

Performance Evaluation of Mobile Network Operators Based on Input-Oriented Constant Return to Scale Model

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ABSTRACT

This research evaluated the performance of major mobile network operators (MNOs) in Nigeria using data envelopment analysis (DEA). The DEA method that is based on input-oriented constant return to scale (CRS) model is considered. The objectives of this research were to analyze existing methods used for the evaluation of MNOs' performance and explored DEA which is a non-parametric method that relies on a linear programming technique for optimization. The aim is to evaluate the technical efficiency (TE) of each network operator and consequently determine their ranking. The result obtained shows the distributions of MNOs that are technically efficient and those that are technically inefficient. Also, the ranking according to their relative efficiency was presented. The findings, which are based on the CRS model, show that among the four Nigerian major MNOs examined (MTN, 9mobile, Glo, and Airtel), 9mobile ranked as the most efficient mobile operator followed by the MTN, then GLO, while Airtel has the lowest rank.

KEYWORDS

CRS, DEA, Frontier Analysis, MNOs, Mobile Subscribers, NCC, Performance Evaluation, Technical Efficiency, Telecommunication Industry

INTRODUCTION

Telecommunication industries have seen a sequence of successive improvement in the field of communication technologies over the last few decades; progressing from an analog system that cannot handle the growing capacity needs in a cost-efficient manner to a 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) necessitated the need to research as regards the evaluation of MNOs' performance (Budu, J. & Boateng, R., 2015). The Nigerian Communication Commission (NCC) reported that Nigeria had limited telephone networks for many years, and the number of waiting customers was estimated at around 10 million people before the year

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2001 (Ifeoma, 2015). By 2001, the Nigerian government liberalized the telecommunication industry which was monopolized by the Nigerian Telecommunications Limited (NITEL). The competitive market intervention introduced by the NCC has made wireless communication in Nigeria to witness exponential growth with an increase in the number of mobile subscribers (Ononiwu & Akinwale, 2016). As a result, the Nigerian mobile communication markets was rated the fastest in Africa.

As the telecommunication industry witnessed a rapid increase in subscribers, the NCC introduced a policy to ensure QoS with the flexibility and choice of operator. Also, researchers have contributed to this development in terms of proposing suitable standards and performance analysis (Kehinde, A.I., Lawan, S., Adunola, F.O., & Isaac, A.I., 2017). This makes the MNOs compete for subscribers to remain in the business. The MNOs introduced different strategies to retain their subscribers. Some operators have introduced cost strategy to attract subscribers while some have used the quality services strategy to monitor their network and constantly optimize the communication network. Evidence has shown that an ever-increasing number of GSM operators with its lower tariffs on calls has led to a continuously increasing the number of subscribers (Tella, Adetoro, & Adekunle, 2009). The findings have shown that both the regulators and the MNOs have focused mostly on the quality of operation and less on the technical efficiency (TE). In particular, to the best of the authors' knowledge, no work has explored the data envelopment analysis to evaluate the efficiency of MNOs. Thus, the efficiency of operation, which is the focus of this paper is important for the operators to become productive. In this era of rapidly changing technology and business model, it is necessary for the regulator to adopt efficiency measures and for the MNOs to work toward productivity (Kayisire, D., & Wei, J., 2016).

The remaining sections of this paper are organized as follows: The next section discusses the literature review. In sections three and four, the research methodology and the performance evaluation of MNOs are presented respectively. Section five discusses the results and contributions while conclusion, future research, and recommendations are discussed in the last section.

LITERATURE REVIEW

This paper begins the review by making a distinction between the problem being addressed and the current practice being used by the NCC to evaluate the performance of MNOs. The current methods for MNOs' performance evaluation focused on effectiveness while the proposed method focused on efficiency. Therefore, it is important to explore the difference between these two concepts. In the literature, the term "efficient" is very much confused and misused with the term "effective". Efficiency is a measurable concept that quantitatively evaluates the ratio of output to input. Thus efficiency is concerned with how well things are done (Ajibesin, A. A., Ventura, N., Chan, H. A., & Murgu, A., 2014).

