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Full Length Research Article

PERFORMANCE EVALUATION OF MOBILE NETWORK OPERATORS IN NIGERIA USING DATA ENVELOPMENT ANALYSIS

*Maharazu M.K.[1], Ajibesin A.A.[2], Kasim M.[1], Sa'idu M.B.[1] and Isa A.[1]

[1]University Library, Kaduna State University, Kaduna, Nigeria
[2]Department of Telecommunications, American University of Nigeria, Yola, Nigeria

*Corresponding Author Email Address: munirkubau@gmail.com Phone: +2348038446361

ABSTRACT
This research concerns the deployment of Data Envelopment Analysis (DEA) to evaluate the performance of Mobile Network Operators (MNOs) in Nigeria. The existing performance evaluation methods for MNOs is studied and analyzed; thereafter, the Data Envelopment Analysis (DEA) model was used to compute and compare the technical efficiency of each of the major MNOs in Nigeria for a period of six years (2015- 2020). The result obtained was analyzed into efficient and the inefficient MNOs and then performed ranking of the MNOs. The findings show that, among the four major Nigerian MNOs (MTN, 9mobile, GLO and Airtel) examined, MTN is the most efficient mobile operator based on Banker, Charnes and Cooper/ Variable Return to Scale BCC/VRS model followed by 9mobile, Glo and Airtel which has the least efficiency. This finding shows that mobile operators like MTN and 9mobile are committed to the best practice use of resources. It was further revealed that the efficiency of mobile operators for all the observed years is proportional to the GDP contributions and hence a lower efficiency in 2017 has shown a drop in the GDP contribution.

Keywords: Mobile Network Operators, Data Envelopment Analysis, Input, Output, Efficiency

INTRODUCTION
The Telecommunications industry has witnessed a sequence of successive improvements in the field of communication technologies over the last few decades; Progressing from analogue system that cannot handle the growing capacity needs in a cost-efficient manner to digital system that is fast, reliable and cost effective (Usman & Ozovehe, 2015). This progress was driven by high demand for good quality service, high spectral efficiency, standardization and new services from both customers and regulatory bodies. The growing need for quality of service (QoS) mandated the need to have so many studies regarding the evaluation performance of MNOs.

The Nigerian Communications Commission (NCC) reported that Nigeria had limited telephone networks for many years, and the number of waiting customers was estimated around 10 million people before the year 2001 (Ifeoma, 2015). By 2001, the Nigerian Government liberalized the Telecommunications Industry which was monopolized by the Nigerian Telecommunications Limited (NITEL). Since then, wireless communication in Nigeria has witnessed an exponential growth with increase in the number of mobile subscribers (Ononiwu et al. 2016). This growth was attributed to the rapid growth in subscribers and was rated as one of the fastest growing Global System for mobile communication markets in Africa. According to NCC, the explosive growth of wireless communications service has significant contribution on Nigerian Gross Domestic Product (GDP) and generated huge revenue for the network operators.

Competition for subscribers is getting fierce. Operators used price wars in order to win more subscribers; while mobile subscribers have more choices regarding which GSM operator to use. This has come with a challenge for the operators to attract, maintain and move subscribers to high-value services such as voice, data and multimedia applications. For these reasons, network operators must provide good quality services which require monitoring and quality assurance with a view to optimizing the network. The ever-increasing number of GSM operators with its lower tariffs on calls has led to continuously increasing number of subscribers (Tella, et al. 2009), which has made Nigerian GSM market the largest in Africa.

A lot of resources are invested in the mobile network sector from both the private companies and regulatory bodies for ensuring high QoS. Despite this huge investment, many complaints came from the mobile users about the poor QoS offered by the network operators ranging from poor networks coverage; call tariff, poor internet services, drop calls rate, blocked calls, to inter-connectivity between different providers. This resulted in huge losses and sometimes sanctions or fines from NCC. Therefore, effective monitoring and managing of wireless network are important in order to meet up with deleted expectations of the users.

In an effort to improve the QoS of Nigerian telecom network, the NCC has deleted setup Key Performance Indices (KPIs) to measure the effectiveness of the services provided by Mobile Network Operators (MNO). This method has a drawback when it comes to determining the best performing MNO. Many discrepancies exist in the results obtained from the different studies conducted by Upadhyay, et al. (2014); Galadanci & Abdullahi (2018); and Usman & Ozovehe (2015) in their effort to rank the best performing MNO in Nigeria. Those studies focused on the effective performance of MNOs in some major cities across the nation using test drive and the set Key Performance Indicators KPIs.
There is a need for rigorous and in-depth studies on the performance of MNOs (Nigam, Thakur & Singh, 2009). Such studies would offer valuable lessons to MNOs in terms of best practices and benchmarking. A frontier analysis approach to effectively determine the technical efficiency of Nigerian MNOs was proposed.

