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MODELLING FOR PUBLIC ELECTRICITY INFRASTRUCTURE AND URBAN DEVELOPMENT STOCK: A CASE STUDY OF UYO URBAN, AKWA IBOM STATE, NIGERIA

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ABSTRACT

Purpose: The aim of the study was to develop a model for public electricity infrastructure and urban development stock in Uyo, Akwa Ibom State.
Design/methodology/approach: Data was collected through field surveys using structured questionnaire to elicit responses from the respondents in the study area. Physical enumeration was carried out to identify all electricity infrastructure available and all urban development stock in the study area, and their relative demand on public electricity was determined using an ideally estimated daily electricity supply of 18 hours. Multiple regression analysis was used to determine the relationship between the variables measured in the study.
Findings: Result of the study revealed that public electricity infrastructure development was found to be at its lowest ebb and erratic, not able to meet the ever-increasing demand to meet the socio-economic needs of the people.
Research limitations/Implications: Systematic provision electricity infrastructure with facts and figures, rather than using the present-day random approach so as to match the demand with supply requirements and efficient infrastructure supply prediction model developed are recommended for public electricity infrastructure development in the study area.
Originality/value – Based on the findings of the study, it is concluded that the provision of public electricity power infrastructure in Uyo urban is inadequate and cannot meet the demands of residents.

Keywords: Modelling, Public, Electricity, Infrastructure, Urban, Development

1. INTRODUCTION

Infrastructure facilities are basic amenities provided to make life easier and without which the needed environment as well as primary, secondary and tertiary productive activities will not function (Obayelu *et al.*, 2014). Thus, it can be deduced that infrastructure facilitates, the production of goods and services and itself refers to basic social services such as schools, hospitals and public electricity infrastructure. Williams (2014) asserted that public electricity infrastructure include electricity generated from water, gas, solar, wind, other renewable and their entire ancillary hardware, for example, power stations (nuclear, coal, oil, gas turbines, combined heat and power systems), grids, wind turbines, photovoltaic and gas pipelines and their software infrastructure.

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Electricity undoubtedly plays a crucial role in the physical, industrial, and socio-economic development of society. It is fundamental to the overall growth and functioning of the world economy (Apergis and Payne, 2010; Hull and Klitgaard, 2012; Nelson *et al*., 2013; Aziz *et al*., 2013; Onakoya and Yakubu, 2017; and Singh et al., 2019; ECN, 2022). It is central to every major challenge and opportunity the world is faced with today (United Nations, 2018). According to the United States Congress Office of Technology Assessment (1991) economic growth depends on the availability of reliable supply of electricity. Not only do people need public electricity supply for their basic needs like lighting, cooking, heating and ventilation, refrigeration, and other domestic uses; there is a growing demand for supply of public electricity for industrial, commercial, social and administrative purposes.

The World Bank Development Report (1994) associated economic growth with infrastructure development; and that, output is being constrained by unreliable power. According to the report, adequacy of infrastructure helps to determine one country's success and another's failure in diversifying production, expanding trade, coping with population growth, reducing poverty, or improving environmental conditions. Industrialization also increases the demand for public electricity, consequently, creating the need for adequate public electricity infrastructure (World Bank, 1994). Thus, as Agenor and Moreno-Dodson (2006) put it, good public infrastructure (such as a reliable power grid or well-maintained roads), reduces private sector expenditure on maintenance of capital stock and also slows down the pace of urban development. This, according to the source, may raise capital formation and spur growth. A world without electricity amounts to non-mechanized production while erratic and unstable supplies of electricity disrupt production and impacts negatively upon the durability of the machines (UNIDO, 2010).

Urban development stock on other hand is level capital accumulation in an urban area and seen as one of the most significant issues in human settlements all over the world. Urban areas are regarded as centres of economic growth and catalysts for various forms of development (Ofem, 2012). It is a meeting point of socio-cultural activities and a pedestal for the exchange of ideas and other forms of innovations (Ofem, 2012). Urbanization comes with changes and improvements in physical development, spatial expansion and demographic changes, which manifest in the stock accumulated over time. This stock has pressure on existing infrastructure. Studies in urban growth show a strong correlation between urbanization and infrastructure development. This is the case in countries such as Japan, South Korea, and Taiwan (Annez and Buckley, 2008).

Unfortunately, infrastructural decay is the major problem facing Nigeria (Asaolu and Oladele, 2006). Power generation, the authors added, is one of such instances of infrastructure decay in Nigeria. The lack of effective management of physical infrastructure in the face of rapid urban growth has, according to Ofem and Udoudo (2016) compounded the pressure on existing infrastructure, thus, leading to rapid deterioration in the quality of life index in Nigeria.

1.1. Aim of the Study

The aim of the study was to develop a model for public electricity infrastructure and urban development stock in Uyo, Akwa Ibom State.

1.2. Research Hypothesis

To achieve the aim of the study, an hypothesis was formulated which states that:

Ho : There is no significant effect of public electricity infrastructure on urban development in Uyo urban

1.3. Research problem

The rapid growth and development of Uyo capital city since 1987 following the creation of Akwa Ibom State has brought about demographic and physical changes within the urban setting. Consequently, there is increased demand for public electricity for domestic, commercial and industrial purposes. This development, in turn, places a immense pressure on available public electricity infrastructure.

According to Uduak *et al*. (2018), evidences abound that public electricity infrastructure and supply are on the decline in Uyo urban. The urban centre continues to expand unabated even beyond the fringes on a daily basis without a corresponding increase in public electricity supply and infrastructure development. The situation, in turn, uncontrollably leads to overburdening and aggravation of existing inadequate infrastructure. Thus, whereas the demand for electricity by households and other uses increases astronomically in Uyo urban, the daily supply continues to decrease sharply. This development has left a lot of people with no other option than to look for alternative means of power supply like generators, fossil fuel and solar panels to satisfy their electricity needs. This scenario is associated with hazards and vulnerabilities, socio-economic implications, environmental issues such as noise and air pollution, and environmental degradation (exception of solar source which rather costly to acquire).

