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Evaluating the Effect of Prepaid Metering System on Revenue Generation using Cronbach's Alpha SPSS

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Abstract: *Unpaid bills, billing inconsistencies, and post-billing are some examples of electricity theft. On the other hand, customers can pay for utilities like water or electricity in advance of use with a prepaid metering system. Therefore, the main goal of this study was to find out how the BEDC's revenue collection was affected by the prepaid metering system. The study's population consists of 3,500 data points gathered from Benin Electricity Distribution Company (BEDC). Fifty (50) questionnaires were distributed and returned. A 5-point Liker scale was used to create a variable for the questionnaire. A factor analysis was used to examine the pattern of correlations among a collection of observable variables. The Cronbach's alpha reliability test was used to assess the instrument's dependability. The resulting value of 0.997 indicates that the instrument (questionnaire) used has a high degree of dependability. Kendall's coefficient of concordance (W) was used to examine the respondents' ratings for agreement, and the resultant value of 0.892 indicated that the judges interviewed had a high degree of agreement. The values of W are closer to 1, indicating agreement, and the correlation between factors 1 and 4 (0.493) was the most significant. The energy usage of low-income households is also low. Customers at BEDC, Okada Business District, also greatly appreciate the prepaid metering system.*

Keywords: *Cronbach's Alpha, Electricity Theft, Prepaid Metering System, Revenue, Okada Business District*

INTRODUCTION

Nigeria's electrical ecosystem has seen numerous changes as a result of the country's growing demand and constrained supply. The way Nigeria's electrical sector functions has undergone substantial modifications. To start the process of privatizing the electricity sector, the National Electric electricity Authority (NEPA) was first renamed the Power Holding Company of Nigeria (PHCN). To make the transition from the government monopoly to the private companies as smooth as possible, unbundling was done. The Transmission Company of Nigeria (TCN), six generating companies, and eleven distribution companies were subsequently formed out of the PHCN (Adil *et al.*, 2020; Adongo *et al.*, 2021; Obiorji and Iwuoha, 2021). As a result, a competitive electricity market governed by a single regulatory body was established by the restructuring of the power business. Consequently, the majority of stakeholders have clearly deemed Nigeria's power reforms to be a failure (Ogbe, 2023; Kgaphola *et al.*, 2024). The Federal Government, businesses across a range of industries, and Nigerian citizens have all

expressed serious concerns about the country's unpredictable and unstable power supply (Adedeji, 2017). Nigerians generally agree that the energy supply in the nation is now unstable and in bad shape. The electricity supply has impacted the country's economic development (Arango *et al.*, 2017; Arif *et al.*, 2021, Arkorful, 2022) and is characterized by poor transmission, low accessibility, and epilepsy (Adongo *et al.*, 2021; Yan and Wen, 2021; Tanwar *et al.*, 2022). In fact, a wide range of variables have been recognized as obstacles in the electrical industry. A few examples of contributing factors include inadequate policy initiative, a lack of an asset protection mechanism, a poor maintenance culture, inadequate gas supply, vandals sabotaging pipelines, poor town and urban planning that makes it difficult to control power distribution, poor staffing, water mismanagement that affects the national grid, and poor transmission (Aslam *et al.*, 2020; Arowolo & Perez, 2020). Furthermore, because of its impact on power distribution, electricity theft has become a rising concern in the electricity business.

Like adding money to a phone card, customers can pay for energy or other services in advance via a prepaid meter system (PMS). Instead of receiving a charge after usage, consumers pay credits, and their service is stopped when the credit runs out, until additional credit is paid. This technique does away with projected billing and encourages transparency and cost control. Electricity use is intimately related to the Sustainable Development Goals (SDGs), especially SDG 7. SDG 7 seeks to guarantee that everyone has access to modern, affordable, dependable, and sustainable energy. This involves having access to energy, which is essential for accomplishing a lot of other SDGs. Expanded access to electricity is essential for industrialization, better health, education, and poverty alleviation, as well as for reducing the effects of climate change. Additionally, prepayment metering systems (PMS) can play a major role in accomplishing a number of SDGs, especially those pertaining to sustainable cities and communities (SDG 11) and inexpensive and clean energy (SDG 7). Prepaid meters also provide a way to move toward more sustainable and equitable energy systems by encouraging energy efficiency, facilitating improved financial management of energy use, and possibly lowering energy poverty. By offering a more flexible and controllable payment method, prepaid metering can increase the number of families with access to power, particularly in developing nations. Prepaid metering has been linked to lower electricity consumption as consumers become more aware of their energy use, according to studies (de Oliveira Ventura *et al.*, 2020). Additionally, prepaid systems can assist reduce energy poverty by giving consumers control over their spending and preventing them from accruing big, unaffordable bills (Khonjelwayo & Nthakheni, 2021). Furthermore, PMS can increase electricity suppliers' revenue collection, allowing them to make investments in access expansion and infrastructure improvements (Dike *et al.*, 2015).

