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Quality Cost Appraisal of Locally Manufactured Distribution Cables with Rising Trend of Electrical Fire Outbreak in Nigeria

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ABSTRACT

This study assessed the sustainable parameters of electric distribution cables produced in Nigeria to aid the elimination of hazards associated with overheating of inferior cables in this country. This involved sampling of different gauges of fore brands (Wesco, Cutix, Scan and Coleman) of Nigerian made house wiring/installation cables from major industrial markets of his nation and testing them for conformity with NIS and IEEE specifications. The gauge/cross sectional area of cables investigated ranges from 1mm^2 to 16mm^2 while resistivity, elongation, flame retardant, tensile strength constitutes quality indicators evaluated with prevailing market prices cost in Nigeria within November 2021. Results showed that the four cable brands appraised conformed to set standards for tensile strength, resistivity, and flame retardant with Cutix cables exhibiting top profiles. Wesco, Cutix and Coleman cables exhibit low smoke and fume while scan revealed low smoke and halogen free cable burning features. Coleman cable showed a linear relationship in the elongation curve while Wesco, Cutix and Scan tend to follow the plasticity profile. Thus, proper care must be taken during installation of Coleman cables to avoid damage to the cable surface. Cutix cables are most expensive among all gauges due to their high copper content of their conductor material compared to other sampled brands.

1. INTRODUCTION

The escalating trend of electrocution, overheating of electrical appliances and fire outbreak in Nigerian homes and business places called to question the claim that Nigerian made electrical cables are ahead of the set standard curve. This is due to unabated hazards attributed to overheating of electrical cable despite ever increasing high patronage of distribution cables produced in this country. Although, Iroegbu-Chikezie (2014) reported importation of substandard electrical cables in this country as prime to this menace, the works of Berhard (2017), Egwuagu and Nwankwojike (2019), Obukoeroro and Uguru (2021) never exonerate resident cable manufacturers in Nigeria. According to Berhard (2017), scrupulous manufacturers who skimp on quality and safety to produce cheaper cables caused the influx of substandard cables in the Nigerian market. Egwuagu and Nwankwojike (2019) study, revealed high profile short practice in the production and marketing of 1mm^2, 2.5mm^2,

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and 4mm^2 electrical cables by some local manufacturers and marketers due to high demand of them in house wiring and installation. Obukoeroro and Uguru (2021) exposed the substandard nature of these highly demanded gauges of electric power distribution cables in Onitsha markets.

The experimental evidences of Nimlyat *et al.* (2017), Egwuagu and Nwankwojike (2019), Obukoeroro and Uguru (2021) lend to the reports of faulty electrical cables as significant cause of multisystem morbidity, mortality and loss of properties. Oludiran and Innih, (2011) attributed significant cause of electrical burns due to faulty electrical cables while Iroegbu-Chikezie (2014) linked frequent fire outbreak at homes and offices in Nigeria to the use of inferior quality or substandard electrical cables for electricity distribution and wiring applications. Duru, (2015) reechoed Niger State government position that electrical faults accounted for 60% of fire related disasters across the state between January to December 2012. In May 2014, family at Mushin, Lagos State lost all their personal belongings in an electrical fire which was said to originate in one of the wall outlets (Adekunle *et al.*, 2019). In addition, electrical sparks were reported as the cause of fire which damaged properties worth millions of Naira at Nigerian Telecom's building situated at Lagos and federal civil service secretariat, Abuja (Triumph, 2015; Lauryn, 2017).

These incident reports contradicts Adetoro (2012) which showed that five highly demanded brands of Nigerian made cables conform to the Nigerian Industrial Standard (NIS) for single core 1.5mm^2, twin core 2.5mm^2 and three core 2.5mm^2 electrical cables at 95% confidence interval for the mechanical and electrical properties. Since none of these conflicting records of Nigerian made electrical cables neither sampled all gauges of electric power distribution cables from substantial region/states of this nation nor assessed all the quality indicators of the cable brands, there is need for reassessment of the cables' quality with matching cost. This because conformance to set standards as essential for of electrical cables to conduct electricity efficiently, safely and cheaply while Lewachi (2021) showed cost as first among the prime factors affecting the demand of each cable brand. Thus, this study assessed the technical and economic viability of electric power distribution cables manufactured in Nigeria to aid relevant authorities in taking decisive actions to eliminate hazards associated with the use of inferior electrical cable in this country.

