VOLUME 3, 2019 ISSN: 2617-4537
DOI: 10.31058/j.data.2019.31001

Investigation on Smart Meters and Revenue Generated for a Year Using Eko Electricity Distribution Company of Nigeria as Case Study

N.T Makanjuola[1*], O.O Shoewu[1], L.A Akinyemi[1], O.D Ogunsanya[1]

[1] Department of Electronic and Computer Engineering, Faculty of Engineering, Lagos State University, Lagos, Nigeria

Email Address

tunjimakanjuola@yahoo.com (N.T Makanjuola), engrshoewu@yahoo.com (O.O Shoewu), letua034@gmail.com (L.A Akinyemi), oluwasegun.david39@gmail.com (O.D Ogunsanya)
*Correspondence: tunjimakanjuola@yahoo.com

Received: 25 October 2018**; Accepted:** 25 December 2018**; Published:** 12 February 2019

Abstract:

In the early phase of household technology, delivery of electricity is completely depended on traditional energy meters. These meters play a key role in measuring the consumption of electrical energy in individual households. The usage of these meters has been slowly declining with the advancement in technology as rapid changes has been made to encounter the problems occurred by the traditional meters. The major problem arises when habitants are unaware of their daily behavior. Monthly feedback given to the consumers is not sufficient as the consumers will not have knowledge on how much energy does the individual appliances consume. To overcome the problems of traditional electricity meters, Smart Meters have been upgraded and developed. With the use of Smart Meter data, energy alerts (signals) will be provided to the consumers based on hourly utilization of energy. The primary objective of the Smart Meters is to reduce the energy consumption in the households being installed in. This work utilizes what was obtained from Eko Electricity Distribution Company of Nigeria. The real time Smart Meter data sets are obtained from Eko Electricity Distribution Company of Nigeria?

Keywords:

Smart Meters, Advanced Metering Infrastructure, Automated Meter Reading, Home Area Network

1. Introduction

The importance of smart meters has come more sharply into focus as the market has grown. Utilities are gaining improved operations and reliability, along with reduced labour costs, while customers are becoming more engaged and in control of their energy use.

By providing near real-time information on cost and usage, smart metering will encourage consumers to reduce their demand, directly contributing to lower energy bills, energy system resilience, and carbon emission reductions. Smart metering will result in more engaged and active energy consumers and enable faster switching. This will in turn lead to a more dynamic and competitive retail energy market. Smart meters will also enable more efficient operations for both energy suppliers and network operators, unlocking savings that will translate into lower bills for households and businesses.

So, a smart meter is basically an electronic device that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing [1]. They are primarily called AMI (advanced metering infrastructure) or AMR (automated meter reading) meters. Smart Meters can be wired or wireless. The meters collect the energy usage information in very detailed format and transmit that information directly to the utility company every day, throughout the day. Wired Smart Meters send the usage data via electrical lines or telephone lines. Electric Smart Meters have a second antenna to "talk" to new Smart appliances and devices. This is called the Home Area Network (HAN). These appliances and devices, such as thermostats, air conditioning units, refrigerators, washing machines, dishwashers, and various sensing units are outfitted with 2-way transmitter/receivers which send to and receive information from the Smart Meter throughout the day.

To overcome the problems of traditional electricity meters, Smart Meters have been upgraded and developed. With the use of Smart Meter data, energy alerts will be provided to the consumers based on hourly utilization of energy. The primary objective of the Smart Meters is to reduce the energy consumption in the households. My thesis utilizes real time Smart Meter data sets obtained from Eko Electricity Distribution Company of Nigeria.

1.1.Statement of Problem

The government of Lagos state has a goal to install smart meters in all houses in the state within the next five years. Despite the government officials efforts, there is a slow growth in the installation of smart meters in Lagos state. As at February 11 to April 10, 2016, just about 5,400 electricity consumers in Ijora, Festac, Iponri, Orile, Masha, and Mushin Town of Lagos State have acquired new smart meters designed to replace the old prepaid meters [2]. Need therefore arises to investigate why, despite the Government efforts, there is no persistent deployment of smart meters across Towns in Lagos State.

Following are a few potential sources that may create a variance on your electric billing statement:

Lifestyle: The size of your household has increased or you have had guests stay for an extended period. You added features to your home that require additional electricity, such as a whirlpool or hot tub. Hobbies that include the use of power tools, ovens and other high electrical resistance tools or appliances are being used.