In the Okada business district of Edo State, Nigeria, there are now two ways to collect revenue: prepaid and postpaid. Sales are made via credit or cash. A prepaid billing system that is being implemented for revenue collection will soon require customers to pay for electricity in advance. Revenue collection costs will therefore most likely be reduced or eliminated entirely. Invoices for services that have already been paid for or that the customer has not used are common in this district. BEDC will increase its revenue collection capacity, reduce its revenue collection expenses, and resolve the problem of inaccurate billing by putting in place a prepaid revenue collecting system. Thus, the purpose of this study is to ascertain how the Benin Electricity Distribution Company's revenue generation is affected by the prepaid metering system using Okada Business District.

MATERIALS AND METHODS

2.1 Sampling Procedure

The Okada Business District's Benin Electricity Distribution Company (BEDC) gathered customer information from roughly 3,500 research participants. Statistical calculations utilizing the Yamane; 1967 formula, which is as follows, were used to calculate the study sample size.

$$n = \frac{N}{1+N\,(0.15)^2} \quad (1)$$

Where,

n = Sample size

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N = Sampled population of Okada business district
e = Level of precision or confidence level
At 0.15 significance
Hence:

$$n = \frac{3{,}500}{1+3{,}500\,(0.15)^2}$$

n = 46.205

Hence, 50 questionnaires were needed for the analysis.

2.2 Data Collection

The collection of data in this research work was carried out using questionnaires. The first two approaches were informal and relied on the level of communication and comprehension between the researcher and the BEDC customers. The questionnaire used for the study was created using a five-point rating system. It was built based on the initial exploratory survey and literature search. The questions were specific and presented in few sentences in the most straightforward manner possible without compromising clarity. Respondents had to mark the level that best reflected their feelings regarding each item on the questionnaire. A 5 point Likert scale was used to create a variable in the questionnaire (Fig. 1). Fifty (50) of the questionnaires that were distributed were returned. The questionnaires were distributed and collected using a person-to-person method.

Table-1 A variable into questionnaire based on 5-point likert scale

S/N	Scale Item Description	Opinion Continuum					
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	
i	Credit based metering and billing is the dominant mode of electric power utility delivery (postpaid)						
ii	Credit metering is characterized by high labour intensity						
iii	High credit i.e. high dept rate						
iv	Credit based metering and billing is characterized by high financial risk						
v	Electricity provision involves not only the installation of the physical infrastructure and equipment but also effective operation of the administrative infrastructures						
vi	Meter reading is labour intensive, need for access to household						
vii	Loss of time and resources for clients and distributor due to connection and disconnection						
viii	Credit based system business processes are very resources intensive invoicing, information processing, customer feedback, support, client monitoring						
ix	Low-income households have low levels of energy consumption but the same level of administration and maintenance costs						
x	There is no need for meter reading in PPMs						

2.3 Data Analysis

2.3.1 Kendall's Coefficient of Concordance (W)

Based on the surveys that were distributed, Kendall's coefficient of concordance (W) was employed as a statistical tool to ascertain the degree of agreement between various viewpoints. From 0 (no agreement) to 1 (total

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agreement), it goes from there. Characters, variables, and so on can serve as the judges. If R is an n x m matrix in which rij is the rank of the j-th of m objects as judged by the i-th of n judges. Then;

$W = 12S/m^2n\ (n^2 - 1)$ (2)

Where;

S is the sum of the squared deviations of the column sums from the mean column sum

$s = \sum(rj - r/m)2$ (3)

In the case where the objects to be ranked are the judges themselves,

n = m

And;

$W= 12S/n^3\ (n^2- 1)$ (4)

Each pair of objects to be ranked appears the same number of times, which is a characteristic of Youden arrays as they relate to ranking matrices. In this instance;