For instance, in Tanzania, similar study was conducted targeting the MNOs performance. Sulaiman, et al. & Wei (2018) conducted a study in Tanzania with the aim of evaluating the MNOs of the

country using Data Envelopment Analysis methodology. They discovered interesting evidence on the best way to rank MNOs. The study used five inputs and outputs got from the Tanzania Communications Regulatory Authority's 27 reports (2010-2016). Their result revealed that three of the MNOs in the country are considered the most efficient MNOs. This has contributed a lot in their ranking of the best MNOs in the country. And it has also presented a significant compass for choosing the right MNO in the country. The MNOs considered are Vodacom-Tanzania, Airtel-Tanzania, Tigo, Zantel, Smart, Halotel, and Tanzania Telecommunication Company Limited. Vodacom-Tanzania, Airtel-Tanzania and Tigo are ranked first, second and third respectively. This means that they are the most efficient MNOs in Tanzania.

NCC has reported the effectiveness of MNOs in Nigeria with a focus on average performance. In the literature, we discovered that scanty studies were conducted in Nigeria on the performance evaluation of MNOs and most of the available studies either used drive test or KPIs to evaluate MNOs in Nigeria. Therefore, we propose new approach to performance evaluation of MNOs in Nigeria using DEA method. This method evaluates the actual economic efficiency such as technical efficiency (TE) rather than mere effective evaluation of the system and provides alternative ways to stir MNOs into becoming one of the best performers.
This study provides answers to the following research questions:

- Which MNO is most efficient in Nigeria?
- What can be done in order to improve their efficiency?

Essentially, this research work can be beneficial to telecommunications regulatory bodies and mobile network service providers and can serve as a basis for feasibility studies to the potential mobile network operator. The results of this research would also be valuable to researchers and scholars, as it would form a basis for further research. It will also help the mobile network operators to change their modus operandi in order to win more subscribers in this emerging and highly competitive market.

MATERIALS AND METHODS

Research Design

This study considered a non-Parametric Method that relies on a linear programming technique for optimization of the MNOs performance, i.e. Data Envelopment Analysis. This technique evaluates the productivity of an organization (in this case, MNOs) by comparing the amount of output(s) produced in relation to the amount of input(s) used.
Because this research used numerical data to explain the efficiency of MNOs, a quantitative research approach was adopted. Quantitative study focuses on the representation of statistical and numerical data. It involves the manipulation of observations in order to describe or explain a phenomenon. There are two approaches to evaluate efficiency: the constant return to scale (CRS) and the variable return to scale (VRS). In this research, we consider constant return to scale approach in addition to envelopment model.

Model Selection

There are different efficiency models that are based on linear programming techniques. Among them Envelopment model is the most effective and most used (Ajibesin, et al. 2014). We consider this model and use the frontier analysis to determine the efficiency of each MNO and also rank the MNOs based on their performance.
In DEA, two methods are usually considered – input or output oriented. This study uses input-oriented approach because it focuses on optimization of resources used to obtain the output.
Input-oriented approach is a term used to indicate that an inefficient unit can be made efficient through minimizing the amount of inputs used while the amount of outputs produced remains constant. In other words, input-oriented approach is used when you want to reduce the inputs to see if same outputs can be realized with the same quality. While CCR does not mandate an approach being input-oriented or output-oriented to produce result, BCC does not work that way.
DEA solver package called (OSDEA) was used to solve for the efficiency of MNOs. OSDEA is open source software that uses linear programming to solve for efficiencies.
We implemented the DEA model to compare the last six years of each of the major MNOs in Nigeria. The result obtained was analyzed into efficient and the inefficient MNOs and then, performed ranking of the MNOs. Twenty four Decision Units were formed based on the number of years and DMUs; while the metrics are derived from the KPIs.

