$_2$, industrial activities 'X'$_3$ and street lighting 'X'$_4$.

Methodology

The theory of multiple regression analysis technique was applied to the data. The data was collected from PHCN Jos District Office over a period of 3 years between 2019–2021, (end years inclusive). The data was confined to Jos town only. The relationship that exist between the dependent variable 'Y' and that operational variable X_1, X_2, X_3, X_4 was established. Joint relationship between independent variable was dropped from the model to see its effect (contribution) to power consumption.

Formulation of the Model

For the purpose of the study, we have five variables, four independent and one dependent. We denote the independent variable by the letter 'Y' and call it 'Total Power Consumption 1 (TPC) and Jos metropolis', while the independent variables shall be denoted by X_1, X_2, X_3 and X_4 and shall represent residential, commercial, industrial and street lighting consumption respectively. We formulate our model for the five variable case as:

$$Y_1 = B_0 + B_1X_{11} + B_2X_{12} + B_3X_{13} + B_4X_{14} + E_1 \qquad (1)$$

Where the parameters B0, B1, B2, B3, B4 are coefficients of the regression whose estimate we denote by b_0, b_1, b_2, b_3, b_4 respectively.

E_1 is the stochastic disturbance. The assumption for the model (1) are same as for any linear regression model.

Application of Data

Practical applications of the theoretical concepts to this investigation are discussed based on a data collected over a period of three years.

The data was made up of five columns and a total of 16 observations. We also observed that the following relationship:

$$Y = X_1 + X_2 + X_3 + X_4 \qquad (2)$$

Between the dependent and independent variables holds.

We shall verify by the use of our formulated model (1.1) that this deterministic relationship of Y on the independent variable actually holds. The method of reduction of data was applied to give the results and intermediate calculations. The scale for the reduction is every one unit represents 100,000 kilowatts of electricity generated and consumed. We represent here the summary of data.

Summary of data

$\sum_{i=1}^{36} x_i = 2469.6$ $\sum_{i=1}^{36} x_i^{\ 2} = 17976.64$

$\sum_{i=1}^{36} x_i = 286.5$ $\sum_{i=1}^{36} x_i^{\ 2} = 2447.47$

$\sum_{i=1}^{36} x_i = 851.5$ $\sum_{i=1}^{36} x_i^{\ 2} = 22342.82$

$\sum_{i=1}^{36} x_i = 9.1$ $\sum_{i=1}^{36} x_i^{\ 2} = 2.49$

$\sum_{i=1}^{36} x_i x_i = 2.0793.03$ $\sum_{i=1}^{36} y_i x_i = 262632.96$

$\sum_{i=1}^{36} x_i x_i = 60851.75$ $\sum_{i=1}^{36} y_i x_i = 29828.45$

$\sum_{i=1}^{36} x_i x_i = 632.98$

$\sum_{i=1}^{36} x_i x_i = 91301.58$

$\sum_{i=1}^{36} x_i x_i = 6915.01$

$\sum_{i=1}^{36} x_i x_i = 73.56$

$\sum_{i=1}^{36} x_i x_i = 921.32$

$\sum_{i=1}^{36} y_i = 3616.74$ $\sum_{i=1}^{36} y_i^{\ 2} = 364667.52$

Results of regression analysis

The computer was used to obtain regression results for the data in Appendix B. We reproduce below the regression results.

Table 1: Means and standard deviations

Variable	Mean	Standard Deviation
X_1	68.6	17.197
X_2	7.958	2.187
X_3	23.653	7.907
X_4	0.25	0.077
Y	100.461	24.692

Table 2: Correlation Coefficients

Variable	X_1	X_2	X_3	X_4	Y
X_1	1	0.561	0.723	0.18	0.978
X_2	0.561	1	0.229	0.294	0.554
X_3	0.723	0.229	1	0.083	0.843
X_4	0.18	0.294	0.083	1	0.127
Y	0.978	0.554	0.843	0.127	1

Table 3: Coefficient of regression

Variable	Coefficient	Standard Error	T- Statistics
Constant of Regression	0.069	0.05	1.389
X_1	1.002	e^{-03}	976.926
X_2	0.996	$6e^{-03}$	176.442
X_3	0.996	$9e^{-03}$	518.454
X_4	0.835	0.134	621.50

Corrected R2 = 1, corrected R + 1, F (4.31) = 1696672.6, the total power consumption (Y) increased by 1.002 x 100,000 = 100,200 kilowatts for every one unit increase in residential consumption. Similarly, there is an increase of 99,600, 99600 and 83500 kilowatts each for every one unit increase in commercial, industrial and street lighting respectively.