2. MATERIALS AND METHODS

This study involved sampling of four brands of Nigerian made electrical cables mostly used for home and workplace wiring in Nigeria from three major industrial markets in each State of Nigeria and Abuja. The cable brands include Wesco, Cutix, Scan and Coleman with cross sectional area of 1mm^2 to 16mm^2 while resistivity, elongation, flame retardant and tensile strength constitute the evaluation parameters. The experimental quality assessment of the specimen cables was conducted at the Quality Control and Assurance Laboratory of Wesco Cable Nigeria Limited, Ogun state in Nigeria. This involves conductor tensile strength, conductor material resistivity, insulating material elongation and flame retardant tests. Thereafter, the mean values of these parameters obtained as per each brand cables were analyzed and compared using Analysis of Variance (ANOVA) for conformity with Nigerian Industrial Standard/International Electrotechnical Commission (NIS/IEC) and Institute of Electrical and Electronics Engineers (IEEE) specifications. The cost of the cables were comparatively analyzed using the prevailing local and international market prices in November 2021.

The tensile tests were conducted using a XHET 2000 microcomputer tensile testing machine in accordance with IEC 60228 and IEC 17025 procedures. A bare copper conductor specimen stripped from each sampled cable of length 30cm was fitted in-between the jaws of the tensile test machine by means of grips. One end of the conductor test specimen was fitted to the stationary knob while the other end was attached to a movable knob. The digital tensile test machine is switched on and it stretches the cable gradually and uniformly from zero. The rate of separation of jaws of the tensile test machine was carried out at 100 mm per minute until the tensile test specimen was fractured and the machine automatically stops. The breaking load is noted down from the digital display of the tensile testing machine, and the tensile strength (σ) was calculated using equations (1) while the percentage elongation (l) was determined using equation (2).

$$\sigma = \frac{F}{A} \quad (1)$$

$$l = \frac{l_2 - l_1}{l_1} \times 100 \quad (2)$$

Where F is the breaking load(N), A is the cross-sectional area(mm^2), d is the diameter of the conductor (mm), l_2 and l_1 are the elongated length and original gauge length of the specimen. The test was repeated for the five brands and five specimens of each brand respectively.

The conductor resistance test based on with IEC 60028 method applies in this investigation while ZDCY intelligent resistance tester/SC 7032 general conductor resistance fixture constitutes the apparatus used. A copper conductor specimen stripped from each sampled cable was clamped unto the resistance bridge of the resistance tester and current is applied to the conductor material. The resistivity of the copper sample was read from the electronic display of the testing machine and recorded. The insulation material elongation tests were carried out using XHET 2000 elongation tester and in accordance with IEC 60189 -3 method. The insulation material coating of the cable was stripped from the conductor material and 30cm of the test specimen was positioned between the jaws of the elongation tester. One end of the specimen was secured to the stationary knob while the other end was attached to an adjustable knob. The elongation testing machine was switched on and the dial of the elongation tester was pre-set to zero and the testing was initialized. The insulating material was pulled (stretched) till it ruptures and the process was stopped. The distance between the initial position of the adjustable knob and the final position of the knob gives the value of the elongation and it is read from the electronic display. The process was repeated for the cables and sizes sampled.

The flame retardant tests were based on IEC 60695 procedure using a flame test apparatus. A cable specimen of approximately 60cm was mounted vertically using two clamps after which a predefined flame was applied to the bottom end using a flame torch for a period of 60 minutes and at an angle of 45^{o}. The area affected by the fire was measured using a metre rule and the unaffected area was also measured. The duration it took the cable to burn out after the flame was removed was timed and recorded. The electrical cable sampled passes the test if the burning cable extinguishes itself after the flame has been removed and the fire damage is at least 50mm from the upper mounting clamp. The test was repeated for all the cables brands and sizes sampled in this work.