Lighting, refrigeration, appliances and cooking: These account for approximately 56% of the average total energy usage in the normal household. Using the computer, stove, hot water, hair dryer or washing machine and clothes dryer for extended periods of time will increase your kWh usage. During winter months, use of lighting in your home increases. The location of refrigerators and freezers is very

important. Never place a refrigerator or freezer in direct sunlight or in an unfinished space such as a breezeway, garage or out-building. The refrigerator or freezer will have to work harder to overcome the excessive heat in the spring, summer and fall. Be sure that refrigerators and freezers have adequate ventilation.

Equipment maintenance: The average 50-gallon electric water heater runs about 3 hours per day every day, and uses 410 kWh per month. However, during cold winter months, heat loss from the tank and colder water flowing into the tank can result in higher usage. An insulation jacket can make a difference. Water heaters can also be overworked if the thermostat is set too high or not working properly. It is important to clean or replace the condenser, coils or filters on your appliances regularly. You may need to replace the appliance itself. Many times old electrical wiring will have loose connections, resulting in increased electrical usage and creating potential safety hazards.

Seasons: The additional heating or cooling load will cause an increase in electric usage. Heating and cooling processes account for approximately 44% of the total energy usage of the normal household. Electrical inefficiencies can also be traced to space heaters, improper use of extension cords, damaged cords, faulty wiring, or lightning damage. Electric water-pressure pumps will run overtime if there are underground water leaks or pressure tank problems. The use of electric fireplaces, livestock heaters or vehicle block heaters in the winter can dramatically increase your energy consumption. Running a dehumidifier or watering lawns, gardens and animals in the summer months will increase your energy usage.

Weather: Lightening may have damaged the well pump, sump pump or appliance, increasing the running time of the pump or appliance. If underground wiring or insulation is damaged, an increase in electrical usage may occur when the ground is saturated with moisture.

Hidden users: Keep an eye out for other hidden users of electricity in your home that you have added in the past month or the past year. Think of whether you had house guests using more hot water, a construction project, or other out-of-the-ordinary activity that may have bumped up your usage for that month. Has there been any underground excavation recently? If you have underground wiring, the electric wires may have been nicked, resulting in a direct short.

1.2.Literature Review

In the past years, a lot of research works have been carried out to analyze smart meter and its benefit to the society. The American Council for an Energy-Efficient Economy reviewed more than 36 different residential smart metering and feedback programmes internationally. This is the most extensive study of its kind (January 2011). Their conclusion was: "To realize potential feedback-induced savings, advanced meters (smart meters) must be used in conjunction with in-home (or on-line) displays and well-designed programmes that successfully inform, engage, empower and motivate people". There are near universal calls from both the energy industry and consumer groups for a national social marketing campaign to help raise awareness of smart metering and give customers the information and support they need to become more energy efficient, and what changes they must make to realize the potential of proposed smart meters. These devices (i.e. smart meters) are being introduced in many power systems world-wide to provide real time power consumption and price information to consumers. Previous systems [3,4,5], which

utilized one-way communications to collect meter data, were referred to as AMR (Automated Meter Reading) Systems.

The world's largest smart meter deployment was undertaken by EnelSpA, the dominant utility in Italy with more than 30 million customers [6,7,8]. Between 2000 and 2005 Enel deployed smart meters to its entire customer base. These meters are fully electronic and smart, with integrated bi-directional communications, advanced power measurement and management capabilities, an integrated, software-controllable disconnect switch, and an all solid-state design. They communicate over low voltage power line using standards-based power line technology from Echelon Corporation to Echelon data concentrators at which point they communicate via IP to Enel's enterprise servers. Demonstrating that with power line communication, smart meters don't require WiFi radios [9,10,11].

The system provides a wide range of advanced features, including the ability to remotely turn power on or off to a customer, read usage information from a meter, detect a service outage, change the maximum amount of electricity that a customer may demand at any time, detect "unauthorized" use of electricity and remotely shut it off, and remotely change the meter's billing plan from credit to prepay, as well as, from flat-rate to multi-tariff [12,13,14,15].