For the fact that all coefficient of regression are positive, we conclude that there is a positive linear relationship between the residential, commercial, street lighting and industrial consumption with TPC. Table one above shows that residential consumption has the highest mean of 68.6 kilowatts among all the four independent variables such fact agrees with the unreduced data. Also, commercial, industrial and street lighting have means 7, 956, 23653 and 0.25 kilowatts respectively and points to their average contribution to the power equation. We observed that the coefficients of regression for commercial and industrial activities are the same even though their means differ, the reason being that while the means are the individual means of the variables in question, the coefficient of regression are considered over the average change in TPC (Y) for the period under study, thus their relative contributions to the overall consumption. Table 3, shows the correlation coefficient of each variable with itself and each of the other four variables. There is a high correlation coefficient between total power consumption and residential consumption which confirms our initial assumption that increase in power consumption within Jos metropolis is mainly due to high rate of urbanization.

The high correlation between total power consumption and industrial consumption may be considered to be the results of an inherent relation between the numbers of industries in the Jos metropolis and general demand on electricity i.e. increased power consumption will increase correspondingly with number of industries. An overall test of the significance of the regression equation is provided by F-statistics, which is the variance ratio. A 5% level of significance, the critical value of F is 3.250, which is less than the empirical value of F = 1696672.6, thus we reject any hypothesis that these regression coefficients are all zero, and conclude that the regression equation is significant. X_2 = 1, means that there is a perfect relation between TPC and X_1, X_2, X_3, and X_4. And the fact that R = 1 means that a positive perfect relationship exist between the dependent and independent variables. For further investigation we shall drop the variables X_4 and compare Y with X_1, X_2 and X_3 to see what changes it may introduce into the model. This is consistent with our assumption that it is insignificant, based on the low correlation between Y and X_4.

On regression Y and X_1, X_2 and X_3, the following results were obtained:

Table 4: Coefficients of regression for X_1, X_2 and X_3

Variable	Coefficient	Standard Error	T- Statistics
Constant of Regression	0.219	0.064	3.423
X_1	1.003	e^{-03}	679.09
X_2	1.001	$8e^{-03}$	121.428
X_3	0.992	$3e^{-03}$	367.465

Corrected R^2 = 1, Corrected R = 1
Standard Error Estimate = 0.084hough X_4
F (3.32) = 1009019.23

Y = 0219 = 1,003 x 1 = 1.001 x 2 = 0.992 x 3 (3)

We observe that, even though X_4 has been dropped from the equation R^2 still maintains its value of unity, which means the regression equation still fits perfectly and that goes to confirm the insignificance of street lighting in the total power consumed.

When we eliminated X_4 from model (1.2) the coefficients of regression b_1, b_2 and b_3 changed as can be seen for expression (1.2). For example there is an increase of 0.007 in b1, which increased per unit contribution of X_1 by 700 kilowatts. This change is relatively small, but not unexpected since elimination of X_4 did not generally after the model, as confirmed by R^2. The relative increases in per unit contribution of other factors are also expected to be of this magnitude.

In general, it is noticed that the relation between Y and X_4 is very week as shown by their coefficient of correlation which is only 0.127, but the per unit contribution to the total power consumption is all the same high, as shown by the coefficients of regression of X_4. This fact can be explained by the expression (1.2). The model 5.1 will be equivalent to expression (1.2) if and only if the coefficients are all approximately equal to 1. It is not surprising then that the B's in expression (1.2) are all approximately, 1, with only b_0, being approximately equal to zero.

We also notice that the total power consumption 'Y' increase only slightly per unit increase on each of X_1, X_2, and X_3.

A t-test of the coefficients of regression also indicates that they differ significantly from zero, and the significance of the new model is confirmed by the F-statistics.

The relative moderate correlation coefficient between Y and X_2 is partially explained by the fact that most commercial activities take place in the day, a phenomenon that can be characterized by low electricity consumption.

The correlation between Y and X_4 is rather very low, this is confirmed by the mean of X_4 0.25 kilowatts and therefore, we are inclined to consider the contribution of X_4 on Y as insignificant.

Table 3 indicates the t-statistics for each of the coefficients of regression. Using this test, to check the coefficients of regression degree of freedom, the critical value is 2.03, which is less than the empirical value of t- 976,926, thus we conclude that this estimate is significantly different from zero. A similar test for the other coefficients confirms that they differ significantly from zero, except for the constant of regression, whose critical value exceeds the empirical value hence points to the fact that it does not differ significantly from zero.

We develop this investigation further by using (1.5) and regression total electricity consumption (Y) over residential (X_1), commercial (X_2) and industrial (X_3) consumption but dropping each variable in turn to allow for a comparative analysis of variable to variable contribution to total consumption.

Regression of total power consumption on residential and commercial consumption, below.