3. RESULTS AND DİSCUSSİON

This investigation showed that manufacturers of all the cables sampled used copper and polyvinyl chloride (PVC) as electrical conducting and insulation materials for their production. This observation tallies with Egwuagu and Nwankwojike (2019) which reported copper and PVC as conductor and insulation materials mostly used for producing house wiring cables in Nigeria because copper has significantly lower specific electrical resistivity than aluminum. Resistivity is a property of materials which quantifies how strongly a given material opposes the flow of electric current. A low value indicates that the material readily allows the movement (flow) of electric charge with little tendency of overheating/flaming. Comparative analysis shown in figure 1 depicts that the resistivity all brands and gauges of electrical cables studied are less than the specified maximum permissible values as per each gauge. Consequently, the tested cables offered little obstruction to the flow of electric current and therefore suitable for various household and office applications.

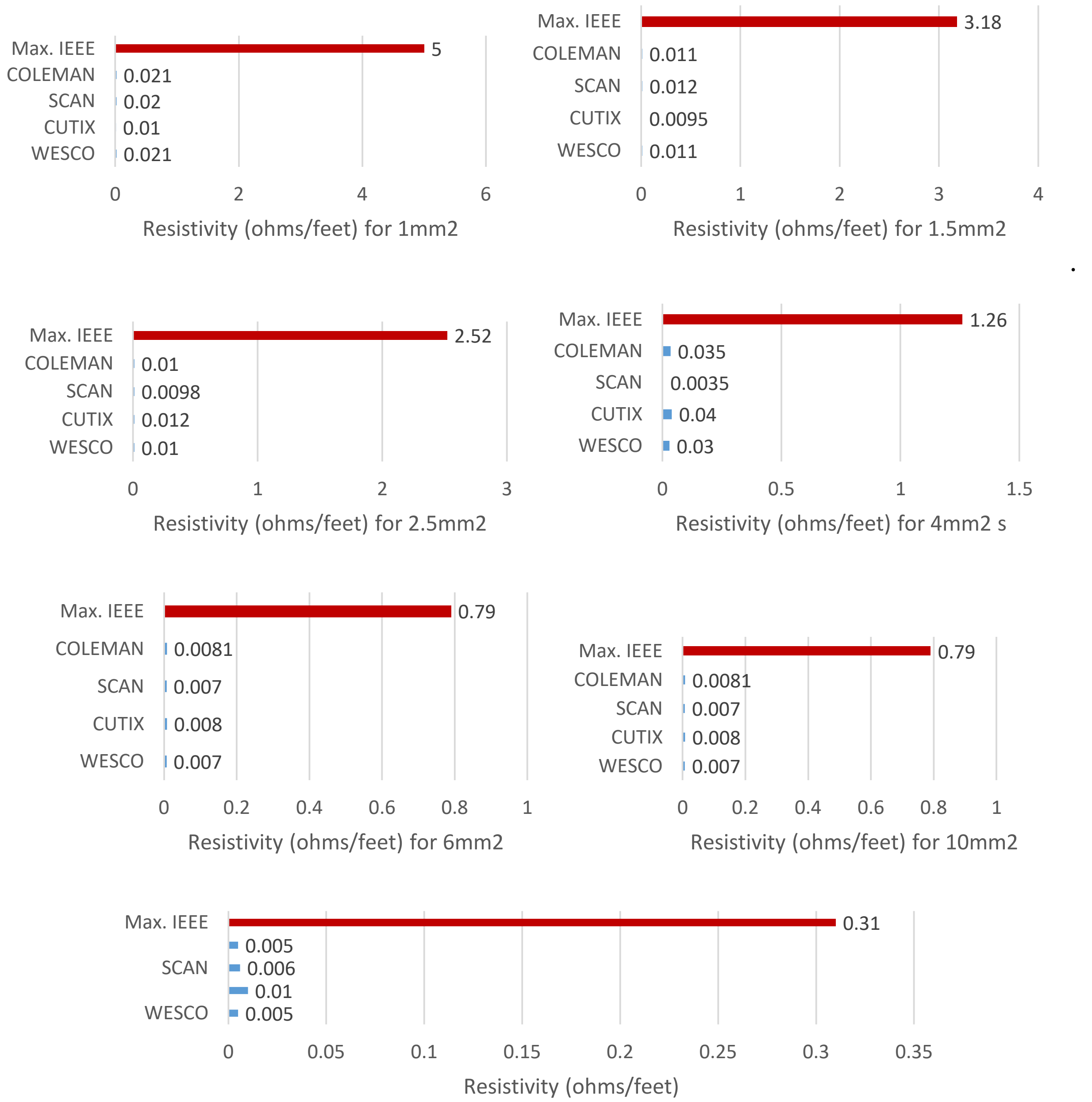

Figure 1: Resistivity Profiles of Nigerian made brands of electrical cables

The analysis of burn out time recorded from flammability test of cables shown in figure 2 indicates that all brands and gauges sampled meet the minimum requirement of 60seconds self- extinguish time as for all brands and sizes sampled, the burn out time were less than 60 seconds.