To achieve efficiency, performance evaluation is based on the correct combination of multiple inputs and multiple outputs (Moreno, P., Andrade, G.N., Angulo-Meza, L., & Soares de Mello, J.C.C.B., 2015). "Effectiveness" is mainly concerned with achieving objectives. In terms of MNOs, their effectiveness is measured based on the ability to attain certain predetermined goals and objectives such as Call Drop Rate. The objective of the effective evaluation is only to produce results or outcomes (Fagbohun, O.O. & Adetan, D. O., 2017). Thus, effectiveness is concerned about doing the right things rather than how well things are done. This research work is concern about how well the MNOs achieve their objectives. This is necessary because any operator that consumes more resources for instance to achieve little output cannot compete effectively with their peers.

Many studies have worked on the performance evaluation of MNOs. An example is the performance evaluation of Tanzania's MNOs (Sulaiman, Hemed, & Wei, 2018). The study evaluated the performance of MNOs using Data Envelopment Analysis. The operators' technical efficiency was determined with the best way to rank the MNOs. The study considered five inputs and outputs obtained from the Tanzania Communications Regulatory Authority's 27 reports (2010-2016). Their result revealed that three of the MNOs in the country are leading in terms of TE. This has contributed

a lot in terms of choosing efficient MNOs 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. Similarly, (Alwadood, Noor, & Kamarudin, 2011) considered the DEA methodology to perform the ranking of a public university in Malaysia. Six departments were selected for the study. The result of the analysis showed some departments are more efficient than others. The efficient departments have been recommended to be the benchmark departments for other inefficient departments.

Nigam, Thakur, Sethi, & Singh (2012) conducted a study on how to benchmark the Indian Telecommunication Service Providers for relative efficiencies. The study also used the DEA to compute the comparative efficiencies of mobile telecommunication companies. They applied two DEA models: Charnes, Cooper, and Rhodes (CCR) originally proposed in 1978 and Banker, Charnes and Cooper (BCC) proposed in 1984. The study considered relative efficiency of 126 utilities and the benchmark was determined for the Indian Mobile Telecommunication Sector. The result revealed that strategic plans can be developed to improve the performance of the inefficient utilities, and a model for benchmarking was developed for the service providers in India.

Papadimitriou & Prachalias (2009) used DEA to estimate the marketing expenses of global telecommunication operators. The study explored the possibility and capability of global telecommunication operators to maximize the efficiency of their productive factors. The outputs considered are the total revenues of the eighteen companies; while the inputs considered include marketing expenses, number of staff, investments, traffic of mobile telephony, and traffic of fixed telephony. The result of the study revealed that marketing expenses have to be reduced if only they want to achieve a high level of efficiency. Meza, de Mello, Gomez & Moreno (2017) used Network Data Envelopment Analysis (NDEA) to evaluate Post-graduate programs of Brazilian universities. They argued that NDEA is appropriate for performance evaluation to rank the post-graduate program in Brazilian universities. Paco & Perez (2015) in their work used DEA to evaluate the relationship of information and communication technology, and the efficiency of hotels in Portugal. The result of the study showed the possibility of using ICT to identify efficient and inefficient hotels and perform the ranking of hotels in Portugal.

In terms of analyzing the trend, (Zhang, Song, Peng, & Song, 2012) evaluated the investment efficiency of the Chinese provincial panel data from 2003 to 2008 using DEA methodology. The method was used to identifying the trends of thirty provinces and autonomous regions. The result showed that there exist differences among the investment efficiencies in different regions but tend to diminish year by year. It has also established that investment efficiency in some provinces has a significant relationship with their investment rates in the national total investment.

In Nigeria, measuring the performance evaluation, especially in the telecommunication sector has been by basic tools and central tendency such as finding the average, mode, and using Key Performance Indicator (KPI). Galadanci & Abdullahi (2018) used KPIs set by NCC to evaluate the performance of GSM networks in Kano state, Nigeria. The result of the study showed that four have failed to meet the minimum threshold set by the NCC for the following: Call Setup Success Rate (CSSR), Handover Success Rate (HOSR), and call blocking. This method was used to align with the NCC submission to rate the operators' effective performance. A Similar method was used by (Upadhyay, Singh, & Kumar, 2014) for the performance analysis of the GSM network in Aligarh City, India. In their study, the drive test was combined with the KPIs to analyze the effective performance of the GSM network in Aligarh City, India. The Drive testing is a method of collecting information for measuring and assessing effective performance such as the coverage, capacity, and Quality of Service (QoS) of MNOs, while A Key Performance Indicator is a method used to measure the value that demonstrates how effectively an MNO is achieving key business objectives. The analysis has shown that these approaches can only evaluate the effectiveness of mobile operators and incapable to measure their relative efficiency. In order words, they are incapable of evaluating the TE of mobile operators. Most of the available papers used drive test and the KPIs to determine the performance of Nigerian MNOs.