$W= 12S/\lambda^2n\ (n^2 - 1)$ (5)

Where;

The frequency of a particular comparison is denoted by X. Each pair of members is ranked n - 2 times when each group member ranks every other member except himself. This is clear from the fact that only people I and J omit the (ij) pair, whereas no one else does. In this instance,

A = n - 2

And;

$W= 12S/n\ (n - 2)^2\ (n^2- 1)$ (6)

Zeros on the major diagonal define the data matrix, R, that corresponds to equation 5. In the event that the test statistic W is 1, all judges or survey participants were in agreement and gave the list of objects or concerns the same order. If W is zero, the respondents' answers may be considered essentially random and there is no general tendency of agreement among them. A moderate level of agreement between the different answers is indicated by an intermediate value of W. W will therefore fall between 0 and 1, with values near 0 denoting no agreement and values around 1 denoting agreement.

2.3.2 Cronbach's Alpha

The percentage of test score volatility attributable to true score variance was estimated in this study using a Cronbach alpha estimate (α). All values between 00.0 and 1.00 are likewise feasible, and it can vary from 00.0 (if no variance is consistent) to 1.00 (if all variance is consistent). Therefore, it can be concluded that a test is 90% reliable and, consequently, 10% unreliable if the Cronbach alpha for a set of scores is 0.90. In an effort to find underlying variables, or factors, that account for the pattern of correlations among a collection of observable variables, a factor analysis was also employed.

RESULTS AND DISCUSSION

Table-2 displays the matrix representation of the responses that BEDC's Okada Business District customers provided.

Table-2 Responses obtained from the customers of BEDC in Okada Business District

Respondents	1	2	3	4	5	6	7	8	9	10	11	12
1	9	9	8	9	10	8	9	7	8	8	11	9
2	7	11	10	9	9	8	9	10	8	10	9	8
3	9	10	9	12	8	12	10	11	10	9	11	10
4	8	7	9	7	8	7	7	10	9	7	9	7

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5	8	7	9	7	8	10	7	7	9	8	8	10
6	10	9	9	11	10	8	9	9	11	9	11	10
7	10	10	8	9	11	9	10	12	11	9	11	10
8	12	10	11	9	10	10	9	11	10	11	10	12
9	10	9	9	9	11	10	11	8	12	10	9	10
10	11	10	9	9	9	11	10	9	9	11	10	11
11	11	8	9	8	8	10	7	7	7	7	3	11
12	10	9	8	9	7	8	8	7	8	9	11	11
13	10	9	9	7	9	8	7	7	9	10	9	9
14	11	12	9	8	9	10	11	12	10	10	11	9
15	10	10	9	9	8	7	7	8	9	8	11	10
16	8	7	9	7	7	6	7	8	8	9	8	8
17	7	8	7	6	7	8	7	7	6	7	6	8
18	8	7	8	7	6	7	8	7	7	6	8	7
19	9	8	7	8	9	8	9	8	8	8	8	9
20	8	7	9	8	6	7	8	7	7	6	8	7
21	7	6	5	6	6	7	6	6	6	5	6	6
22	7	8	8	9	6	7	8	7	7	6	7	8
23	8	7	9	9	7	6	7	8	6	7	8	7
24	7	8	9	9	6	7	8	7	7	6	8	8
25	9	7	9	9	7	6	7	8	6	7	8	8
26	8	6	7	8	6	6	7	7	6	8	7	8
27	7	8	8	7	6	6	7	7	8	6	8	7
28	7	6	7	7	6	6	7	6	7	6	7	8
29	11	10	12	11	10	12	11	10	9	8	9	12
30	12	11	12	10	12	11	12	9	9	11	10	11
31	15	12	13	11	13	15	14	13	14	13	14	13
32	16	18	16	18	21	19	17	15	15	18	14	13
33	19	19	20	21	20	21	22	21	21	20	23	23
34	16	19	17	18	21	19	17	16	15	18	14	15
35	19	19	21	22	20	19	22	23	21	20	23	26
36	17	18	20	21	19	19	22	23	22	21	22	21
37	22	21	23	22	22	21	22	23	20	22	21	22
38	15	19	17	18	21	19	17	16	15	18	14	15
39	16	18	20	19	18	19	20	21	22	20	19	22
40	19	22	20	21	19	21	22	23	22	22	22	23
41	23	27	24	22	24	26	23	22	23	24	23	24
42	25	28	25	22	25	26	26	23	24	24	23	24
43	27	28	26	25	22	23	26	24	26	23	24	24
44	27	28	26	25	23	24	27	26	27	25	24	25
45	29	27	27	23	25	27	24	27	26	24	25	25
46	29	28	29	25	24	27	25	27	24	25	26	26
47	28	27	23	27	25	27	27	24	26	24	25	25
48	21	25	26	27	25	24	27	25	27	25	24	26
49	23	27	27	25	27	27	24	27	25	26	25	24
50	22	26	26	26	28	26	25	26	26	25	24	25