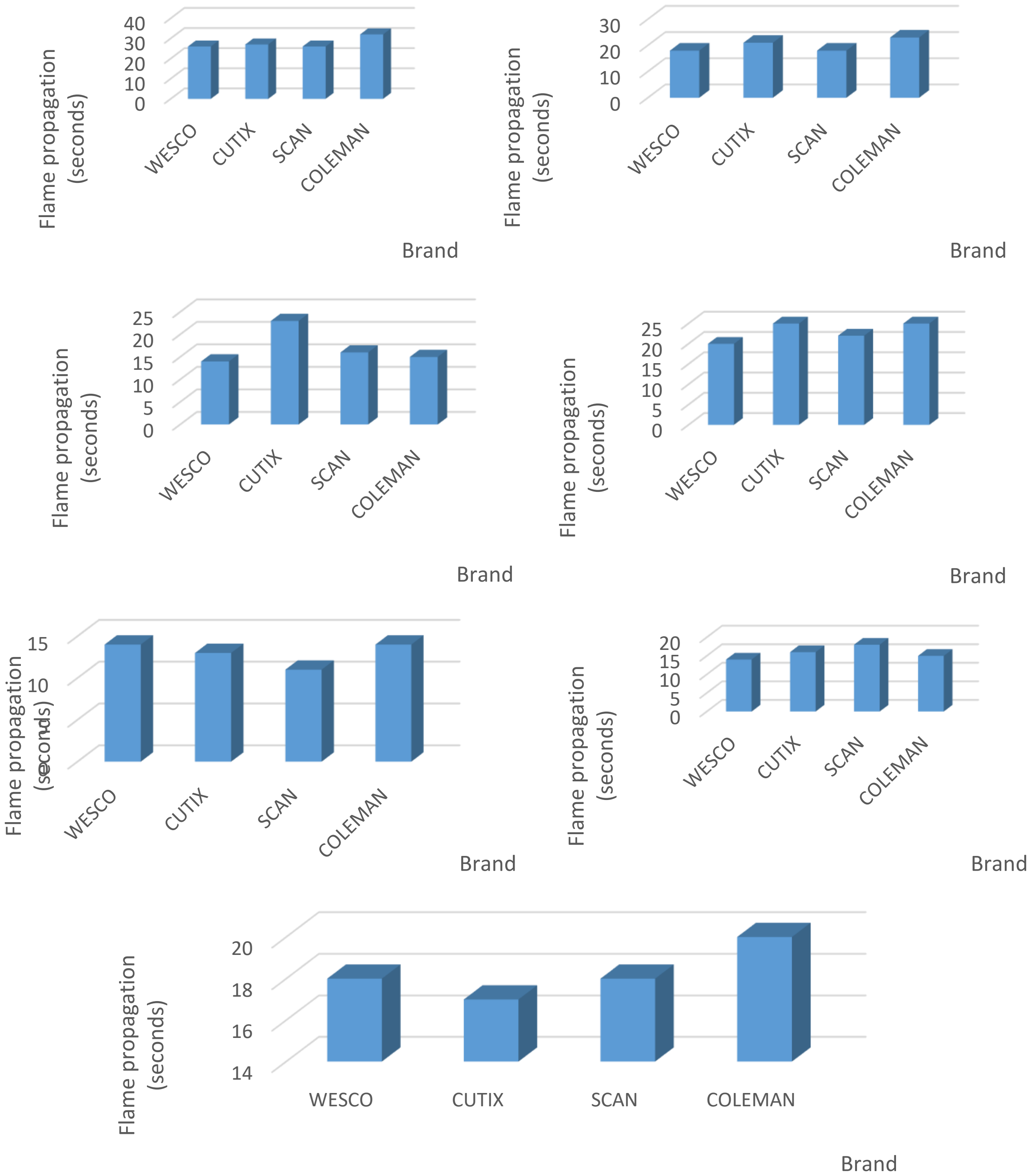

Figure 2: Flame propagation profiles of Nigerian made brands of electrical cables