Ononiwu, Akinwale, Agubor, & Onojo (2016) evaluated the performance effectiveness of mobile network operators in Nigeria using KPIs and drive test in Owerri metropolis. The MNOs involved are MTN, Airtel, GLO, and Etisalat. The result of the analysis showed that most MNOs in Nigeria have failed to meet the requirements set by NCC with regards to the parameters observed. Etisalat was said to have a fair effective performance than any other MNOs.

As earlier mentioned, while the KPIs and the drive test tools are adequate for effective performance, they are inappropriate to evaluate the actual TE of MNOs. Moreover, the tools are capable of evaluating only a single metric. Therefore, an alternative methodology that can resolve multiple metrics (both inputs and outputs) is required to appropriately determine the efficiency of MNOs. It is evident from the literature reviewed that DEA has these features and provides the required result with regards to the efficiency evaluation. It was also shown that DEA provides more reliable data to be used for decision making in organizations than KPIs and drive tests that only concern the output results and not minding the number of inputs been used. To the best of the authors' knowledge, no research work has considered the evaluation of Nigerian MNOs' performance using the DEA methodology and approaches. This is the main contribution to knowledge which is believed has serious implications for MNOs operations because inefficient operators cannot compete appropriately with others.

RESEARCH METHODOLOGY

In this section, a brief background of DEA is first discussed. Then, procedures for the research are discussed. It describes the research design and method of data analysis used to obtain the outcome of the study, and the tools used to obtain the results. This study considered a DEA, which is a non-parametric method using a linear programming technique for optimization of the MNOs' performance. This technique evaluates the efficiency/productivity of an organization (in this case MNOs) by comparing the amount of output(s) produced to the amount of input(s) used to determine their efficiency. Thus, the frontier analysis is performed to determine the efficiency of each MNO and also rank the MNOs based on their relative performance.

DEA Method and Orientation

Data Envelopment Analysis (DEA) is a mathematical programming technique that measures the relative efficiency of a homogeneous set of decision-making units (DMUs). The DEA is capable of using multiple inputs to produce multiple outputs. The DEA can identify the DMU that are efficient and those that are inefficient. The level of inefficiency for each of the inputs and outputs can be determined (Charnes, Cooper, & Rhode, 1995). Furthermore, it can provide a means of comparing the efficiency of DMUs with each other based on several inputs and outputs (Ajibesin, A.A., 2018). This is used to evaluate the relative efficiency of DMUs (MNOs). The DEA has been applied in numerous studies since its inception. It has been used to test the TE in the education sector, manufacturing, banking and economics, telecoms, healthcare, among others (Aldamak & Zolfaghari, 2016). DEA models can be modified to suits the needs and to achieve a function (Aldamak & Zolfaghari, 2016).

The concept of efficient analysis was introduced by Harry Markowitz in 1952 to evaluate efficient DMUs. The DMUs such as mobile operators that are not efficient are projected unto the efficient frontier, which can be achieved by the *DEA orientation*. The input orientation is considered if the objective is to minimize the input variables or resources while the same level of output is kept. The *DEA output orientation* is considered if the objective is to improve the output results with the same input resources. DEA with input orientation is considered in this study.

Returns to Scale Approach

The DEA Returns to Scale (RTS), is another feature. There are two types of RTS used by the DEA: Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS). The *Constant Returns to Scale* (CRS) approach: the CRS approach proposed by Charnes, Cooper, and Rhodes (CCR) takes the

assumption that the amount of changes or increase in inputs, would lead to a proportional change or increase in outputs produced. This assumption is used whenever it is observing that mobile operators are performing their services at an optimal scale. Besides, the assumption of CRS means that scale of operation or size of the mobile network is not a factor to determine the relative efficiency. In this study, the CRS approach is adopted to evaluate the TE of MNOs in Nigeria. It is assumed that Nigerian MNOs are operating at an optimal scale.