Accurate public electricity-user statistics in Uyo urban is not known, thus, making it difficult to match the available infrastructure for supply potentials with demand requirements. This situation worsens daily as there is no known model to guide the projection of the provision of electricity infrastructure that matches the urban development trend in Uyo urban.

1.4. The study area

Uyo urban, the study area, constitutes the built-up area of Uyo capital city, the administrative centre of Akwa Ibom State and those other areas declared by government as planning areas within Uyo Local Government Area (LGA) and its environs (Ofem *et. al.*, 2010). It lies between latitudes 4° 30′ and 5° 05′ north of the Equator and longitudes 7° 54′ and 8° 00′ east of the Greenwich Meridian. It is formed around the central core of Uyo city, the headquarters of Uyo LGA with an imaginary axis at Itiam Etoi. It is bounded in the East by Uruan LGA, West by Abak LGA, North by Ikono, Ibiono Ibom and Itu LGAs; and South by Etinan, Ibesikpo-Asutan and Nsit Ibom LGAs. The limit of Uyo urban *vis-à-vis* the location of Uyo LGA is as presented in Figure 1.

The projected 2023 population of the neighbourhoods that make up Uyo urban from the 1991 census figures of 288,688 was 674,106 persons. This increase in population due to urban dynamics over time places a huge demand for public electricity and appropriate public electricity infrastructure in the area.

According to Udofia and Ituen (2018) Uyo is supplied by the Aba-Ikot Ekpene-Uyo-Calabar 33KV overhead transmission line stepped down to 11KV and further down to 415V along the streets for public consumption. Today, Uyo is serviced by three power sub-stations strategically located across the urban centre with a network of connections within and beyond the study area

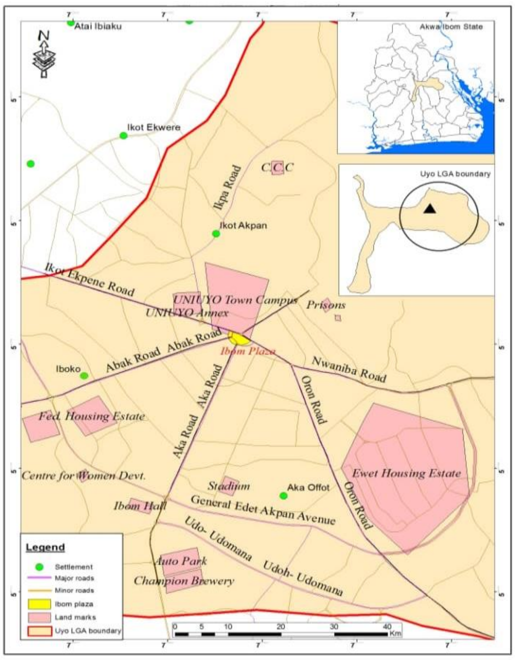

Figure 1: Map of Uyo Urban

Source: GIS Laboratory, Department of Geography and Natural Resources Management (2023)

2. Literature Review

The prediction of public electricity demand is important. Ekpenyong *et al.* (2013) examined an aggregate model for the prediction of electricity demand using Calabar South in Cross River State of Nigeria as a case study. Three levels of models comprising; the basic empirical model, the *Phi* (ф) model and the composite model for the prediction of electricity demand in Calabar South LGA were examined. Data were collected from primary sources which included households, industries and so forth. Models and equations were built for public facility, agricultural electricity, recreational, domestic electricity and industrial electricity demands. The study revealed that the total electricity installed in Nigeria is about 9, 000 MW out of which slightly above 105 MW is supplied to Calabar District and 16 MW supplied to Calabar South LGA; by 2020, it was expected to be 64, 200 MW. They opined that the developed model was capable of forecasting electricity demand on a sectional as well as on a zonal basis. This would provide necessary planning data for electricity generation, transmission and distribution.

Briggs and Ugorgi (2017) carried out an assessment of electricity demand and prediction model for the future public electricity requirement in Rivers State by the year 2025. The data for electricity allocation and load utilization of the state for the period of five years (2011 - 2015) were collated from the central dispatch office of Port Harcourt Electricity Distribution Company (PHEDC), Port Harcourt. Two different statistical analyses, "Regression exponential and least square methods," calculations, graphs were reviewed and applied to justify the analysis. While predictions were 211.30 MW and 207.10 MW by using regression exponential and least square analysis models respectively for the first year 2016, the load requirement of Rivers State for the year 2025 was expected to increase to 2113 MW and 2071 MW respectively. It is thus observed that there is a great positive correlation between the electricity demand and the years. This implies that as the years go by, the demand for electricity increases. The positive relationship was attributed to the fast growth of development in Rivers State. The study also revealed that the regression exponential model should be adopted because it captured the elastic demand of the consumers during peak and off-peak periods with an appreciable growth rate of 21.6%. In the light of the above analyses, specific action plans should be put in place to ensure that projections are being matched with reality through conscious infrastructure development if targets are to be met. Projections should not be limited to the actual estimated quantity of public electricity required for the period of projection, but exponentially done to take care of the upshot in the years, since infrastructure provision comes with an attendant implementation time-lag.