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The data matrix was inputted into SPSS software for data reduction analysis based on principal component, minimum and maximum likelihood analyses.

Reliability

A. Variables

VAR00001 VAR00002 VAR00003 VAR00004
VAR00005 VAR00006 VAR00007 VAR00008 VAR00009 VAR00010 VAR00011 VAR00012

B. Scale

'ALL VARIABLES') ALL

C. Model

ALPHA

D. Statistics

DESCRIPTIVE SCALE CORR COV

E. Summary

TOTAL MEANS VARIANCE COV CORR

Table-3 shows the case processing of the items and Table-4 shows that the results result of reliability statistic.

Table-3 Case Processing Summary

Case	N	%
Valid	50	100.00
Excluded	0	0.00
Total	50	100.00

Table-4 Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No of Items
0.997	**0.997**	12

Since no example was eliminated, as shown in Table-3, all responses were genuine. Table-4's Cronbach's Alpha value is 0.997. According to the questionnaires, the dependability agreement of the respondents is 99.7% reliable and only 0.3% unreliable. The item statistics summary is displayed in Table-5.

Table-5 Summary item statistics

	Mean	Minimum	Maximum	Range	Maximum /Minimum	Variance	No of Items
Item Means	13.902	13.580	14.200	.620	1.046	.040	12
Item Variances	53.883	48.507	60.857	12.351	1.255	13.254	12
Inter-Item Covariances	52.075	45.946	57.735	11.789	1.257	6.786	12
Inter-Item Correlations	.967	.938	.985	.047	1.050	.000	12

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There is no correlation between the two variables when the value is 0. A positive correlation is shown by a value greater than 0; that is, when the value of one variable rises, the value of the other also rises. A negative relationship is shown by a value smaller than zero, meaning that when one variable's value rises, the value of the other variable falls. However, the number of 1.050 indicates that there is a positive correlation. Variance 0.000 suggests that the model as a whole is significant and that the predictor variables, the number of prepaid meters under the prepaid billing system explain a variation in revenue collection expenses. Table-6 displays the description statistics for the collected data.

Table-6 Descriptive statistics

	Mean	Std. Deviation	Analysis N
VAR00001	1.4200	.49857	50
VAR00002	2.2800	1.08872	50
VAR00003	1.5400	.73429	50
VAR00004	2.5600	1.48681	50
VAR00005	1.8400	1.07590	50
VAR00006	2.0000	1.03016	50
VAR00007	2.1600	1.14927	50
VAR00008	2.0600	1.15016	50
VAR00009	2.4800	1.46022	50
VAR00010	2.3600	1.38151	50
VAR00011	2.0200	.99980	50
VAR00012	1.8400	1.20136	50

Variable number 001 (credit-based metering system) had the lowest communalities, whereas variable number 009 (low-income household maintenance cost) had the highest communalities of 0.926. Table-7 displays the data matrix's component matrix.

Table-7 Communalities

	Extraction
VAR00001	**.564**
VAR00002	.756
VAR00003	.777
VAR00004	.848
VAR00005	.777
VAR00006	.791
VAR00007	.760
VAR00008	.856
VAR00009	**.926**
VAR00010	.862
VAR00011	**.905**
VAR00012	**.921**

Extraction Method: Principal Component Analysis.

Fig. 1 displays the Scree plot of the components that were recovered using principal components analysis (PCA). We did not remove the components whose eigenvalues were less than one (1). The largest eigenvalue, greater than 4, is found in Factor 1. Principal component analysis is used for extraction, and varimax with Kaiser normalization is used for rotation.