Table 5: Produced the results

Variable	Coefficient	Standard Error	T- Statistics
Constant of Regression	3.911	3.99	0.98
X_1	1.399	0.063	22.165
X_2	0.074	0.496	0.15

Corrected R^2 = 0.954

Corrected R = 0.977
Standard Error = 5.313
F (2.33) = 361.489

Table 6: Regression coefficient for X_1 AND X_3

Variable	Coefficient	Standard Error	T- Statistics
Constant of Regression	3.371	1.235	2.73
X_1	1.108	0.025	43.878
X_3	0.89	0.055	16.196

Corrected R^2 = 0.995
Corrected R = 0.977
F (2.33) = 3363.6

Table 7: Regression coefficient for X_2 AND X_3

Variable	Coefficient	Standard Error	T- Statistics
Constant of Regression	3.371	1.235	2.73
X_1	1.108	0.025	43.878
X_3	0.89	0.055	16.196

Corrected R^2 = 0.838
Corrected R = 0.916
F (2.13) = 91.799

We now concentrate our discussions on Y, X_1, X_2, and X_3 based on the results we have obtained. The regression of Y on X_1 and X_2 produced an increase of 39600 and a decrease of 92700 kilowatts per unit contribution of X_1 and X_2 respectively to the TPC. This shows that without the industrial consumption, the share of residential consumption will substantially increase, making more kilowatts of generated power available for residential consumption. This makes it imperative that PHCN should have accurate records of the industries and monitor their growths very closely if stability of power supply is to be achieved. By taking such proper records it will be possible to accommodate the extra demand from increase in number of industries in their plan for generating electricity, thereby restoring stability of power supply at all times.
Secondly the regression of Y on X_1 and X_2 produced an increase 10,500 and a decrease of 10200 kilowatts per unit contribution of X_1 and X_3 respectively.
When there are no commercial activities, the supply rate of residential consumption increase while that of industrial decrease. This also point to the part commercial activities play in the general power consumption. This also requires that growth of commercial activities should be closely watched with a view of meeting the demands as they come and hence the demands of residential and industrial.
The regression of Y on X_2 and X_3 leaving X_1, which is the dominant factor led to an astronomical increase in per unit share of X_2 and X_3, as 3297000 kilowatts and 136800 kilowatts respectively. This demands that proper records should be kept of increases in the number of residential units and a possible evaluation of their demand of electricity made on monthly basis. This results is expected, as the more commercial and industrial activities grow, the number of residence will also increase. The increase in commercial and industrial activities can only be explained by the fact that both are closely related with X_1. For example, the increase in the number of people working in the industries who will make use of more electricity at home and more industrial work would imply more commercial activities.

We also observed from the results in Table 5, 6 and 7 that the value of R^2 and R is no longer unity. Rather, we have only 99% and 94% of each of the total deviation explained by the respective equations. This also goes a long way to show the effect of each variable on the total consumption. For example removing X_1 the dominant factor, yields R^2 = 0.838 and removing X_2 yield R^2 = 99%. It means in the power consumption that X_2 contributes more hence the need to watch its growth.

Remarks, observation and conclusion

This study does not pretend to offer profound insight into Electricity Consumption in Jos Metropolis. It simply reports some interesting relationship which exists between residential, commercial, industrial and street lighting as being the components of power consumption in Jos Metropolis. These relationships have to be considered if demand and supply of electricity in Jos should reach equilibrium stage.
By considering the mean value X_4 when compared with other mean value of X_1, X_2, X_3 (Table 1), as well as the correlation between Y and X_1, we decided to eliminate it from the model on the assumption that it is very insignificant.
This led to the model:
$Y = 0.129 = 1.0063 X_1 = 0.0992 X_3$
An assumption of non-significant of X_4 confirmed in Table 4, where the coefficient of regression did not significantly changes as well as R^2.
However, it is important to remark that the use of streetlights, which is a new phenomenon in Jos Metropolis, should be critically reviewed as it amounts to waste of insufficient energy. It is recognized that emphasis appears to now go to using solar energy technology to power street lights. We advise that proper records of monthly consumption of electricity should be kept as this is one way the public demand for electricity could be known. We suggest the use of computer in keeping such records. With keeping such records, it will be possible to make use of statistical forecasting model to predict future consumption pattern within Jos Metropolis taking into account the role (demand) of individual factors. From the study we discovered the implication of one factor of consumption on another, and we also observe a positive linear relationship between the independent and dependent variables.

Further research

These results, modest as they are, should however be of interest to PHCN, Jos District. They are also of interest as they point to the need for further investigation of the phenomenon. For example, the model could be effectively used in predicting future demands on total power consumption or even demand of individual factors. Since the test confirms the adequacy of the model such forecast of or prediction are also likely to be valid.

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