Public electricity demand, unlike other consumption goods, is a derived demand. It is not valued for itself, but for what can be done with it. This means in effect that it is not wanted for its own sake, but rather for the light and heat which it can provide. Public electricity consumption is also linked to urbanisation. This holds true as any increase in urbanisation often brings with it corresponding changes in land use, increase in transportation, industry, infrastructure and the use of domestic appliances. It can be argued that an increase in urbanisation leads to an increase in public electricity consumption as the demand for goods and services may increase in due course. According to Medlock (2009), the exceptional economic growth and major improvements in standards of living in general over the last few decades have mainly come about because of the replacement of the work force with mechanical power through technological progress. Given the gap in socio-economic development in Africa, and in order to improve such standards in the continent, better use of technology via electricity may need to be at the centre of long-term planning (Adom *et al*., 2012). In the words of Obayelu *et al*. (2014) infrastructural facilities are basic services without which the needed environment as well as primary, secondary and tertiary productive activities will not function.

Urban development is said not only to cover the increase in urban land and population, but also an increase in number and efficiency of urban infrastructure (Black and Henderson, 1999). Consequently, urbanization strongly influences the growth process, influencing both the efficiency of growth and the extent of income inequality within an economy. In turn, growth influences the urbanization process, driving the spatial evolution of production and population agglomeration. Black *et al*. (1999) modelled an economy composed of cities of endogenous size and number, under conditions of exogenous population growth and endogenous economic growth. This model explored two main themes, namely, how urbanization affects efficiency of the growth process and how growth affects the nature and patterns of urbanization. The review of literature on urban development and infrastructure is relevant for this study.

Urban public electricity infrastructure has been shown to impact on urban development. Atanda *et al*. (2017) examined the nexus between urbanization and public electricity crisis in Lagos State using questionnaire to elicit information from one hundred randomly selected Lagos residents in Akoka and Onike areas. The study adopted the survey research design and cross-sectional analysis. The design was chosen because of the research questions raised and the stated hypotheses. More so, it was chosen because researchers observed the behavioural pattern of one or more variables instantly which will also afford the study to take an informed decision and make appropriate policy options. The population of the study included the residents of Lagos metropolis. Lagos State was selected because it is the second most populated state and commercial city in Nigeria. The study drew its sample size of 100 from the population of the Lagos residents around Akoka and Onike areas of Yaba Local Government of Lagos State. These areas were selected basically because the exercise was just a pilot study and for the purpose of minimising cost. Akoka and Onike also afforded them the opportunity to harvest opinions of a typical residential area of Lagos pertaining to public electricity crisis and urbanization.

3. METHODOLOGY

This study is based on a survey research. Data were gathered from the general population using survey instruments. The instruments for data collection were Public Electricity Infrastructure and Urban Development Questionnaire (EIUDQ), physical enumeration and review of records. Data on the effect of the available public electricity infrastructure on urban development in Uyo were collected. The result of the survey therefore, provided the data base required for the research analyses and outcomes through testing of the hypothesis.

The target population for the study was sampled by segmenting the study area into a 57 units or squares using Spatial Sampling Framework. This enabled a good geographical spread of the area to be achieved. A total of 50 segments were obtained from the sub-division of the study area. As a result, 50 neighbourhoods, each with the highest population from the respective segments were selected. From the 50 neighbourhoods selected for this study, a total population figure of 183,083 was obtained from the 1991 population figures. Thus, projecting to 2023, a total population of 456,304 persons was obtained. From the above figure, the number of households within the sampled 50 neighbourhoods for the study was determined by dividing the population figure by the mean household size of five persons (NPC, 1991), thus bringing the figure to 90,898 households. Sample population to be surveyed from the 90,898 households thus obtained for this study was derived by using the Taro Yamene formula, shown in Equation 1, for the estimation of sample population from a finite population size, n = N/1+N(e)^2.

$$n = \frac{N}{1 + N(e)^2} \qquad \ldots Equation\ 1$$

Where, n is the sample size; N is the population of the study; 1 is a constant and e is the level of significance. Therefore, number of households for study, where N = 90,898:

$$(n) = \frac{90898}{1 + 90898(0.05)^2} \quad = 398.247 \ \approx 398\ households$$

The sample size for each settlement was obtained by dividing the number of households within the neighbourhood by the total number of households in the study area and multiplying the result by the total sample size of 398 households. Systematic random sampling technique was used to select households for the study. Structured questionnaire was administered on each of the respondents who were the heads of the households and the results compiled for data analysis. A detailed analysis of sample population for the study is presented in Table 1.

Table 1: Sample Population Projection (Sampled Communities)

S/N	Neighbourhood	1991 Popn.	2023 Projection	No. of Households	Sample size
1	Nkim Ibiono	490	1,222	244	2
2.	Ntak Inyang	311	775	155	2
3.	Ibiaku Uruan	3,922	9,778	1,956	9
4.	Iba Oku	899	2,241	448	3
5.	Nduetong Oku	899	2,241	448	3
6.	Afaha Oku	4,127	10,289	2,058	9
7.	Ekritam II	2,759	6,878	1,376	6
8.	Ikot Obio Enang	2,445	6,095	1,219	5
9.	Afaha Idoro	939	2,341	468	3
10.	Mbribit Itam	2,146	5,350	1,070	5
11.	Effiat Offot	4,179	10,418	2,084	9
12.	Ibiam	11,450	28,544	5,709	53