It is obvious from the plotted graphs in Figure 2, that 1mm^2 Coleman cable has the highest burn out time which stood at 30 seconds while Wesco cables has the least burnout time at about 23 seconds. Coleman cable also maintained the leading burn out time for 1.5mm^2 gauge followed by Cutix cable while Scan cable had the least self- extinguish time. However, the performance of 2.5mm^2 Coleman cable increased remarkably as its burn out time reduced drastically to about 14 seconds for 2.5mm^2 size while 2.5mm^2 Cutix cable performed uncharacteristically as it depicts the highest burn out time, even though it is within the set standard. This trend continued for the 4.0mm^2 sizes where Coleman and Cutix had the highest burn out time with Wesco and Scan cables trailing with minimum burn out time for this cable size. Scan cable takes a lead with the least burn out time for $6mm^2$ cable size. This impressive performance by the sampled Nigerian cables to self- extinguish within the recommended time is commendable, however, it was observed that Wesco, Cutix and Coleman cables exhibited low smoke and fume while burning and can be classified as LSF (low smoke and fume) cables. The cables burned with formation of dense black smoke and a toxic gas presumed to be hydrochloric gas was perceived and, the ashes formed did not ignite the cotton at the bed of the flame test apparatus. Scan cable burned clearly with less flame and low smoke. The scan cable can be classified as LSHF (low smoke and halogen free) but it had a foul smell while burning with little ash formation and small amount of white smoke was observed. Cutix cable outperformed other sampled brands for $16mm^2$ and had the least burn out time of about 17 seconds while Coleman cable had the highest burn out time of about 19 seconds.

The average tensile strength of all cables' brands/gauges studied shown in table 1 met the set standard of $12.5N/mm^2$ – $25N/mm^2$. However, Cutix cable exhibited best tensile strength and can withstand more pressure (pull) during service without fracture. The tensile strength of cable sizes $6mm^2$ – $16mm^2$ were relatively low as compared to the $1mm^2$ - $4mm^2$ cable sizes. This low tensile strength is characterized by high elongation or strain values and can be attributed to the stranding of the cables sampled. Thus, higher loads were required to fracture the cables of sizes $6mm^2$ – $16mm^2$ unlike $1mm^2$ – $4mm^2$ cable sizes. The behaviour of the insulating material for the various cables sampled when subjected to pull is shown in Figures 3 – 6. The commonly used insulating material is PVC- polyvinyl chloride for coating the conductor material. PVC has found profound application in electrical cable coating because it offers good protection from mechanical damage during use. The elongation curve for cables follows the plasticity profile in which the PVC materials yields till it gets to the ultimate tensile strength before fracture, but this is unlike the material utilised by Coleman cable which have a linear relationship for the elongation curve. Therefore, the Coleman cable is most likely to experience surface defect during installation which may ultimately limit the performance of the cable during use such as its susceptibility to electrical losses and might cause electrical defects of appliances or spark/ electrocution. The varying profiles of the polyvinyl material for the various sampled brands when subjected to elongation test could be a pointer to the surface defect noticed during installation of electrical cables at homes and offices. In some cases, these cables are pulled beyond their yield limit and hence the torn portion of the electrical cable can expose the conductor material to corrosion and in some situations, these defected surfaces can lead to electrocution.

Table 1: Analysis of Tensile Strength of Nigerian Made Brands of Electrical Cables