However, this study focuses on the investigation of smart meters and revenue generated for a year, using Eko electricity Distribution Company as a case study, where data from Ibeju-lekki business unit are considered.

2. Research Methodology

This chapter deals with the statistical methods used for the study and includes study area, population and sampling techniques, data collection procedure, research instruments and data analysis.

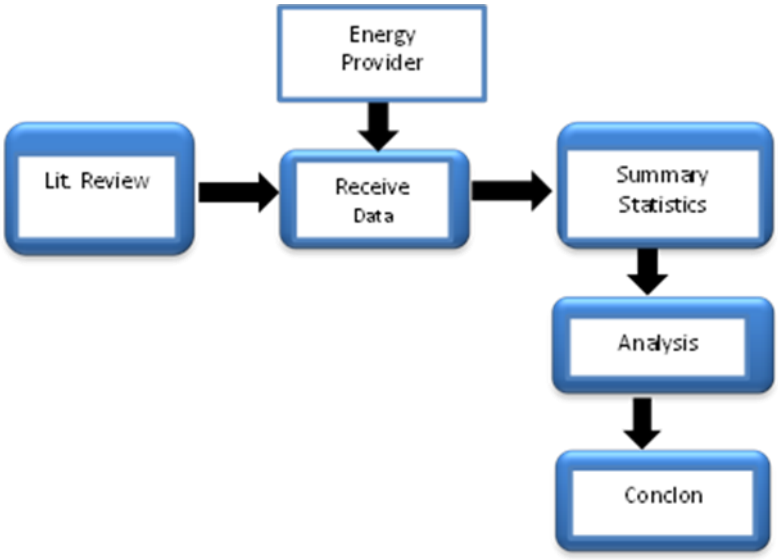

Figure 1. *Flow of Research Methodology.*

The data which is measured using Smart Meters is obtained from an energy provider. The results which are obtained from data are plotted in the form of graphs and observations are done regarding the consumption, price-cost of the household and further statistical analysis. Particularly, in this stage, the results are statistically summarized from the received data. The flow of research methodology is shown in Figure 1.

2.1. Study Area

Stratified sampling method was used for this study. The customers in Lagos East Region were stratified according to the types of consumers (that is domestic and commercial). Samples were drawn from each strategically and proportionately until the intended sample size was reached.

2.2.Population And Sampling Techniques

The project sampling was conducted in Lagos East Region (i.e Ibeju-Lekki), which is made up of districts like Badore, Awoyaya, Lakowe, Abegede, Araromi etc. Simple random sampling method will be used to select one of the business units for the study.

The Yamane's simplified formula was used to calculate the sample size for the study. It is identified as:

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

Where
n: sample size

N: Total population for a business unit

e: The precision (0.05)

Therefore, the sample size chosen from a district for the study was 393 EKEDC residential customers.

2.3.Case Study

An analysis of data involving a method of research is called case study. Some stepshad been followed in the case study of this research. The steps are as follows:

1) In the first step of our study, the Smart Meter data is obtained from a local energy distributor, that is, Eko Electricity Distribution Company (EKEDC).

2) This received data is then evaluated and analyzed. Smart Meter data is a validated one as it is obtained from an energy utility distributor.

3) The received data contains two sets of Microsoft Excel sheets.

4) After reading the data, we need to interpret the real Smart Meter data in a new Excel sheet. In the formulated sheet we arranged months, price, energy consumption and calculation of cost is determined.

5) Based on the results obtained, graphs are plotted for months versus consumption (KWh), months versus price, and months versus Revenue. The month is plotted on the x-axis and consumption is plotted on the y-axis for time-consumption graph; time on the x-axis and price on the y-axis for time-price graph; time on the x-axis and cost on the y-axis for time-cost graph; 6. The above computed steps are repeated for the first nine months in a year.

6) Finally, flattening of the consumption pattern is observed.

7) By performing the above steps, case study is successfully implemented.

2.4.Data Analysis

Based on the systematically analyzed data, the graphs are drawn as follows. The selected graphs are displayed in the report as the data is interesting.

1) Energy consumption graph of some households are shown in the below figures by considering consumption (KWh) on the y-axis and Months on the x-axis.

2) The graph showing the revenue generated from the Non-smart meters and Smart meters is given below by considering Revenue (₦) on the y-axis and Months on the x-axis.