The Envelopment Model

The envelopment model is a technique for TE evaluation to improve the efficiency performance in MNOs using multiple inputs and multiple outputs. With the envelopment model, MNO efficiency scores are known. Simply, the ratio of the output achieved to the input defined efficiency but there exists a situation where there are multiple inputs and multiple outputs variables. In that case, the model finds the maximum efficiency which an MNO can achieve under a set of weights (Toloo M., Emrouznejad A. & Moreno P., 2015). These sets of weights then provide optimal values that efficiency ratio can be achieved from n observations. By contrast, the existing approaches that are being used by the NCC do not resolve a ratio problem with multiple inputs and multiple outputs simultaneously. In other to evaluate the TE using a weighted ratio, a set of n observations on the MNOs where each observation, say $j \{j = 1, 2, \dots, n\}$ uses n multiple inputs $x_{ij} (i = 1, 2, \dots, m)$ to produce s multiple outputs $y_{rj} (r = 1, 2, \dots, s)$ are considered. Then, performance in terms of efficiency ratio for MNO _{j} is expressed as:

$$\frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \quad (1)$$

where $u_r (r = 1, 2, \dots, s)$ and $v_i (i = 1, 2, \dots, m)$ are unknown weights. The weights assigned to each input and each output are used as variables in the optimization process. So to optimize a particular MNO, the objective is to:

$$\max \frac{\sum_{r=1}^s u_r y_{r0}}{\sum_{i=1}^m v_i x_{i0}} \quad (2)$$

Some constraints could be considered so that the maximization problem is bounded. For example, a set of normalization for each MNO is assumed such that efficiency is less than or equal to unity (Moreno, P., Andrade, G.N., Angulo-Meza, L., & Soares de Mello, J.C.C.B., 2015). With this approach, an envelopment model was formulated using transformation technique to change the non-linear programming into a multiplier model, then the dual of multiplier was derived to obtain envelopment model as (Toloo M., Emrouznejad A. & Moreno P., 2015):

$$\theta^* = \min \theta$$

subject to:

$$\sum_{j=1}^n \lambda_j x_{ij} \leq \theta x_{i0}, \quad i = 1, 2, \dots, m$$

$$\sum_{j=1}^n \lambda_j y_{rj} \geq y_{r0}, \quad r = 1, 2, \dots, s$$

$$\lambda_j \geq 0, \quad j = 1, 2, \dots, n \quad (3)$$

where λ_j are unknown weights with $j = 1, 2, \dots, n$ and they correspond to the MNO numbers. MNO_0 is one of the n MNOs under evaluation and θx_{i0} and y_{r0} are the i^{th} input and r^{th} output for MNO_0 respectively. Model (3) is the expected input-oriented CCR with Constant Returns to Scale (CRS) envelopment model and its interpretation is summarized as follows:

Definition: If $\theta^* = 1$, then the MNO under evaluation is a frontier point (efficient), that is, no other MNO operates more efficiently than this MNO. Otherwise if $\theta^* < 1$, then the MNO under evaluation is inefficient, that is, this MNO can either increase its output levels or decrease its input levels to attain the frontier point (efficient).

However, θ^* represents the efficiency score of MNO_0 based on input-orientation. This model assumes a CRS, meaning that all observed variables combinations can be scaled up or down proportionally. In this case, the model assumes that MNO_s are able to linearly scale down the inputs to improve efficiency. Thus, the goal of this work is to minimize the inputs while the outputs are kept at their current levels, hence, the reason for considering the input-orientation approach. The envelopment model is implemented in the next section and the efficiency scores of each MNO are obtained.

Decision-Making Units and Requirements

The Decision-Making Units (DMUs) for this research are the four major MNOs in Nigeria – MTN, 9mobile, Airtel and GLO. Considering the performance metrics used as inputs and outputs, four DMUs were not sufficient for the solver. To achieve a fair DEA result, a basic requirement for the number of DMUs selection must be considered. This standard states that the DMU must exceed the two times the number of indexes (input and output). Another guide reported by Charnes, Cooper, & Rhodes, (1978) is a rough rule of thumb having the following relationships: $X > \max \{Y \times Z, 3(Y + Z)\}$, where X is the number of DMUs, Y is the number of inputs and Z is the number of outputs. As a result, the data set that was considered for this work extended to 20 DMUs ($X = 20$), $Y = 3$, and $Z = 3$. Mathematically, $X > \max \{3 \times 3, 3(3+3)\}$, that is, $X > \{9, 18\}$. In other words, the 20 DMUs are greater than 18 DMU minimum requirements. Thus, the data set satisfied the above conditions.