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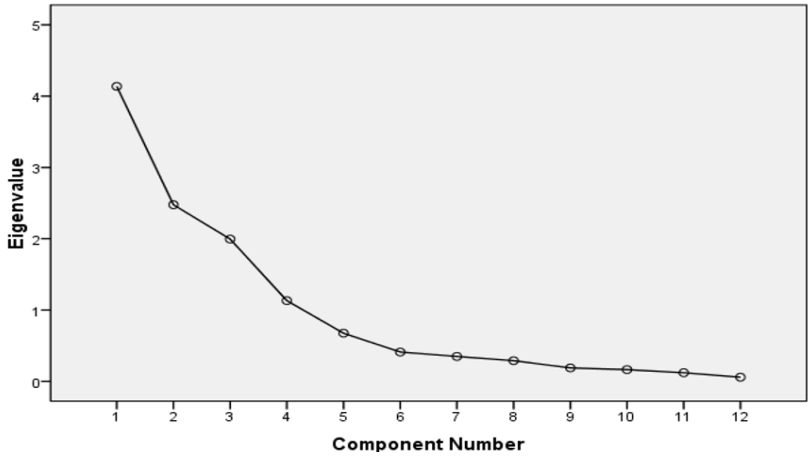

Fig. 1 Scree Plot

The analysis of responses with Kendall's Coefficient of Concordance (KCC) is shown in Table-8ai and aii.

Table-8ai Analysis Kendall's Coefficient of Concordance (KCC)

Respondents	1	2	3	4	5	6	7	8	9	10	11	12	Ri
1	9	9	8	9	10	8	9	7	8	8	11	9	105
2	7	11	10	9	9	8	9	10	8	10	9	8	100
3	9	10	9	12	8	12	10	11	10	9	11	10	121
4	8	7	9	7	8	7	7	10	9	7	9	7	95
5	8	7	9	7	8	10	7	7	9	8	8	10	98
6	10	9	9	11	10	8	9	9	11	9	11	10	116
7	10	10	8	9	11	9	10	12	11	9	11	10	118
8	12	10	11	9	10	10	9	11	10	11	10	12	125
9	10	9	9	9	11	10	11	8	12	10	9	10	116
10	11	10	9	9	9	11	10	9	9	11	10	11	119
11	11	8	9	8	8	10	7	7	7	7	3	11	96
12	10	9	8	9	7	8	8	7	8	9	11	11	105
13	10	9	9	7	9	8	7	7	9	10	9	9	104
14	11	12	9	8	9	10	11	12	10	10	11	9	122
15	10	10	9	9	8	7	7	8	9	8	11	10	106
16	8	7	9	7	7	6	7	8	8	9	8	8	92
17	7	8	7	6	7	8	7	7	6	7	6	8	84
18	8	7	8	7	6	7	8	7	7	6	8	7	86
19	9	8	7	8	9	8	9	8	8	8	8	9	100
20	8	7	9	8	6	7	8	7	7	6	8	7	89
21	7	6	5	6	6	7	6	6	6	5	6	6	72
22	7	8	8	9	6	7	8	7	7	6	7	8	89
23	8	7	9	9	7	6	7	8	6	7	8	7	91
24	7	8	9	9	6	7	8	7	7	6	8	8	92
25	9	7	9	9	7	6	7	8	6	7	8	8	93
26	8	6	7	8	6	6	7	7	6	8	7	8	84
27	7	8	8	7	6	6	7	7	8	6	8	7	85
28	7	6	7	7	6	6	7	6	7	6	7	8	79

29	11	10	12	11	10	12	11	10	9	8	9	12	125
30	12	11	12	10	12	11	12	9	9	11	10	11	130
31	15	12	13	11	13	15	14	13	14	13	14	13	160
32	16	18	16	18	21	19	17	15	15	18	14	13	200
33	19	19	20	21	20	21	22	21	21	20	23	23	250
34	16	19	17	18	21	19	17	16	15	18	14	15	205
35	19	19	21	22	20	19	22	23	21	20	23	26	255
36	17	18	20	21	19	19	22	23	22	21	22	21	245
37	22	21	23	22	22	21	22	23	20	22	21	22	261
38	15	19	17	18	21	19	17	16	15	18	14	15	204
39	16	18	20	19	18	19	20	21	22	20	19	22	234
40	19	22	20	21	19	21	22	23	22	22	22	23	256
41	23	27	24	22	24	26	23	22	23	24	23	24	285
42	25	28	25	22	25	26	26	23	24	24	23	24	295
43	27	28	26	25	22	23	26	24	26	23	24	24	298
44	27	28	26	25	23	24	27	26	27	25	24	25	307
45	29	27	27	23	25	27	24	27	26	24	25	25	309
46	29	28	29	25	24	27	25	27	24	25	26	26	315
47	28	27	23	27	25	27	27	24	26	24	25	25	308
48	21	25	26	27	25	24	27	25	27	25	24	26	302
49	23	27	27	25	27	27	24	27	25	26	25	24	307
50	22	26	26	26	28	26	25	26	26	25	24	25	305