3) Price graph is shown in the below figure by considering price on the y-axis and Months on the x-axis.

The Figure 2 below shows the energy consumption of the households in the selected business unit, that is, Ibeju-lekki, for the Smart and Non-smart meters. This shows that more households are still using Non-smart metering systems in their houses. In the diagram below, the x-axis illustrates the month and the y-axis illustrate the amount of energy consumed very month.

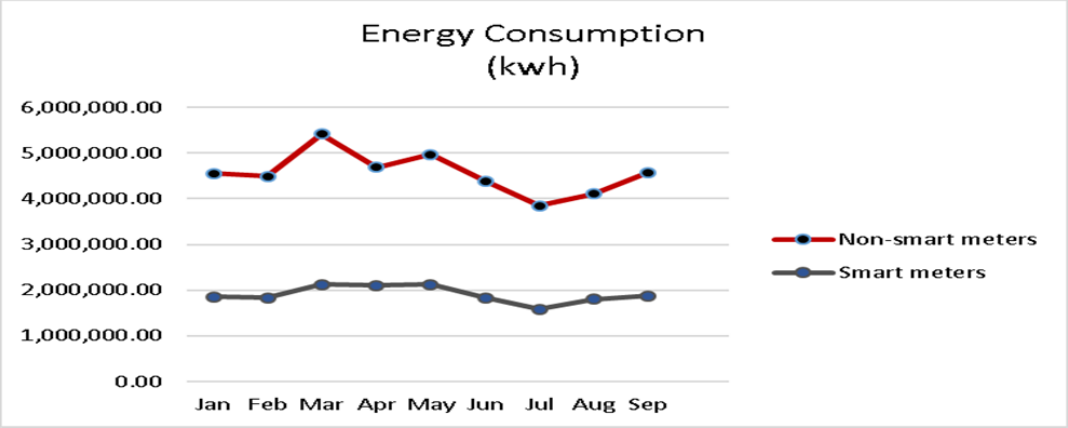

Figure 2. *Energy Consumption.*

The Figure 3 below indicates the differences between the pricing of energy of the selected business unit and how it affects the consumption of energy in this area. The pricing varies for the months in both Smart and Non-smart metering systems, but the average pricing, ₦29.78 and ₦27.88, shows that the smart system of metering is costlier compared to non-smart system of metering.

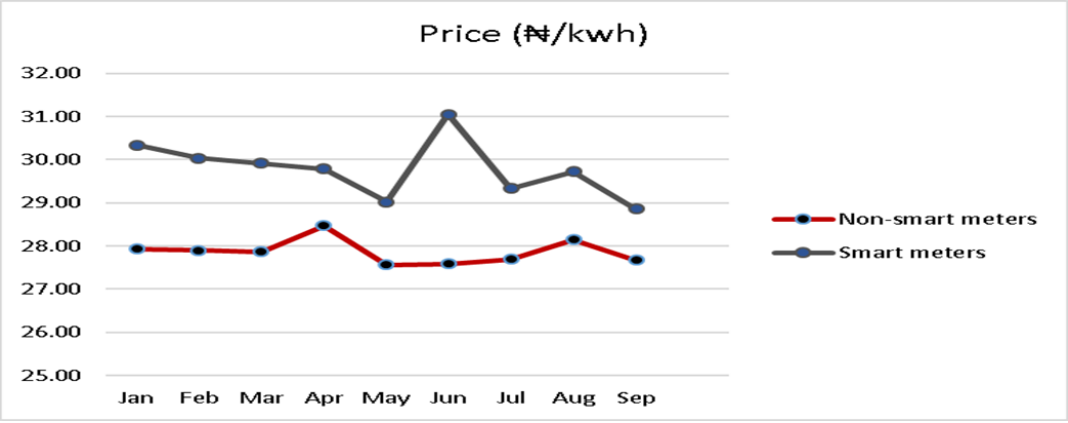

Figure 3. *Price (₦/kwh).*

There is so much difference between the revenue generated from the smart system of metering and non-smart system of metering.

From the Figure 4 below, the revenue generated from the non-smart system metering in each case is double of that of smart metering system.