13.	Nsentip	10,727	26,742	5,348	49
14.	Udo Ekpo Inyang	12,277	30,606	6,121	57
15.	Atim Atakpo	11,174	27,857	5,571	51
16.	Udosen Uko	10,701	26,677	5,335	49
17.	Ekpo Obot	10,745	26,787	5,357	49
18.	Paul Bassey	9,965	24,842	4,968	46
19.	Asutan	8,987	22,405	4,481	41
20.	Anua Offot	6,521	16,257	3,251	14
21.	Ibiaku Offot	1,383	3,448	690	5
22.	Use Offot	3,674	9,159	1,832	9
24.	Ifiayong Usuk	2,778	6,926	1,385	6
25.	Obot Obom	695	1,733	347	3
26.	Nsukara Offot	1,706	4,253	851	6
27.	Ifa Ikot Okpon	616	1,536	307	2
28.	Itiam Ikot Ebia	1,226	3,056	611	5
29.	Atan Offot	3,387	8,444	1,687	7
30.	Anua Obio	813	2,027	405	3
31.	Obio Offot	2,006	5,001	1,000	6
32.	Use Ikot Ebio	640	1,596	319	2
33.	Ikot Asat	800	1,994	399	3
34.	Afia Nsit I	1,023	2,550	510	3
35.	Obio Etoi	908	2,264	453	3
36.	Mbierebe Obio	2,375	5,921	1,184	5
37.	Itiam Etoi	3,227	8,045	1,609	7
38.	Mbiabong Ikot Antem	1,232	3,071	614	5
39.	Mbak Akpan Ekpenyong	707	1,763	353	3
40.	Mbak Ikot Abasi	1,883	4,694	939	6
41.	Ikot Inyang Esuk	2,482	6,188	1,237	5
42.	Ifa Ikot Akpan	1,226	3,056	611	5
43.	Ikot Eeto	779	1,942	388	3
44.	Ikot Abasi Idem	440	1,097	219	2
45.	Afaha Atai	2,482	6,188	1,238	5
46.	Ikot Iko	1,092	2,722	544	3
47.	Mbiokporo Nsit	3,423	8,534	1,707	7
48.	Oboyo Ikot Ita	3,056	7,619	1,524	7
49.	Mbiokot	707	1,763	353	3
50.	Afaha Ikot Osom	602	1,501	300	2
51.	Ikot Oku Obio	1,261	3,144	629	5
52.	Ikot Okure	1,751	4,365	873	6
53.	Mbikpong Atai	823	2,052	410	3
54.	Ibiaku Issiet	3,453	8,608	1,722	8
55.	Nung Udoe	5,037	12,557	2,511	11
56.	Nung Ukana	1,567	3,907	781	5
57.	Afaha Ikot Owop	2,189	5,457	1,091	5
	Total	183,083	456,304	90,898	648

Source: Computed by the researchers' (2023)

Numbers were assigned to responses to enable evidences to be presented in quantitative form. In this case, quantifiable measures in terms of numerical ratings and quantifications were used to obtain data that were used in testing the relationship between the variables identified for the study.

Data on public electricity infrastructure variables were obtained from Transmission Company of Nigeria (TCN), Afaha Ube Transmitting Station; the National Integrated Power Project (NIPP), Ikot Abasi; Nigerian Electricity Management Services Agency

(NEMSA), Uyo; PHEDC, Uyo and residents in the study area. Also, data on urban development variables and socio-economic variables were obtained from surveys through field work and questionnaire administration. These variables identified are presented in Tables 2 and 3. Analyses of data were carried out to determine the relationship between the variables in the study. Urban development variables used in this study were limited to those items or facilities that place a demand on public electricity in the study area.

The Multiple Regression Analysis was employed to investigate causal relationships between the variables. It was helpful in measuring the actual impact of each independent variable in predicting the outcome of the dependent variable. This technique could only be applied to make generalisation about a larger sample size. Udofia (2011) recommended 15 samples to arrive at a fairly accurate result. Hence, the adoption of this statistical technique was justified. The model is presented in Equation 2.

$$Y = a + b_1X_1 + b_2X_2 + \cdots + b_nX_n + e \qquad \text{... Equation 2}$$

Where, Y is the dependent variable (contributions), X_{es} is the independent variables (changes), a = the intercept, b = regression coefficient, and e = the residual or error term.

Table 2: Public electricity demand and supply and infrastructure (Independent) variables needed for the study

Variable	Definition of Variable	Unit of Measurement
Public Electricity Demand	Quantity (Daily)	Kilowatt-hours (Kwh)
Public Electricity Supply	Quantity (Daily)	Kwh
Public Electricity Infrastructure	Power sub-stations	Number
Transformer		Kwh
Electric Poles		Number
Meters		Number
Alternative Power Sources	Generators	Number
Solar Power		Number
Cost of alternative sources		Naira

Source: Compiled by the researchers' (2023) from literature review.

Table 3: **Urban Development and Socio-economic (dependent) variables**

Variable	Definition of Variable	Unit of Measurement
Urban Development	Housing Stock	Number
	Roads	Number
	Street Lights	Number
	Fountains	Number
	Small scale industrial activity	Number
	Medium scale industrial activity	Number
	Schools	Number
	Tertiary Hospitals	Number
	General Hospitals	Number
	Cottage hospitals	Number
	Health centres/posts	Number
	Post offices	Number
	Markets	Number
	Eateries	Number
	Financial institutions	Number
	Supermarkets/retail shops	Number
	Fire stations	Number
	Petrol filling stations	Number
	Media houses	Number
	Churches	Number

	Mosques	Number
	Pharmacies	Number
	Pipe-borne Water	Number
	Boreholes	Number
	Telecommunication Masts	Number
Socio-economic factors	Monthly income	Naira
	Household Size	Number
	Educational level	1 – 4*
	Occupation	1 – 4**

Source: Compiled by researcher (2023) from literature review

*1: No formal education	**1: Civil servant - 4
2: Basic/primary education	2: Self-employed - 3
3: Secondary education	3: Artisan - 2
4: Tertiary education	4: Unskilled Labour – 1

4. PRESENTATION AND DISCUSSION OF RESULTS

4.1. Provision of Electricity Infrastructure

To determine the level of provision of public electricity infrastructure in the study area the data in Table 4 were generated.