Brand	Gauge (mm^2)	Breaking Load (N)	Area (mm^2)	L_1	L_2	DL (%)	Tensile Strength (N/mm^2)
WESCO	1.00	13.74	1.00	30.00	36.00	20.00	13.70
CUTIX		17.19	1.13	30.00	36.60	22.00	15.20
SCAN		12.48	0.99	30.00	38.40	28.00	12.67
COLEMAN		15.37	1.04	30.00	37.20	24.00	14.80
WESCO	1.50	27.85	1.96	30.00	36.69	22.30	14.20
CUTIX		27.22	1.77	30.00	37.50	25.00	15.40
SCAN		27.83	2.06	30.00	38.01	26.70	13.50
COLEMAN		31.54	2.06	30.00	37.16	23.87	15.30
WESCO	2.50	34.57	2.49	30.00	36.42	21.40	13.89
CUTIX		40.29	2.55	30.00	37.70	25.67	15.83
SCAN		34.76	2.41	30.00	37.29	24.30	14.45
COLEMAN		38.93	2.43	30.00	37.47	24.90	16.00
WESCO	4.00	50.50	3.98	30.00	37.67	25.56	12.70
CUTIX		64.12	4.16	30.00	37.89	26.30	15.43
SCAN		60.45	3.80	30.00	37.56	25.20	15.90
COLEMAN		60.63	4.05	30.00	37.34	24.45	14.98
WESCO	6.00	175.87	7.65	30.00	36.45	21.50	23.00
CUTIX		184.69	7.70	30.00	37.08	23.60	24.00
SCAN		140.29	7.79	30.00	36.91	23.03	18.00
COLEMAN		153.78	8.09	30.00	37.21	24.02	19.00
WESCO	10.00	309.22	12.88	30.00	37.62	25.40	24.00
CUTIX		291.96	12.69	30.00	37.65	25.50	23.00
SCAN		316.90	13.20	30.00	37.56	25.20	24.00
COLEMAN		346.41	13.86	30.00	38.55	28.50	25.00
WESCO	16.00	355.50	20.43	30.00	37.14	23.80	17.40
CUTIX		346.60	19.64	30.00	38.19	27.30	17.65
SCAN		348.33	21.24	30.00	36.96	23.20	16.40
COLEMAN		368.14	21.40	30.00	38.28	27.60	17.20