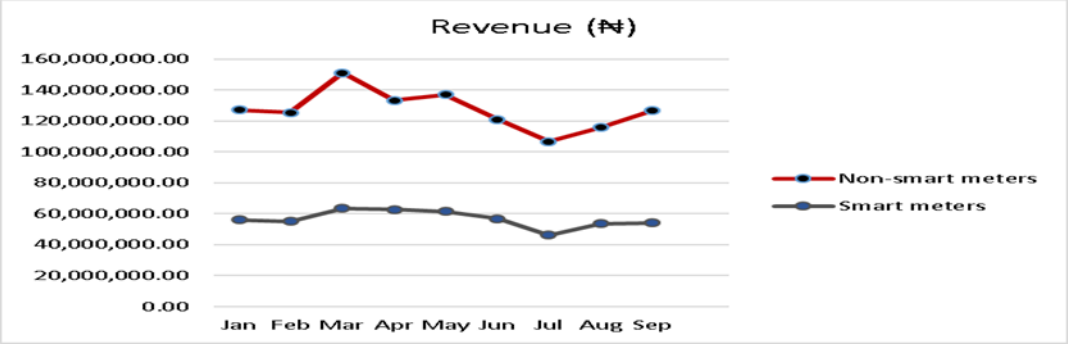

Figure 4. *Comparison of Revenue Generated from Smart and Non-smart meters.*

3. Analysis, Discussion and Representation of Results

This session presents analysis on the data collection for the study. It relates to determining customer perception and acceptability on the use of smart metering systems, factors customers consider before accepting smart meters and ECG managements 'strategies in promoting the use of smart meters. The socio-demographic characteristics of respondents are first analyzed to help understand customers 'perception and attitudes in accepting smart meters.

Table 1. *Socio-demographic characteristics of respondents.*

Age of Respondents	Frequency	Percentage
20-29	65	16.5
30-39	184	46.8
40-49	120	30.5
50-59	24	6.1
Total	**393**	**100**

3.1.Socio-Demographic Characteristics

The following socio-demographic characteristics were considered; Age and level of education.

3.1.1. Age of Respondents

The analysis on the age of respondents indicated that majority of the customers (46.8%) are between the ages of 30-39 years. This is followed by customers in the age group of 40-49 years and they constitute 30.5%. Customers between the age group of 50-59 years were found to have the least representation of 6.1%. The details are presented in table 4.1 below:

3.1.2. Level of Education of Respondents

The study found that the level of education of respondents was generally high in the study area. It was found that as high as 33.5% of the respondents has tertiary level education and this is followed by 28.7% of those who have secondary level of education with only 12.2% having no formal education. 25.4% of the respondents however had primary education. The details are found in Table 2 below.

Table 2. *Level of Education of Respondents.*

Level of Education	Frequency	Percentage
Primary	100	25.4
Secondary	113	28.7
Tertiary	132	33.5
No Education	48	12.2
Total	393	100

3.1.3. Customers' Perception on Acceptability of Smart Meters

The perception customers hold on any new product being introduced directly or indirectly will affect whether such productwill be patronized by customers or not. Based on the background, customers of EKEDC Lagos-east Region's perception were explored and the findings are presented in Table 3 below.

Table 3. *Customers' Perception on Acceptability of Smart Meters.*

Customers' perception on acceptability	Frequency	Percentage
Very acceptable	48	12.2
Acceptable	52	13.2
Fairly acceptable	185	47.1
Not acceptable	48	12.2
Indifferent	60	15.3
Total	**393**	**100**

From table 3 above, it was found that a very small percentage of customers (12.2%) indicated that the introduction of smart meters is very acceptable. Thereasons for this is that they can now regulate their energy consumption and only buy what they need at a time. Again, the customers felt it was very acceptable because no bills will be brought to them any longer and field officers will no longer embarrass them with disconnection of power supply for their inability to pay their bills on time. The study further found that with the introduction of the smart meters, the services of meter readers will not be needed. As such, fraudsters who pose as EKEDC meter readers can no longer intrude their premises. Some customers perceive the introduction of the smart meter as fairly acceptable and they constituted 47.1%. They are of the view that when EKEDC is able to purchase durable smart meters and train enough field officers to respond promptly to customers 'demand in relation to the use of the smart meters, the services will be acceptable. It was also found that when accesses to vending points are improved and the units can be bought anytime of the day even in the night, can convince customers to accept the use of smart meters. From the above, it can be concluded that majority of the respondents think that the use of smart meters is not acceptable because of the numerous problems associated with it. They also think that the old post-paid meters do not give customers a lot of problems as compared to the smart meters and as such the old post-paid meters is preferred to the prepaid meters.