Table 4: Responses on Availability of Public Electricity Infrastructure in the Study Area

S/N	Responses	SA	A	D	SD	IND
1	A transformer is available within the vicinity	59%	31%	8%	2%	0%
2	An electric pole is available in the compound	79%	10%	9%	2%	0%
3	Cables connecting the compound to the electric poles are available	72%	20%	2%	7%	0%

Source: Field Data (2023)

Table 4 indicates that majority of the respondents agreed that there was provision of infrastructure in the study area. Up to 59% of the respondents strongly agreed that there were transformers within their vicinities and 79% strongly agreed that there were poles within their vicinity while 72% agreed that there were cables transmitting the electricity to their compounds. These responses reveal that electricity supply infrastructures are provided while the question as to why the supply of public electricity is inadequate arose. This was attributed to the fact that transformer capacities could not meet up with the power requirements of the area. Equally, where transformer capacities were high, electricity supply was not enough to power such transformers, thus forcing PHEDC to resort to rationing electricity supply to the area.

The data presented in Table 5 indicate that the provision of public electricity infrastructure was basically the responsibility of the Port Harcourt Electricity Distribution Company (PHEDC) who contributed 61% of transformers, 55% of electric poles, 79% of cables, and 80% of meters. The impact of the government is not felt very much in the provision of public electricity infrastructure, contributing about 23% of transformers, 10% of electric poles, 12% of cables, and 8% of meters. The data also indicate that there are contributory efforts in varying degrees by people to the provision of infrastructure either as individuals or through the communal efforts of residents. Since PHEDC is the major provider of public electricity infrastructure in the study area with little or no government or corporate influence, they may not be able to cope with the demand and supply dynamics playing out in the study area.

Table 5: Provider of Infrastructure

Infrastructure	Provider	Percentage
Transformers	Government	23
	PHEDC	61
	Individuals	6
	Corporate effort of street residents	10
Total		**100**
Poles	Government	10
	PHEDC	55
	Individuals	20
	Corporate effort of street residents	15
Total		**100**
Cables	Government	12
	PHEDC	79
	Individuals	2
	Corporate effort of street residents	7
Total	**100**	
Meters	Government	8
	PHEDC	80
	Individuals	10
	Corporate effort of street residents	2
Total		**100**

Source: Field data (2023)

Table 6: Responses on Availability of Meters

Availability of Meters	Number	Percentage
Household with meters (Yes)	409	63
Household without meters (No)	239	37
Total	**648**	**100**

Source: Field data (2021)

Table 6 shows the level of availability of meters. The data reveal that 63% of the respondents in the study area had meters in their houses while 37% of the respondents did not have meters. More than one quarter of the population does not own meters. As such, they are exposed to the estimated billing system by the system operators. There is likelihood of errors, inconsistencies, and suspicion in this form of assessment of public electricity consumption.

4.2. Urban Development Stock

The data on urban development are presented in Table 7. From the data in Table 7, the major urban development infrastructure are: housing stock (5,342), retail shops (4,528), street lights (1,419), places of worship (314), boreholes (271), households with pipe-borne water (240), telecommunication masts (148), schools (144) and super markets (112). All these urban development stocks need public electricity to work effectively. With the current infrastructure level, the public electricity supply will be too low to meet the demands of the citizens, making them to forcibly resort to alternative sources of electricity supply.

To further investigate the adequacy or otherwise of public electricity supply in relation to urban development stock, the public electricity demand and supply schedules were generated from the data obtained from the respondents. The data indicate that the public electricity supply (4528.2 KW) to the study area, which is about 32% of the demand (14114.5KW) is too low, and as such, not able to meet the power needs of the area. This accounts for why public electricity is being rationed among consumers and why most people do not have power supply for the most part of the day. This has an undeniable negative impact on the socio-economic lives of the people of the area.

Table 7: Urban Development Indices in the Study Area

S/N	Urban Development Stock	Frequency	Percentage
1	Housing stock	5,342	39.90
2	Roads with street lights	31	0.24
3	Roads without street lights	501	3.75
4	Street lights	1,419	10.61
5	Water Fountains	2	0.01
6	Schools	144	1.10
7	Hospitals	5	0.04
8	Clinics	11	0.08
9	Health Centres	14	0.10
10	Telecommunication Masts	148	1.11
11	Health Posts	12	0.09
12	Cottage Hospital	26	0.20
13	Markets	23	0.17
14	Eateries	23	0.17
15	Banks	9	0.07
16	Petrol filling stations	58	0.43
17	Churches /Mosques	314	2.35
18	Households with pipe-borne water	240	1.80
19	Boreholes	271	2.02
20	Pharmacies/medicine shops	83	0.62
21	Fire stations	1	0.01
22	Super markets	112	0.85
23	Retail shops	4,528	33.85
24	Media houses	6	0.04
25	Small-scale industries	42	0.31
26	Medium-scale industries	11	0.08
	Total	**13,376**	**100.00**

Source: Field data (2023)

At the community level, the capacities of the transformers serving the neighbourhoods in relation to the demand was considered. Transformers are inductive devices and are rated in Kilovolt Amperes (KVA). Their active power (current) lag behind the apparent power (voltage rating) and is referred to as “lagging power factor”. Thus, for any given transformer rating in KVA, the active power (actual current) in Kilowatts (KW) produced is measured by multiplying the apparent power rating (KVA) by the power factor ($\cos \phi = 0.8$) (Mehta and Mehta, 2013). Thus, in arriving at the transformer capacities from the transformer ratings in the study area, the low power factor resulting in additional losses of active power was considered and the transformer capacity (active power) was obtained by multiplying the transformer rating in KVA by the power factor, 0.8. This gave a true picture of the actual carrying capacity in KW of the transformers in the study area. In determining the maximum transformer output, it was assumed that, for maximum efficiency, a factor of safety should be introduced and the transformers should operate at 80% installed capacity so as to avoid overloading which may lead to voltage drop and system collapse. In line with this insight, the maximum transformer output used in the computation was also obtained by multiplying the transformer capacity in KW by 0.8, so as to keep the figure within a safe and realistic region. The result is as presented in Table 8.