Performance Metrics

NCC has set the performance metrics for the telecommunication industry in Nigeria. Different indices were established to measure the performance of some aspects of the MNOs activities and are reported monthly and published on the NCC websites. The indices include subscriber statistics, Call Setup Success Rate (CSSR), Drop Call Rate (DCR), Standalone Dedicated Control Channel Congestion (SDCCH CONG) and Traffic Channel Congestion (TCH CONG). These metrics are classified as input and output variables as:

Input variables

i. Drop Call Rate (DCR),
ii. Standalone Dedicated Control Channel Congestion (SDCCH CONG)
iii. Traffic Channel Congestion (TCH CONG)

Output variables

i. Market Size for Voice
ii. Market size for data
iii. Call Setup Success Rate (CSSR)

Null-Hypothesis

Traditionally, MNOs are evaluated and ranked based on the average performance indices published by NCC. This performance evaluation method cannot in anyway express the efficiency of the MNOs. Therefore, the null-hypothesis is that KPIs significantly measure the efficiency of MNOs in Nigeria.

Data Collection

Data for the study is obtained from secondary source. The dataset was sourced from NCC database and Information such as subscribers' statistics, tele-density and QoS data for each MNOs from 2015 to 2020 (6 years) was obtained and formulated for DEA analysis.

Effectiveness of Nigerian Mobile Operators

Effectiveness defines the degree to which the outputs of a mobile operator achieve the stated objectives of that service. The NCC normally sets such objectives. The literature has shown that existing approaches employed by NCC to evaluate the performance of mobile operators are done using a single metric

such as call setup success rate (CSSR) and drop call rate (DCR), which are only appropriate for effective performance. Using this method, there is no way an inefficient mobile operator could be identified or made to be effective. Hence, this section looked at the position of how true efficiency evaluation is obtained, but there is a need to analyse the existing methods, which serve as source of data for the proposed method.

Call Setup Success Rate (CSSR)
Setup Success Rate is one of the parameters used by the NCC to determine the Quality of Service (QoS) standards in service delivery by mobile operators. The QoS evaluates the reliability of a network; and the function of NCC is to ensure that consumers enjoy the high-quality service. The traditional fixed telephone has a high call setup success rate, which is above 99.9%, but the call setup success rate for mobile communication systems is lower. This is because of the effect of transmission impairments such as fading. The call setup success rate by the NCC for all Nigerian operators is to meet 98%.

Drop Call Rate (DCR)
The DCR is a percentage of calls that were cut-off before or during conversation in a telephone network due to technical problem. It is a determinant factor for QoS evaluation. The NCC has set a threshold of <1% for DCR for MNOs.

Standalone Dedicated Control Channel
SDCCH Congestion is the probability of failure of accessing a stand-alone dedicated control channel during call set up. It is the ratio of number of connection failure to the number of attempted calls of a particular MNO. In Nigeria the NCC has set <0.2% as the threshold for Standalone Dedicated Control Channel Congestion.

Traffic Channel Congestion (TCH CONG)
The Traffic Channel Congestion is a type of network congestion that affects the performance of the mobile network and brings dissatisfaction to customers. The NCC has set a target of < 2% for this KPI. It is observed that all of the operators met the set standard for all the observed years and there is no single defaulter.

Market share
The results of voice (GSM) and Internet users are presented in Figure 5 and 6 respectively. The figure expresses the market share of mobile operators from year 2015, to 2020.

Efficiency Performance of Mobile Operators
In this section, the real efficiency evaluation was performed. Therefore, the main focus in this section is to quantitatively evaluate the technical efficiency (TE) known as productivity of mobile operators in Nigeria and to classify them based on their efficiency rating. It is understood that many operators would like to do the right thing by meeting the NCC standard, but are they truly productive and sustainable? A factor that is responsible for inefficiency is the use of too much input resources to achieve an output or objective. This is an important aspect that is generally missing in the NCC reports. Thus, it is not enough to meet an objective set but how well was the objective met.
In order to illustrate this, given that the standard requirement for mobile operators for instance is to reduce the Drop Call Rate (DCR) by 7 units, technical efficiency can help in minimising the inputs to achieve a certain level of outputs with the same quality. Let assume that mobile operator "A" reduces DCR by 8 units and mobile operator "B" reduces it by 6 units. It is easy to judge that mobile operator "A" is more effective than mobile operator "B" for meeting the objective. However, this does not necessarily determine their efficiency until when the multiple inputs and multiple outputs resources consumed in meeting the objective are resolved.
In order to evaluate the TE of mobile operators, we have developed an envelopment model presented earlier. We considered two distinct approaches: the input-oriented CCR/CRS and the input-oriented BCC/VRS. The models determine the degree of efficiency for mobile networks against the best-practice (efficient) and suggest how the inefficient operators could attain efficiency so that they are productive. It is important to establish the model requirements and environment before the actual implementation. First, we analyzed the data used and then discussed the procedures for implementation of DEA.
The main method of gathering the data used for the implementation of envelopment model is through the analysis of data reported by the NCC. The data which have been evaluated are based on statistical average and good for effective performance measurement. In our implementation, we considered efficiency performance evaluation that relied on frontier analysis; that is DEA technique. The first approach is the analysis and transformation of data obtained from NCC using decision making units (DMUs). The metrics or parameters are classified into inputs and outputs.
Unlike the NCC method, which considered the evaluation of variables separately to achieve operation effectiveness, the DEA method combined all the variables for efficiency evaluation. For example, the call setup success rate is separately considered. Similarly, the Drop Call Rate (DCR), the Standalone Dedicated Control Channel Congestion (SDCCH CONG), the Traffic Channel Congestion (TCH CONG), and the market share (GSM and Internet) are all considered separately.