3.2.Factors Customers Consider Before Accepting Smart Meter

Customers are known to be rational as such take into consideration a number of factors before making a decision on whether to accept and use a facility or a product or not. When customers identify that there is more merit to be gained, all things being equal, they accept and use the product or facility. Based on this background, the researcher wanted to determine the factors that influence customers 'acceptability and use of smart meters. The details are summarized in Table 4.

From Table 4, it was identified that the main factors customers consider before accepting a smart meter is the reliability of the meter. This constituted 38.4% of the respondents. Most customers have the perception that the old post-paid meters are very durable and can be fixed for over 25 years without developing any fault. In contrast, meters installed are not durable. It was found that a major lightning strike or a power surge normally causes the smart meters to be faulty. Based on this and the fact that EKEDC at one time replaced a brand of smart meters with another on the basis of durability has made most customers very sceptical about the acceptance of the smart meters. The study also found that most often the meters trip-off or the smart meter purchased card becomes faulty and makes it difficult for customers to upload units bought onto the meter and thereby causing a lot of inconveniences to customers. This situation makes some customers unwilling to accept smart meters for fear of its durability. The perception that the smart meters are not strong causes some customers to always think about how to repair them when they become faulty without inconveniencing themselves. Inferring from the above, customers consider a lot of factors before accepting the smart meters for use. Among the common factors considered are the reliability of smart meters, user friendliness, and access to prepaid vending points.

Table 4. *Factors Customers Consider Before Accepting Smart Meters.*

Respondent	**Frequency**	**Percentage**
Reliability of smart meters	151	38.4
User friendliness of smart meters	83	21.1
Durability of smart meters	64	16.3
Accessing to prepaid vending points	40	10.2
Cost of installation of prepaid meters	34	8.7
Availability of technicians to repair faulty smart meters	23	5.9
Total	**393**	**100**

3.3.Management Strategies in Promoting Customer Acceptability of Smart Meters

Management has adopted a number of strategies for promoting customers‘ acceptability of smart meter. The summaries of this are presented in Table 5.

Table 5. *Management Strategies in Promoting Customer Acceptability of smart Meters.*

Respondent	Frequency	Percentage
Education of Benefits of smart meters	162	41.2
Free installation	82	20.8
Installation of durable smart meters	61	15.5
Increase vending point	57	14.5
Establishment of Emergencies response team	31	7.8
Total	**393**	**100**

From Table 5 above, it was found that embarking on public education on the benefits of smart meter was the main strategy used by management to promote the acceptability on the use of the smart meter. The Marketing Section in conjunction with the prepaid section undertook a number of public educational programmes in the form of community durbars and public announcement on the importance of smart meter. The study found out that all these educational programmes were undertaken prior to the installation of the smart meters. Installation of durable smart meters is another strategy management adopts in promoting smart meter usage (15.5%). It was

found that before the introduction of the use of any type of smart meter, the Research and Development unit undertakes a thorough study on the durability of the smart meter before its use. All these feasibility studies are to ensure that the meters provided to customers are durable, and this measure is to help avoid a situation where after installation, a major defect will be identified such that these meters are recalled. Management has adopted a number of strategies for promoting customers' acceptability of smart meters and the main strategy include public education on the benefits of smart meters, the installation of smart meters and the installation of durable smart meters.

3.4.Summary on Findings

The study examined customers' perception and acceptability on the use of smart meter in Lagos East Region of EKEDC. The aim of this study was to improve customer acceptability by determining the level of acceptability of smart meters, analyze the factors customers consider before accepting the use of smart meter, and determine management strategy in promoting smart usage. Research design adopted for the study was the descriptive method. Both primary and secondary sources of data were used with questionnaire as the main instrument for collecting primary data on customer acceptability, factors customers perceive before accepting the use of smart meters.

4. Conclusions

The conclusions to be drawn were shaped by the following findings of the study:

1) The education level of those using smart meters in Lagos East Region are high with majority of them having tertiary level education. This is due to the fact that these categories of people understand the benefits to be derived from the smart meters as against the old post-paid meters. Hence then high level of acceptability among such customers.