Research Tool

DEA solver package called Open Source Data Envelopment Analysis (OSDEA) was used to solve for the efficiency of MNOs. The TE is evaluated and configured using the DEA tool. The DEA solvers consist of many models, but the envelopment model, which is appropriate for this study is implemented for TE evaluation. The envelopment model has been used widely for this type of problem (Ajibesin, Ventura, Chan & Murgu, 2014). As a result, the model is considered and the DEA solver is used to determine the efficiency of each MNO. The ranking of the MNOs is also determined. This study considered the input-oriented approach because it focuses on the minimization of limited resources

by the MNOs. The input-oriented approach is a term used to indicate that an inefficient unit can be made efficient by minimizing the amount of inputs used while the amount of outputs produced remains constant. This study pointed out that currently, MNOs are evaluated and ranked based on the average effective performance indices published by the NCC. This performance evaluation method cannot in any way express the efficiency of the MNOs. Thus, the model such as KPIs cannot be used to appropriately measure the efficiency of MNOs in Nigeria. Therefore, the envelopment model is an alternative model for TE evaluation of MNOs.

Metric and Data Collection

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. The indices include subscriber statistics, Call Setup Success Rate (CSSR), Drop Call Rate (DCR), Standalone Dedicated Control Channel Congestion (SDCCH CONG), Traffic Channel Congestion, and the market size for voice. The NCC database has provided a good dataset sourced for this study. Information such as subscribers' statistics, teledensity, and QoS data for each MNOs from 2014 to 2018 (5 years) was obtained and formulated for DEA analysis.

PERFORMANCE EVALUATION OF MNOS

The section first presents the results of exiting effective performance that has been adopted by the NCC and then presents the implementation of the proposed envelopment model which is the appropriate method for the evaluation of TE of MNOs.

Effective Performance of MNOs

This section discusses the various metrics based on the key performance indicators (KPI) which are the benchmarks set by the NCC (Segun, I. P., Aderemi, A. A., Nasir, F. & Joke, A. B., 2018). However, the KPIs are limited to the effective performance evaluation of mobile network operators. In addition to the NCC evaluation, many papers reviewed were based their analysis on effective performance to determine which of the Nigerian mobile operator attained a predetermined standard (Dahunsi, F. M. & Kolawole, G., 2015), but these approaches are incapable of evaluating the technical efficiency of the operators as explained. The following are the review of different parameters used for effective performance evaluation:

- **Call Setup Success Rate (CSSR):** CSSR is defined as the fraction of the attempts to make a call that result in a connection to the number that is dialed (Ayo-BeUo, O.A, Aibinu, A. M., Onwuka, E. N., 2014). The CSSR which is one of the parameters used by the NCC to determine the Quality of Service (QoS) standards in service delivery by mobile operators is normally evaluated as a percentage of all call attempts made (Eli-Chukwu, N. Clara, & Onoh, G. N., 2017). The CSSR defined by the NCC is for all Nigerian operators to meet the 98% threshold. Table 1 presents the effective performance of the four major operators namely MTN, GLO, Airtel, and 9mobile over five years of operation. It is observed that only 9mobile and GLO met the set standard of CSSR threshold $> 98\%$ for all the observed years. MTN and Airtel defaulted in 2014 and 2015 respectively.
- **Drop Call Rate (DCR):** The DCR is defined as a percentage of calls that were cut-off before or during a conversation in a telephone network due to technical problems. Also, the DCR which is one of the parameters used by the NCC to determine QoS standards in service delivery by mobile operators is normally evaluated as a percentage of all call attempts made (Tarkaa, N. S & Pahalsan, C. A. D., 2019). The NCC has set a threshold of 1% for DCR (Vandana, K., Sudhakar, M., 2019). Table 2 presents the effective performance of the four operators over five years of

Table 1. Results of Call Setup Success Rate (CSSR)

Operators	2014	2015	2016	2017	2018
MTN	97.45	98.47	98.98	99.05	99.14
9mobile	99.08	99.19	99.24	99.00	99.08
GLO	98.03	98.26	98.26	98.34	98.28
Airtel	98.15	97.61	98.31	98.40	98.36

Table 2. Results of Drop Call Rate (DCR)

Operators	2014	2015	2016	2017	2018
MTN	1.17	0.8	0.59	0.54	0.5
9mobile	0.64	0.51	0.49	0.53	0.48
GLO	0.92	0.52	0.53	0.62	0.52
Airtel	0.76	0.73	0.73	0.68	0.58

operation. It is observed that all operators met the set standard for all the observed years, except MTN that defaulted in 2014.