Implementation of Input-oriented CCR/CRS Envelopment Model for MNOs
In this section, the data was solved using the OSDEA tool. The technical efficiency scores are processed from the solved problem document. The results of the model are analyzed and classified into efficient and inefficient mobile operators, because the tool is able to calculate the technical efficiency of each mobile operator. The DEA tool uses the linear programming embedded within the DEA solver to locate efficient mobile operator, and compare its efficiency with other mobile operators. The efficient mobile operators are those with efficiency rating of □=1. The inefficient DMUs are identified by an efficiency rating of less than1 (□<1).
Table 2 presents the efficiency scores of all DMUs comprising four mobile operators evaluated by the DEA solver. Column two of Table 2 shows the results of technical efficiency scores of all the mobile operators. Column three of Table 2 presents the results of technical efficient ratings (efficient or inefficient) of all the mobile operators. Column four of Table 2 shows the results of technical efficiency scores in their percentages while column five presents the efficiency gap of each DMU.

Implementation of Input-oriented BCC/VRS Envelopment Model for MNO
In this section, this second approach, input-oriented BCC/VRS envelopment model is implemented and evaluated for technical efficiency of mobile operators in Nigeria. Again, the OSDEA tool is considered. Similar to the CCR/CRS Envelopment Model, the

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technical efficiency scores are extracted from the solved problem document. The results of the model are analyzed and classified into efficient and inefficient mobile operators. The technical efficiency of each mobile operator is calculated using the DEA tool and the results are presented in Table 3.

Percentage Efficiency and Percentage Contribution of Telecoms Industry to GDP

In this section, the percentage contribution of telecommunication industry to national

GDP is analyzed for the period of 2015 to 2020. In order to achieve this, we obtained some raw data from the NCC for analysis. Column 2 on table 4 represents the data, which is the percentage contribution of telecommunication industry to GDP in Nigeria.

RESULTS AND DISCUSSION

Figure 1 presents the effective performance of four operators namely MTN, GLO, Airtel and 9mobile over six years of operation; that is 2015 to 2020.

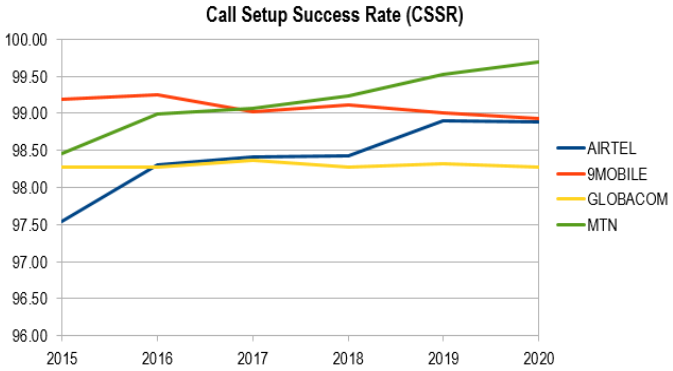

Figure1: Effective performance of four mobile operators based on CSSR

It is observed that 9mobile, MTN and GLO met the set standard of Call Setup Success Rate (CSSR) threshold > 98% for all the observed years with 9mobile showing superiority over other operators. Only Airtel defaulted in 2015.

Figure 2 presents the effective performance of four operators namely MTN, GLO, Airtel and 9mobile over six years of operation; that is 2015 to 2020.