Table 8: Transformer Capacities and Neighbourhood Requirements

S/N	Neighbourhood	Transformer rating (KVA)	Transformerc apacity (KWh)	Maximum transformer output (KWh)	Daily electricity demand (KWh)	Daily electricity supply (KWh)	Electricity supply deficiency (KWh)	Percentage deficiency (KWh)
1	NkimIbiono	0	0	0	86.6	0	86.6	100
2	Ntak Inyang	300	240	192	282.3	64.2	218.1	77.3
3	IbiakuUruan	1,100	880	704	203.8	46.7	157.1	77.1
4	Iba Oku	300	240	192	67.0	15.8	51.2	76.4
5	Nduetong Oku	600	480	384	211.2	48.1	163.1	77.2
6	Afaha Oku	1,100	880	704	304.8	69.2	235.6	77.3
7	Ekritam II	600	480	384	300.8	68.1	232.7	77.1
8	Ikot Obio Enang	600	480	384	140.4	32.2	108.2	77.1
9	AfahaIdoro	300	240	192	186.6	44.9	141.7	75.9
10	MbribitItam	1,150	920	736	160.8	36.9	123.9	77.1
11	EffiatOffot	500	400	320	743.5	168.2	575.3	77.4
12	Ibiam	2,550	2,040	1,632	298.4	113.9	184.5	61.8
13	Nsentip	1,700	1,360	1,088	326.4	124.3	202.1	61.9
14	Udo Ekpo Inyang	1,900	1,520	1,216	308.0	117.3	190.7	61.9
15	Atim Atakpo	2,400	1,920	1,536	288.2	110.2	178.0	61.8
16	Udosen Uko	800	640	512	310.3	118.2	192.1	61.9
17	Ekpo Obot	3,350	2,680	2,144	496.4	187.0	309.4	62.3
18	Paul Bassey	2,100	1,680	1,344	313.9	119.5	194.4	61.9
19	Asutan	3,100	2,480	1,984	347.9	132.2	215.7	62.0
20	AnuaOffot	1,100	880	704	412.6	79.1	333.5	80.8
21	IbiakuOffot	300	240	192	316.7	60.7	256.0	80.8
22	Use Offot	2,200	1,760	1,408	393.8	75.5	318.3	80.8
23	IduUruan	1,700	1,360	1,088	653.8	125.5	528.3	80.8
24	IfiayongUsuk	600	480	384	910.4	174.9	735.5	80.7
25	Obot Obom	300	240	192	114.8	26.5	88.3	76.9
26	NsukaraOffot	3,600	2,880	2,304	239.7	48.7	191.0	79.7
27	Ifa Ikot okpon	2,300	1,840	1,472	610.7	137.8	472.9	77.4
28	Itiam Ikot Ebia	9,700	7,760	6,208	812.4	167.5	644.9	79.4

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S/N	Neighbourhood	Transformer rating (KVA)	Transformerc apacity (KWh)	Maximum transformer output (KWh)	Daily electricity demand (KWh)	Daily electricity supply (KWh)	Electricity supply deficiency (KWh)	Percentage deficiency (KWh)
29	Atan Offot	600	480	384	223.9	50.9	173.0	77.2
30	AnuaObio	600	480	384	381.8	86.6	295.2	77.3
31	ObioOffot	500	400	320	244.3	55.4	188.9	77.3
32	Use Ikot Ebio	900	720	576	204.3	46.6	157.7	77.2
33	Ikot Asat	500	400	320	209.8	47.7	162.1	77.3
34	Afia Nsit 1	500	400	320	76.2	17.8	58.4	76.6
35	ObioEtoi	1,100	880	704	272.8	61.9	210.9	77.3
36	MbierebeObio	1,900	1,520	1,216	449.9	101.9	347.0	77.1
37	ItiamEtoi	9,800	7,840	6,272	725.1	164.0	561.1	77.4
38	Mbiabong Ikot Antem	900	720	576	159.3	36.3	123.0	77.2
39	Mbak Akpan Ekpenyong	300	240	192	230.8	52.5	178.3	77.3
40	Mbak Ikot Abasi	300	240	192	239.3	54.4	184.9	77.3
41	Ikot Inyang Esuk	300	240	192	251.7	58.2	193.5	76.9
42	Ifa Ikot Akpan	1,800	1,440	1,152	214.3	48.9	165.4	73.7
43	Ikot Eeto	300	240	192	119.7	39.8	79.9	66.8
44	Ikot Abasi Idem	500	400	320	86.5	28.7	57.8	66.8
45	Afaha Atai	500	400	320	108.6	35.5	73.1	67.3
46	Ikot Iko	800	640	512	146.9	47.3	99.6	67.8
47	Mbiokporo Nsit	1,400	1,120	896	163.9	52.5	111.4	67.9
48	Oboyo Ikot Ita	500	400	320	96.3	31.6	64.7	67.2
49	Mbiokot	300	240	192	74.2	24.9	49.3	66.4
50	Afaha Ikot Osom	500	400	320	113.0	36.9	76.1	67.3
51	Ikot Oku Uboh	300	240	192	80.6	26.8	53.8	66.7
52	Ikot Okure	1,000	800	640	98.3	22.8	75.5	76.8
53	Mbikpong Atai	300	240	192	136.3	31.3	105.0	77.0
54	IbiakuIssiet	800	640	512	289.0	65.9	223.1	77.2
55	Nung Udoe	500	400	320	529.6	119.8	409.8	77.4
56	Nung Ukana	500	400	320	135.7	31.2	104.5	77.0
57	Afaha Ikot Owop	300	240	192	96.3	31.6	64.7	67.2