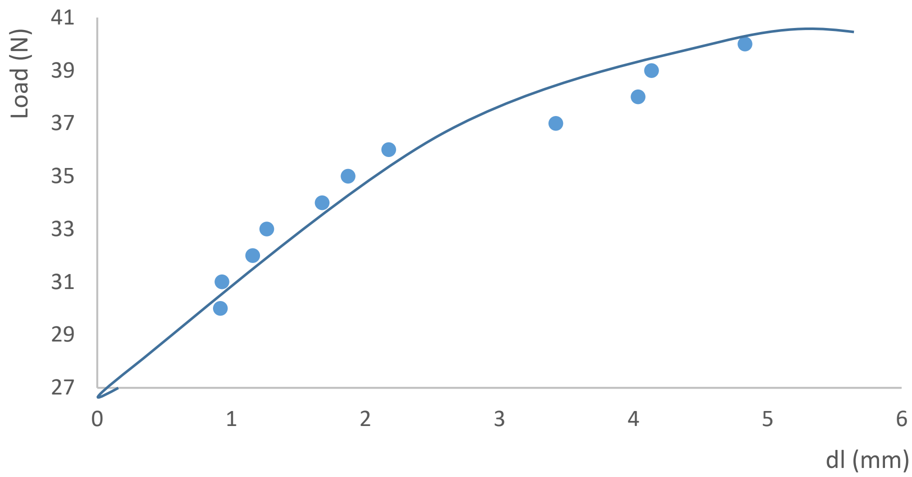

Figure 3: Elongation profile of Wesco cable's insulation material

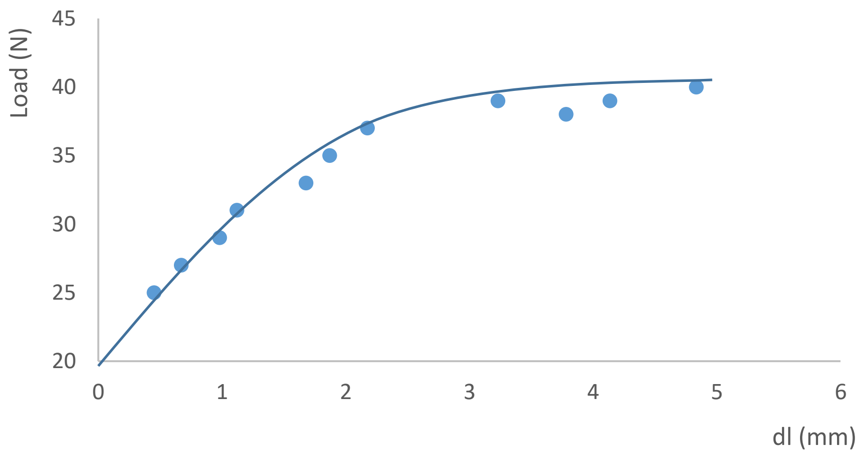

Figure 4: Elongation Profile of Cutix cable's insulation material

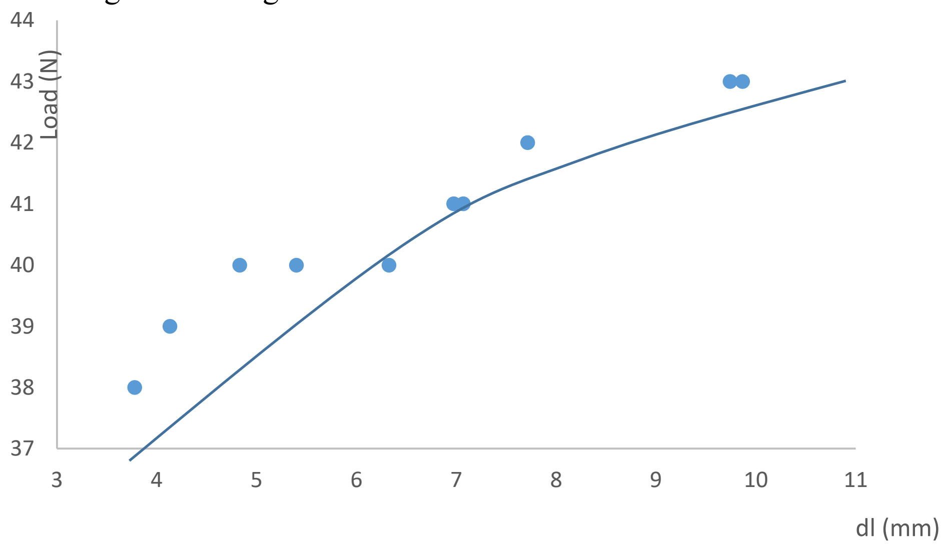

Figure 5: Elongation profile of scan cable's insulation material

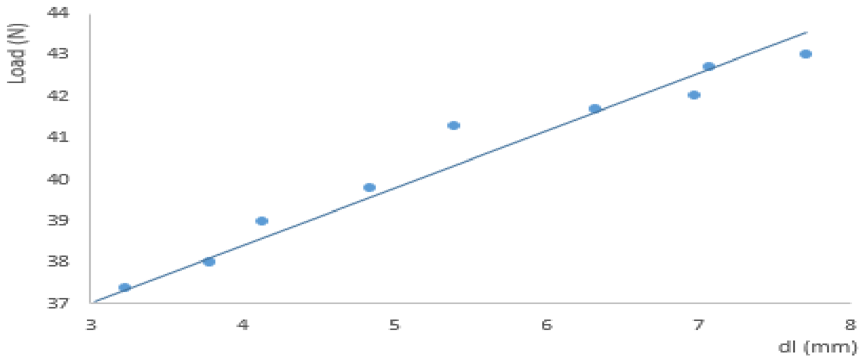

Figure 6: Elongation profile of Coleman cable's insulation material

Since Cost remain constitutes one of the basic factor, end users consider when making decision on the cable brand to use, the cost profile of the Nigeria made electrical cable investigated shown in figure 7 indicates that Cutix cable is the most expensive for all gauges. This can be attributed to the high copper content of their cables as evidenced by the thickness of their conductor material compared to other sampled brands.