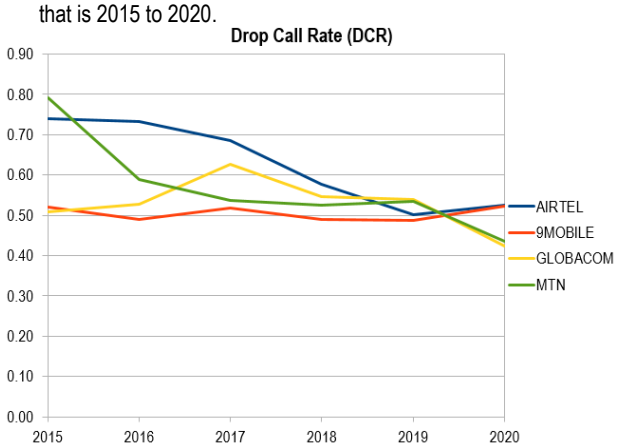

Figure 2: Effective performance of four mobile operators based on DCR

It is observed that all operators met the set standard for all the observed years.

Figure 3 presents the effective performance of four operators namely MTN, GLO, Airtel and 9mobile over six years of operation; that is 2015 to 2020.

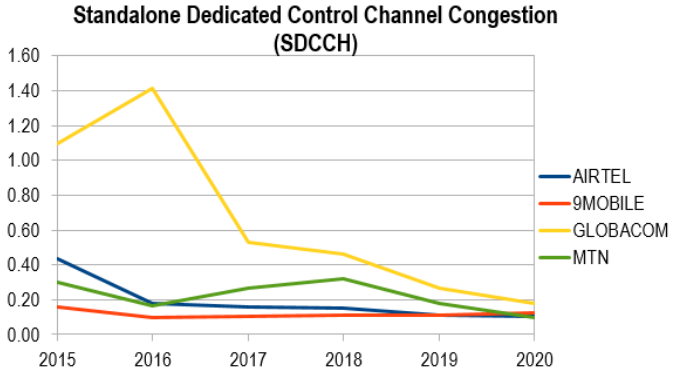

Figure 3: Effective performance of four mobile operators based on SDCCH CONG

It is observed that only 9mobile met the set standard for all the observed years and MTN, GLO and Airtel defaulted in several cases with GLO having the highest number of defaulting.

Figure 4 presents the effective performance of four operators namely MTN, GLO, Airtel and 9mobile over six years of operation; that is 2015 to 2020.

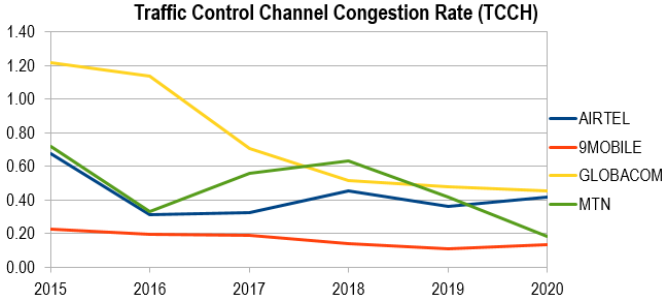

Figure 4: Effective performance of four mobile operators based on Traffic Channel Congestion (TCH CONG)

All the MNOs have satisfied the set threshold of NCC for all the observed years.

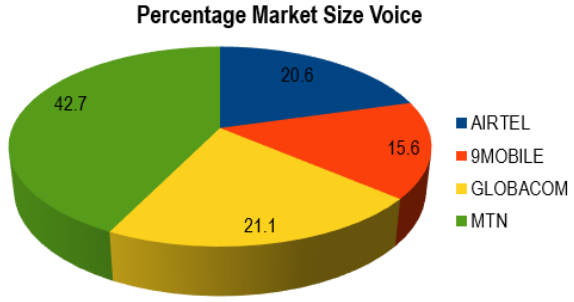

Figure 5: Percentage market size for voice

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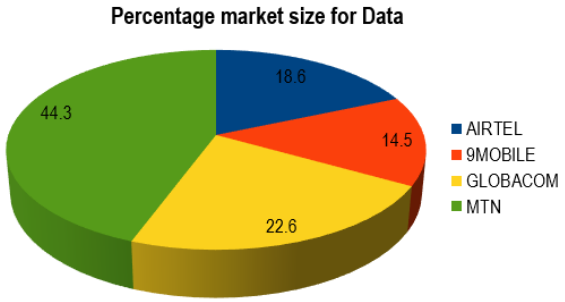

Figure 6: Percentage market size for data

It has been observed that MTN has the highest market share and 9mobile has the least market share for voice and data. For instance, the average percentage market share for the GSM presented in figure 5 below shows that MTN has 39.35% market share for voice followed by Glo with 25.03%, then Airtel with 24.27% and 9mobile with 11.35%. The results are similar for data. MTN has 39.55% market share for data, followed by Glo with 25.95%, then Airtel with 23.33% and 9mobile with 11.12%.