2) Majority of customers have used smart meters between one to two years and based on its have a clear understanding of how the smart meters' work.

3) There is a general perception that smart meters are fairly acceptable to customers in the study area because of problems associated with user friendliness and durability of the smart meters being installed.

4) Customers consider a number of factors before accepting the smart meter. The main factors include reliability of the smart meters, user friendliness, durability and access to smart metering vending points. These inherent characteristics promote the usage of the smart meters since the availability of these makes the prepaid convenient for use.

5) The main strategies management adopt to promote customer acceptability of smart meters include education on the benefit of using smart meter, installation of durable smart meters, free installation and increase of vending points.

6) A minor strategy being adopted by management in promotion of customers' acceptability of smart meters is the establishment of an emergency response unit and the recruitment of more field officers in order to address all technical issues customers may have promptly. From the above, it can be concluded that majority of the respondents have the perception that the use of smart meters is not acceptable because of the numerous problems associated with it. Key among such problems are issues concerning cost of installation, friendliness of the smart meter, durability and reliability.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Recommendations

There is general perception that smart meters are fairly acceptable to customers in the study area. This perception suggests that the acceptability level is quite low. As a result of this management should intensify public education as well as improve on the efficiency of smart metering services in order to increase the acceptability level of customers by addressing their concerns in terms of installing durable and reliable smart meters also acquiring smart meters that are user friendly and increasing smart meter vending points [16].

Customers consider a number of factors before accepting the use of smart meters. Among the key factors are the user friendliness, durability and access to prepaid vending point. It is therefore necessary that management improves on such factors in order to improve the acceptability on the use of the smart meters. Management should not only rely on major strategies of promoting acceptability such as education on benefits on the use of smart meters, free installation, increase vending points but should also emphasized on the need to establish an emergency response unit that will attend to all technical emergency issues relating to prepaid metering issues promptly.

References

[1] Amit, J.; Mohnish, B. A prepaid meter using mobile communication. *International Journal of Engineering, Science and Technology*, 2011, 3(3).

[2] Arthur, B.W. Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal*, 1989, 99.

[3] Brown, R. E. Electric Power Distribution Reliability,1st ed.;Taylor &Francis Group, Boca Raton, 2002, 1-380, ISBN: 9780824744281.

[4] Burger, et al. Functional Specification for a Common Vending System for Electricity Dispensing Systems, Measurement and Control Department, National PTM&C Transmission Group, Eskom, 1992.

[5] Burke, J. J. Power distribution engineering: Fundamentals and applications, M. Dekker, 1994,1-347, ISBN: 978-0-8247-9237-4

[6] Burke, J.J. Power Distribution Engineering: Fundamentals and Applications, Marcel Dekker, 1992.

[7] Carlson, W. B. Innovation as a Social Process: Elihu Thomson and the Rise of General Electric, Cambridge University Press, 2003

[8] Carlsson, B. Technological Systems and Economic Performance: The Case of Factory Automation, Dordrect, 1995.

[9] Chandler, T. The technology development of automatic metering and monitoring systems, Power Engineering Conference, IPEC, 2005.

[10] Chartwell .Energy watch, Get Smart: Bringing Meters into the 21st Century, 2003, Available online: http://www.energywatch.org.uk/uploads/Smart_meters.pdf (accessed on 25 October 2018).

[11] Chartwell, Prepay Metering‘s Impact on Customer Energy Usage, Mark Hall, Webinar, 2008.

[12] Chartwell; Carolyn, J. Presentation on Salt River Project‘s prepayment solution, Webinar, 2008.

[13] Chartwell; Jonna, B. Prepaid Experience, Oklahoma Electric Cooperative, Webinar, 2008.

[14] Chartwell . Prepaid Metering Report, 4th ed.; 2007.

[15] Md, J. I. M.; Surojit, G. IoT based Automatic Electricity Monitoring and remote Load Control System Using PIC 18F4550. IEEE 9th ICCCNT, 2018, DOI: 10.1109/ICCCNT.2018.8494030.

[16] Geyong,Y; Hao, Z; Qijun, C. A Wireless Automatic Meter Reading System Based on Digiatal Image Process and ZigBee-3G. IEEE ICSSSE, 2014. DOI: 10.1109/ICSSE.2014.6887919.