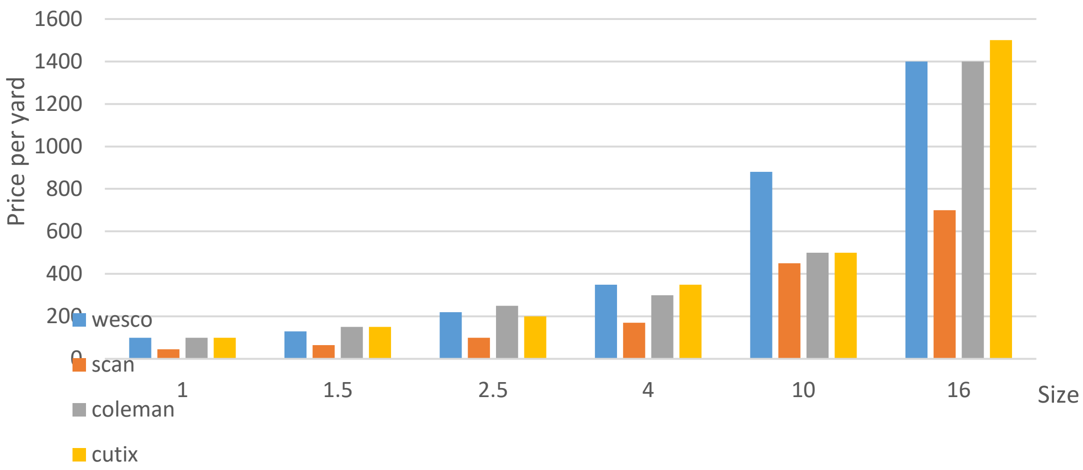

Figure 7: Cost profile of Nigerian made brands of electrical cables

4. CONCLUSİON

This study revealed that the four brands of Nigeria made cables investigated conformed to set standards for tensile strength, resistivity, and flame retardant with Cutix cables exhibiting top profiles. Wesco, Cutix and Coleman cables exhibit low smoke and fume while scan revealed low smoke and halogen free cable burning features. Coleman cable showed a linear relationship in the elongation curve while Wesco, Cutix and Scan tend to follow the plasticity profile. Thus, proper care must be taken during installation of Coleman cables to avoid damage to the cable surface. Cutix cables are most expensive among all gauges due to their high copper content of their conductor material compared to other sampled brands.

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REFERENCES

Adekunle A. Essang N. and Alo A. (2019). Statistical analysis of electric fires in buildings: case study of Lagos State. *Journal of Sustainable Development*. 9(1): 76-92.

Adetoro A. (2014). Assessment of the quality of cables produced in Nigeria. *Global Advanced Research Journal of Engineering, Technology and Innovation*, 1(14): 97-102.

Berhard M. (2017). *Universal cable*. http://www.ucable.com.my/sub-standardcables.html

Duru I. (2015). Death by live wire: Nigerians groan as avoidable electrocution cases become frequent. Saturday Magazine, *The Nation Newspaper*. October 10, 2015. Retrieved from http://thenationonlineng.net/death-by-live-wire-nigerians-groan-as-avoidable-electrocution-cases-become-frequent

Egwuagu M. O. and Nwankwojike B. N., (2019). Empirical Analysis of Core Diameter and Insulation Thickness of House Wiring and Installation Cables in Nigeria. *International Journal of Advanced Research in Science, Engineering and Technology*, 6 (9):10689 – 10694.

Lauryn L. (2017). *'Electrical Spark' Causes Fire Outbreak At Federal Secretariat Abuja*. Retrieved from Skytrend News: https://skytrend-news.com/2017/07/01/electrical-spark-causes-fire-outbreak-federal-secretariat-abuja/

IEEE 400: (2012). Guide for field testing and evaluation of electrical cables. *Cable testing standards*. Retrieved from https://www.ieeexplore.ieee.org/document/6213052

International Electrotechnical Commission (IEC) Standards for Electrical. Electronics and related Technologies. https://www.google.com/search?client=firefoxd&qInternational+Electrotechnical

Iroegbu-Chikezie O., (2014). Building Industry threatened by fake cables and wires. Issues: *The Nation Newspaper*. May 12, 2014. Retrieved from http://thenationonlineng.net/building-industry-threatened-fake-cables-wires

NIS: (2019). Nigerian Industrial Standards for **Electrical** Components and Technology. https://www.google.com/search?q=nigerian+industrial+standard+for+for+electrical+cables

Nimlyat P., Audu A., Ola-Adisa E. and Gwatau D., (2017). An evaluation of fire safety measures in high-rise buildings in Nigeria. *Sustainable Cities and Society*. 10.1016/j.scs.2017.08.035.

Obukoeroro J. and Uguru H. E., (2021). A Survey of Electrical Materials Counterfeiting in Bayelsa State: A Case Study of Yenagoa Local Government Area. *Journal of Physical Science and Environmental Studies*, 7(1): 9-14.

Oludiran, O. and Innih, K., (2011). Electrical Burn Injury in Midwestern Nigeria. *Journal of the West African College of Surgeons*, *1*(2): 18–28.

Triumph (2015). *Fire Guts Kotangora House In Lagos* . Retrieved from Nairaland Forum: https://www.nairaland.com/2258220/updated-fire-guts-kotangora-house Acessed , April 15, 2015.