The DEA is a function of all the six metrics called the indexes. The indexes, which are classified into input and output as shown in Table 1, have been carefully analyzed. This data set represents the resources available for each mobile operator known as (DMU).

Table 1: Decision Making Units (DMU) Table for input and output variables

DMUs	Inputs			Outputs		
	% Market (GSM)	% Market (Internet)	CSSR	DCR	SDCCH	TCCH
AIRTEL2015	20.6	18.6	97.54	0.74	0.44	0.68
9MOBILE2015	15.6	14.5	99.19	0.52	0.16	0.23
GLO2015	21.1	22.6	98.28	0.51	1.09	1.22
MTN2015	42.7	44.3	98.45	0.79	0.30	0.72
AIRTEL2016	21.9	19.2	98.30	0.73	0.18	0.31
9MOBILE2016	14.7	16.3	99.25	0.49	0.10	0.19
GLO2016	23.9	28.6	98.28	0.53	1.41	1.14
MTN2016	39.5	35.9	98.98	0.59	0.16	0.33
AIRTEL2017	24	22.7	98.40	0.69	0.16	0.32
9MOBILE2017	12.6	13.3	99.03	0.52	0.11	0.19
GLO2017	25.8	29.3	98.37	0.63	0.53	0.71
MTN2017	37.6	34.7	99.06	0.54	0.27	0.56
AIRTEL2018	25.4	25.9	98.42	0.58	0.15	0.45
9MOBILE2018	9.9	10.1	99.11	0.49	0.11	0.14
GLO2018	25.4	26	98.27	0.55	0.46	0.51
MTN2018	39.3	37.9	99.24	0.53	0.32	0.63
AIRTEL2019	26.7	26.8	98.90	0.50	0.11	0.36
9MOBILE2019	8.9	7.4	99.01	0.49	0.11	0.11
GLO2019	27.1	23.7	98.33	0.54	0.26	0.47
MTN2019	37.3	42	99.53	0.54	0.18	0.42
AIRTEL2020	27	26.8	98.88	0.53	0.10	0.42
9MOBILE2020	6.4	5.1	98.92	0.52	0.13	0.13
GLO2020	26.9	25.5	98.28	0.42	0.18	0.45
MTN2020	39.7	42.5	99.70	0.43	0.10	0.18

Table 2: Efficiency scores and ratings of mobile operators based on CCR/CRS Model

DMUs	Efficiency Scores	Efficiency Ratings	% Efficiency	Efficiency Gap
AIRTEL2015	1	Efficient	100	0
9MOBILE2015	0.78	Inefficient	77.91	22.09
GLO2015	1	Efficient	100	0
MTN2015	1	Efficient	100	0
AIRTEL2016	0.98	Inefficient	97.79	2.21
9MOBILE2016	0.75	Inefficient	74.99	25.01
GLO2016	1	Efficient	100	0
MTN2016	0.76	Inefficient	75.67	24.33
AIRTEL2017	0.92	Inefficient	91.65	8.35
9MOBILE2017	0.84	Inefficient	84	16
GLO2017	0.89	Inefficient	89.07	10.93
MTN2017	0.72	Inefficient	72.14	27.86
AIRTEL2018	0.77	Inefficient	76.74	23.26
9MOBILE2018	0.85	Inefficient	85	15
GLO2018	0.77	Inefficient	77.1	22.9
MTN2018	0.74	Inefficient	73.52	26.48
AIRTEL2019	0.66	Inefficient	65.64	34.36
9MOBILE2019	0.88	Inefficient	87.67	12.33
GLO2019	0.72	Inefficient	71.58	28.42
MTN2019	0.69	Inefficient	68.6	31.4
AIRTEL2020	0.7	Inefficient	69.54	30.46
9MOBILE2020	1	Efficient	100	0
GLO2020	0.58	Inefficient	58.24	41.76
MTN2020	0.54	Inefficient	54.22	45.78