Source: Field Data (2023)

From Table 8, it can be seen that public electricity supply falls short of meeting the demand of the people of the area with varying degrees of deficiency, ranging from 61.8% to an all-time high figure of 80.8%. This deficiency ratio also ranges from 49.3KW (66.4%) in Mbiokot to 735.5KW (80.7%) in IfiayongUsuk and 86.6KW (100%) in NkimIbiono, who have not had light for more than five years now, because, the only transformer supplying electricity to the area,according to community sources, went bad and was removed for repairs, and replaced. In EffiatOffot, the deficiency ratio is as high as 575.3KW (77.4%) while in Nung Udoe, it is 409KW (77.2%), and 561.1KW (77.4%) and 644.9KW (79.4%) in Itiam Ikot Ebia and ItiamEtoi respectively. Generally, the capacities of the transformers in most of the neighbourhoods do not meet the power needs of the people. Where the transformer capacities are enough to significantly meet the power requirements of a neighbourhood, as in Ibiam (1,632KW), Nsentip (1,088KW), Udo Ekpo Inyang (1,216KW), Atim Atakpo (1,536KW), Ekpo Obot (2,144KW), Paul Bassey (1,344KW), Asutan (1,984KW), Use Offot (1,408KW), Nsukara (2,304KW), Ifa Ikot Okpon (1,472KW), Itiam Ikot Ebia (6,208KW), MbierebeObio (1,216KW), ItiamEtoi (6,272KW), Ifa Ikot Akpan (1,152KW), Mbiokporo Nsit (896KW), Ikot Okure (640KW), and IbiakuIssiet (512KW), the public electricity supply to such neighbourhoods asIbiam (113.9KW), Nsentip (124.3KW), Udo Ekpo Inyang (117.3KW), Atim Atakpo (110.2KW), Ekpo Obot (187.0KW),Asutan (132.2KW), Use Offot (75.5KW), Nsukara (48.7KW), Ifa Ikot Okpon (137.8KW), Itiam Ikot Ebia (167.5KW), MbierebeObio (101.9KW), ItiamEtoi (164.0KW), Ifa Ikot Akpan (48.9KW), Mbiokporo Nsit (52.5KW), Ikot Okure (22.8KW), and IbiakuIssiet (65.9KW) fails to meet up with the transformer capacities, thus, causing such transformers to operate below capacity and constituting a huge waste of resources. This result further buttresses the fact that on all fronts, public electricity supply is very far from meeting the demands of the people of the study area and that the level of infrastructure provision is grossly inadequate when compared to the power needs of the people of the area.

4.3. Testing of Hypothesis

The following null hypothesis was formulated for the study:

H_0 - There is no significant effect of public electricity infrastructure on urban development in the study area.The variables used to test this hypothesis were:E = Electric poles (as proxy for public electricity infrastructure); H = Housing (as proxy for urban development).

The result of the analysis is shown in Table 9.

Table 9: Regression Analysis for Public Electricity and Urban Development Variables

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df_1	df_2	Sig. F Change	
1	.738[a]	.544	.532	43.01385	.544	45.410	1	38	.000	1.406

a. Predictors: (Constant), Housing
b. Dependent Variable: E_{I3}

The regression model indicates that public electricity infrastructure has a high positive impact (0.738) on urban development while the public electricity infrastructure impacted 54.4% (R square = 0.544 x 100) on urban development in the study area. The impact was significant (0.000). As such, the null hypothesis that: There is no significant effect of public electricity infrastructure on urban development in the study area is rejected and the alternate is accepted.

Findings reveal that majority of the respondents agreed that there is provision of infrastructure in the study area. Up to 59% of the respondents strongly agreed that there are transformers within their vicinities, 79% strongly agreed that there are poles within their vicinities, while 72% agreed that there are cables transmitting the electricity to their homes. Despite the provision of poles, cables and transformers, public electricity supply to Uyo urban falls far short of meeting the demand of residents. The findings agree with Williams (2014) who asserted that public electricity infrastructure is not only limited to the provision of poles and cables, but include electricity supply, gas, solar, wind, other renewable and their entire ancillary hardware such as power stations, grids, wind turbines, photovoltaic and gas pipelines and their software infrastructure such as operators, policies and legislations.

The findings also reveal that the provision of public electricity infrastructure was basically the job of the PHEDC, and unable to meet up with the demand and supply dynamics in the study area, people contributed to the provision of infrastructure either as individuals or through the cooperative efforts of the people living on a particular street. This result supports the findings of Anuamaka *et al*. (2016) who examined the problems of electricity generation in Nigeria and found out that the dearth of technological-know-how, meagre financial resources, lack of public electricity mix, poor maintenance management, inadequate and inflexible gas infrastructure, and obsolete equipment were major factors militating against adequate generation of electricity in Nigeria

The result of the regression model used to assess the urban public electricity infrastructure and its impact on urban development indicates that the variables that impacted on socio-economic activities were X_3 (Number of days of public electricity supply), X_4 (Number of days of power outages) and X_5 (Strength of power supply). The regression analysis revealed that the effect power supply has on socio-economic activities is positive (0.352) while the power supply impacted 12.4 % (R square = 0.124 x 100) on the level of socio-economic activities in the study area. This shows that the current effect of public electricity infrastructure is low. It agrees with the study of Atanda *et al*. (2017) who examined the nexus between urbanization and public electricity crisis in Akoka and Onike areas of Lagos State and found out the existence of public electricity supply gap within the Lagos metropolis, and that the public electricity requirement in the state for industrial, commercial, and domestic needs were not met by supply. Urbanization was seen as the root cause of public electricity crisis in the state and that generators provided the main coping alternatives for residents.