Table-8aii Analysis Kendall's Coefficient of Concordance (KCC)

I	**R_i**	$R_i - \overline{R}$	$\left(R_i - \overline{R}\right)^2$
1	105	-201	40401
2	100	-206	42436
3	121	-185	34225
4	95	-211	44521
5	98	-208	43264
6	116	-190	36100
7	118	-188	35344
8	125	-181	32761
9	116	-190	36100
10	119	-187	34969
11	96	-210	44100
12	105	-201	40401
13	104	-202	40804
14	122	-184	33856
15	106	-200	40000
16	92	-214	45796
17	84	-222	49284
18	86	-220	48400
19	100	-206	42436
20	89	-217	47089
21	72	-234	54756
22	89	-217	47089
23	91	-215	46225
24	92	-214	45796
25	93	-213	45369
26	84	-222	49284
27	85	-221	48841
28	79	-227	51529
29	125	-181	32761
30	130	-176	30976
31	160	-146	21316
32	200	-106	11236
33	250	-56	3136

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34	205	-101	10201
35	255	-51	2601
36	245	-61	3721
37	261	-45	2025
38	204	-102	10404
39	234	-72	5184
40	256	-50	2500
41	285	-21	441
42	295	-11	121
43	298	-8	64
44	307	1	1
45	309	3	9
46	315	9	81
47	308	2	4
48	302	-4	16
49	307	-1	1
50	305	1	1
			$\sum_{i=1}^{n}(R_i - \overline{R})^2 = 1{,}337{,}976$

Computerizing $\overline{R}$

$$\overline{R} = \frac{m(n+1)}{2}$$

Where;

m= Judges= 12

n= Total object=50

$$\overline{R} = \frac{12(50+1)}{2}$$

$$= \frac{612}{2} = 306$$

But;

$$S = \sum_{i}^{n}\left(R_i - \overline{R}\right)^2 = 1{,}337{,}976$$

S=Square deviation

Computing kendall's coefficient of concordance W

Where;

$$W = \frac{125}{m^2\left(n^3 - n\right)}$$

$$W = \frac{12 \times 1{,}337{,}976}{12^2\left(50^3 - 50\right)}$$

$$W = \frac{16{,}055{,}712}{17{,}992{,}800} \cong 0.892$$

Since a value of W is closer to 1, it implies agreement.

A stratified sample of the study population was used in the survey research, depending on the sample size that was established. The respondents assigned scores to the twelve variables that were constructed. The Cronbach's alpha reliability test was used to assess the instrument's dependability. The resulting value of 0.997 indicates that the instrument (questionnaire) used has a high degree of dependability. Kendall's coefficient of concordance (W) was used to examine the respondents' ratings for agreement, and the resultant value of 0.892 indicated that the judges interviewed had a high degree of agreement.

CONCLUSION

Power utilities, governments, enterprises, and the general public all suffer from electricity theft. Despite the numerous methods used to identify and stop it, this persists. Revenue loss and load shedding are two drawbacks of power theft that can cause corporate operations to be disrupted. In this study, the effect of prepaid metering system on revenue generation using Cronbach's Alpha SPSS was successfully investigated. The results obtained from the questionnaire after statistical analysis with Crobach's Alpha Spss and Kandell Coefficient of Concordance are reliable and it showed that customers have embraced the prepaid billing metering system and that prepaid billing metering system has brought with it some advantages like making them more careful with their consumption knowing fully well that the higher the credit, the higher the debt rate. Besides, with more installation of the number of prepaid meters, revenue collection costs is expected to reduce in Okada Business District. Thus, BEDC should convert totally to prepay as well as retrofit the already installed meters on post-paid, as it will enhance its revenue collection capabilities at the same time reduce costs associated with collection and the problem of inaccurate billing.

CONFLICT OF INTEREST

There is no conflict of interest

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