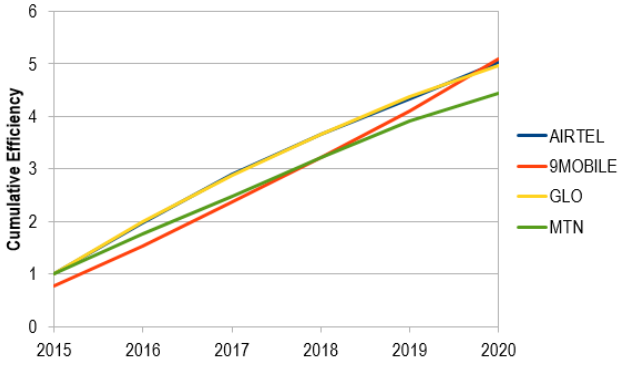

Figure 7: Cumulative efficiency scores based on input-oriented CCR/CRS model

Table 2 presents the results in which all the operators have at least one DMU with efficiency scores of 1; that are (□□□□1), and they are identified as efficient. Only GLO has two DMUs that are efficient. That is, Airtel2015, Globacom2015, and 2016; MTN 2015 and 9mobile2020 have 100% efficiency. As a result, these DMUs are considered as efficient DMUs for those years. The Table shows the 5 occurrence of efficiency out of 24 DMUs. The remaining 19 DMUs have efficiency scores of less than 1(□□<1) but greater than 0, and therefore classified as inefficient mobile operators.

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Column five of Table 2 presents the results in percentage by which an inefficiency mobile operator deviates from efficient frontier (100% efficient). For example, 9mobile2015 has efficiency gap of 22.09%, meaning that the mobile operator can improve its technical efficiency score by reducing certain inputs up to 22.09% (100 – 77.91). Similarly, MTN2020 can do so with approximately 45.78% input reduction. Note that it is possible to project the inefficient mobile operator unto the efficient frontier using the slack model. The slack model implementation is not covered in this study.

It has been observed that efficiency performance of 9mobile and MTN are very close. In addition, in order to appropriately rank all the DMUs of mobile operators and the trends over six years, we determine the cumulative efficiency as shown in Table 2. It is straight forward to see that Glo and Airtel are still taking the lead followed by 9mobile; while MTN has the least cumulative efficiency over the year 2015 to 2020.

Table 3: Efficiency scores and ratings of mobile operators based on BCC/VRS Model

DMUs	Efficiency Scores	Efficiency Ratings	% Efficiency	Efficiency Gap
AIRTEL2015	1	Efficient	100	0
9MOBILE2015	0.99	Inefficient	98.84	1.16
GLO2015	1	Efficient	100	0
MTN2015	1	Efficient	100	0
AIRTEL2016	0.99	Inefficient	99.23	0.77
9MOBILE2016	0.99	Inefficient	98.87	1.13
GLO2016	1	Efficient	100	0
MTN2016	0.99	Inefficient	98.55	1.45
AIRTEL2017	0.99	Inefficient	99.13	0.87
9MOBILE2017	0.99	Inefficient	99.29	0.71
GLO2017	0.99	Inefficient	99.23	0.77
MTN2017	0.98	Inefficient	98.47	1.53
AIRTEL2018	0.99	Inefficient	99.11	0.89
9MOBILE2018	0.99	Inefficient	99.47	0.53
GLO2018	0.99	Inefficient	99.27	0.73
MTN2018	0.98	Inefficient	98.29	1.71
AIRTEL2019	0.99	Inefficient	98.62	1.38
9MOBILE2019	1	Efficient	99.67	0.33
GLO2019	0.99	Inefficient	99.2	0.8
MTN2019	0.98	Inefficient	98	2
AIRTEL2020	0.99	Inefficient	98.64	1.36
9MOBILE2020	1	Efficient	100	0
GLO2020	0.99	Inefficient	99.25	0.75
MTN2020	0.98	Inefficient	97.83	2.17

Table 3 presents the efficiency scores of all the mobile operators evaluated based on input-oriented BCC/VRS envelopment model. Column two of Table 3 shows the results of technical efficiency scores of all the mobile operators ranges over five years. Column three of Table 3 presents the results of technical efficient ratings (efficient or inefficient) of all the mobile operators. Column four of Table 3 shows the percentages of technical efficiency scores. Column five of table 3 presents the efficiency gap of all the MNOs.