5. CONCLUSION AND RECOMMENDATIONS

Based on the findings of the study, it is concluded that the provision of public electricity power infrastructure in Uyo urban is inadequate and cannot meet the demands of the people. This scenario has become a perennial problem. For the situation to improve there must be a conscious positive attempt by the government and relevant agencies towards the provision of the requisite electricity infrastructure and regular maintenance to avoid system collapse.

On the basis of the findings, it is recommended that: Planning of public electricity infrastructure should not be done haphazardly, but with facts and figures. In line with this, an infrastructure supply prediction model, that balances the supply of public electricity with the demand is developed and recommended. The amount of public electricity required by an area should be worked out using population, per-capita electricity consumption, and urban development indices. Thus, if total population of a given area is represented by P_a, the per-capita electricity consumption index is C_a, and the amount of electricity required to power urban development stock is given by UD_a; then, the electricity supply to the area, E_a, and is represented by:

$$E_a = [C_a P_a + UD_a] \qquad ... Equation\ 3$$

This equation applies where prompt attention is given to ailing infrastructure without provisional time-lag.

The capacity of the transformers supplying electricity to neighbourhoods should take into consideration the lagging power factor and system efficiency. Thus, for efficient delivery of adequate electricity supply, the combined transformer-capacity supplying to any given area T_c, should equal:

$$E_a = \frac{KVA}{\cos\Phi \ x\ 0.8} \qquad ...Equation\ 4$$

Where: (cos ϕ) denotes power factor, and 0.8 connotes allowance for system function at 80% capacity for maximum efficiency respectively.

Thus, since cos ϕ = 0.8;

$$T_c = \frac{E_a KVA}{0.8\ x\ 0.8} \qquad ...Equation\ 5$$

Substituting for $E_a = \{[C_a P_a + \ UD_a]$;

$$T_c = \frac{[C_a P_a + \ UD_a]\ KVA}{0.8\ x\ 0.8} \qquad ...Equation\ 6$$

Infrastructure provision comes with attendant time-lag, while the urban population and urban development stock continue to grow unabated. These factors should be considered when planning infrastructure and making projections towards meeting the power needs of any given area. Thus, if the total population of a given area is represented by P_a, the per-capita electricity consumption index is C_a, and the amount of electricity required to power urban development stock is given by UD_a; then, the electricity supply to the area, Ea is represented by:

$$E_a = \{[C_a P_a + \ UD_a] + \ [C_a P_a P_r + \ UD_a G_r]Y\}KWh \qquad ...Equation\ 7$$

Where P_r denotes population growth rate; G_r represents urban growth rate; and Y connotes time-lag envisaged for completion of the infrastructure development project.

Equally, the transformer capacity T_c, supplying electricity to the area will be given by:

$$T_c = \frac{\{[C_a P_a + \ UD_a] + \ [C_a P_a P_r + \ UD_a G_r]Y\}KWh}{0.8\ x\ 0.8} \qquad ...Equation\ 8$$

For example, if provision were to be made for a transformer in Nkim Ibiono, without none servicing the area at the moment, with a population of 1,222 persons, and amount of electricity required for other uses of urban development stock is 82.6KWh; then, the daily amount of electricity needed for the area, using a per-capita energy consumption index of 0.126 KWh, is calculated by:

$E_a = [C_a P_a + \ UD_a]$ = [(0.126 x 1,222) + 82.6] KWh = 236.6 KWh or units.

Also, the capacity of transformer T_c, required for effective daily electricity supply will be:

$$\frac{[C_a P_a + \ UD_a]\ KVA}{0.8\ x\ 0.8} = [(0.126\ x\ 1{,}222) \ + \ 82.6]\ KVA = \ 370KVA$$

Since transformer ratings are standardized, the nearest whole number should be taken, and in this case, a transformer rating of 500KVA would be appropriate for the area. This situation has the advantage of the infrastructure outlasting the development plan period, thus giving room for delays that may arise in the course of the project execution.

If, on the other hand, the total electricity infrastructure network in the same area (NkimIbiono) needs to be overhauled, and the project is expected to last for a period of two years, then, with an average population growth of 2.41% (United Nations, 2023) and current urban growth rate of 6% (Adedini, 2023), the amount of energy needed to power the area effectively at the end of the development period will be:

$E_a = \{[C_a P_a + \ UD_a] + \ [C_a P_a P_r + \ UD_a G_r]Y\}KWh$

= [(0.126 x 1,222 + 82.6) + (0.126 x 1,222 x 0.0241) + (82.6 x 0.06) x 2]KWh

= [236.6 + 3.71 + 9.91] KWh

= 250. 2KWhor units

Also, the capacity of transformer T_c, required for effective daily electricity supply for the same period will be given by:

$$T_c = \frac{\{[C_a P_a + UD_a] + [C_a P_a P_r + UD_a G_r]Y\}KVA}{0.8 \, x \, 0.8}$$

= [(0.126 x1,222 + 82.6) + (0.126 x 1,222 x 0.0241) + (82.6 x0.06) x 2] KVA

= 391 KVA

Now, taking the nearest whole number, a transformer capacity of 500KVA still becomes appropriate. This situation also applies on a larger scale when considering the capacity of generating stations, transmission stations, and distribution stations alike or during complete system overhaul.

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