The table presents the results where 9mobile2019, 9mobile2020, MTN2015, GLOBACOM2015, GLOBACOM2016 and Airtel2015 have efficiency score of =1 (i.e. 100%) and they are considered as efficient mobile operators for those years. Unlike the input-oriented CCR/CRS envelopment model with 5 efficient mobile operators, the input-oriented BCC/VRS envelopment model has 6 efficient mobile operators. Thus, Table 3 shows 6 occurrences of efficiency out of 24 DMUs. Also, two of the operators, namely 9mobile and GLOBACOM are efficient with highest equal number of DMUs with each having two efficient DMUs; while Airtel and MTN have the least equal number of DMUs with each having one efficient DMU. The remaining 18 DMUs have efficiency scores of less than 1 (<1) and classified as inefficient mobile operator. Again, all the GLOs' and Airtel's DMUs are inefficient. It is straight forward to see that Globacom and 9mobile are taking the lead followed by Airtel; while MTN has the least cumulative efficiency over the year 2015 to 2020.

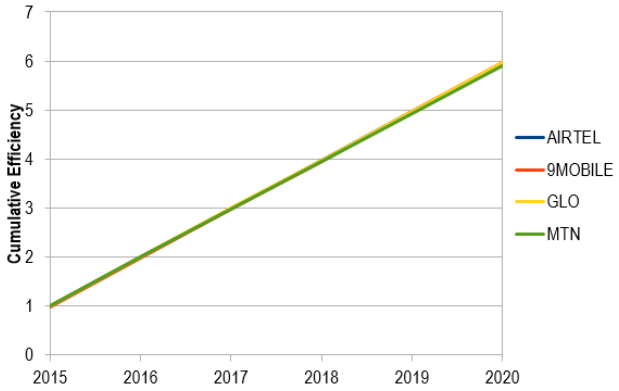

Figure 8 Cumulative efficiency scores based on input-oriented BCC/VRS model

Table 4: Operator Efficiency (%) vs GDP Contribution (%) to Nigeria Economy (2015 to 2020)

Year	GDP Contribution (%)
2015	8.50%
2016	9.13%
2017	8.66%
2018	9.47%
2019	10.33%
2020	12.21%

Table 4: Shows the graphical view of the percentage contribution of telecommunication industry to GDP in Nigeria over six years. We observed a drop in GDP contribution in 2017 from the table. That is, the percentage contribution of telecommunication industry to GDP dropped from 9.13% in 2016 to 8.66% in 2017.

Conclusion

We have considered an envelopment model that is based on input-oriented approach to evaluate technical Efficiency (TE) of mobile operators. The TE results were able to identify which mobile operators are efficient and which are inefficient. In addition, the model was able to suggest how the inefficient mobile operators

could attain efficient frontier; that is to become efficient.
Furthermore, two types of envelopment models were presented for performance evaluation and analyses of mobile operators. The first model called CCR assumed CRS and the second model called BCC assumed VRS. The technical efficiency achieved by mobile operators using CCR/CRS assumption means that all mobile operators are operating at optimal scale. However, in the real world, it is practically impossible to achieve this optimal scale due to factors such as network size, scale of operation and mobile network's administrator level performance. As a result, we have considered BCC/VRS assumption which is suitable for technical efficiency evaluation of mobile operator in the real world.

Our analysis has shown that the proposed model for the evaluation of mobile operators based on technical efficiency is better than the drive test. Thus, the DEA method provides excellent alternative approach to the drive test in terms of resource utilization, productivity, sustainability, policy and decision making for both mobile operators and NCC.

Specifically, we have examined four major Nigerian mobile operators (MTN, 9mobile, GLO and Airtel) and have shown that GLOBACOM is the most efficient mobile operators based on CCR/CRS while the remaining three are the least. Also, the second model that we used to examine four major Nigerian mobile operators (MTN, 9mobile, GLO and Airtel) showed that GLOBACOM and 9mobile are the most efficient mobile operators based on BCC/VRS model; while Airtel and MTN are the least. This finding shows that mobile operators like GLOBACOM and 9mobile are committed to the best practice use of resources.

In addition, our findings have shown a relationship between the efficiency performance of mobile operators, and the GDP contribution by the telecommunications industry. For instance, the efficiency of mobile operators for all the observed years is proportional to the GDP contributions. Consequently, a lower efficiency in 2017 has shown a drop in the GDP contribution.

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