- **Standalone Dedicated Control Channel Congestion (SDCCH CONG):** SDCCH Congestion is defined as the probability of failure of accessing an SDCCH during call set up. It is the ratio of the number of connection failures to the number of attempted calls of a particular MNO (Aliyu, O., Okpo U. O., Anene, E. C., & Abraham, U. U., 2016). The NCC has set 0.2% as the threshold for SDCCH. Table 3 presents the effective performance of the four operators over five years. It is observed that only 9mobile met the set standard for all the observed years. Other operators, MTN, GLO, and Airtel defaulted in several cases.
- **Traffic Channel Congestion (TCH CONG):** The TCH CONG is a type of network congestion that affects the performance of the mobile network and brings dissatisfaction to costumers. It is the rate of blocked calls as a result of resource unavailable (Emuoyibofarhe, O. N, Oyetunji K., Awokola J. A. & Oladeji A. E., 2015). The NCC has set a target of < 2% for this KPI. Table 4 presents the effective performance of the four operators over five years. It is observed that all 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 Table 5. The table expresses the market share of mobile operators from the year 2014 to 2018. It is 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 shares for the GSM presented in Table 5 shows that MTN has 41% market share for voice followed by GLO with 23%, then Airtel with

Table 3. Results of SDCCH CONG

Operators	2014	2015	2016	2017	2018
MTN	0.17	0.31	0.17	0.29	0.41
9mobile	0.10	0.16	0.10	0.11	0.11
GLO	0.34	1.16	1.34	0.53	0.54
Airtel	0.15	0.42	0.18	0.16	0.16

Table 4. Results of Traffic Channel Congestion (TCH CONG)

Operators	2014	2015	2016	2017	2018
MTN	0.46	0.69	0.35	0.58	0.74
9mobile	0.26	0.23	0.20	0.18	0.17
GLO	0.88	1.26	1.12	0.70	0.54
Airtel	0.31	0.65	0.32	0.33	0.49

Table 5. Percentage market size for voice/data

Operators	2014/	2015	2016	2017	2018
MTN	44.44/51.12	42.65/44.28	39.51/35.94	37.61/34.73	39.34/37.81
9mobile	15.11/8.87	15.54/14.45	14.70/16.31	12.59/13.35	10.02/10.23
GLO	20.75/21.65	21.10/22.64	23.91/28.6	25.78/29.27	25.31/26.1
Airtel	19.70/18.36	20.63/18.64	21.88/19.15	24.02/22.65	25.33/25.86

22% and 9mobile with 14%. Similar performance is observed in terms of market share for data (NCC [Online], 2019).

Implementation of the Envelopment Model

As earlier discussed, it is understood that many operators would like to do the right thing by meeting the NCC standard, but the question to ask is if they are truly productive or sustainable? A factor that is responsible for inefficiency is the use of too much input resources to achieve an output or to meet an imposed objective. This is an important aspect that is generally missing in the NCC reports (NCC [Online], 2019). Thus, it is not enough to meet an objective set by a regulator but how well was the objective met is an important component of international best practices? Let us illustrate this using this scenario: given that the standard requirement for mobile operators, for instance, is to reduce the Drop Call Rate (DCR) by 7 units. Considering this scenario, if mobile operator “A” reduces the DCR by 8 units and mobile operator “B” reduces it by 6 units, then, 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 (resources consumed) in meeting this objective (outputs) are evaluated using an appropriate model. The mobile operator ‘A’ might be using excess input resources to attain this reduction unit, which is not technical efficient in terms of Economic productivity. TE evaluation can help in minimising the inputs (resources used) while still meeting this standard set by the NCC. Therefore, the remaining of this section presents the implementation of the envelopment model development under methodology. The result of the envelopment model is the TE scores of MNOs. To evaluate the TE of mobile operators, the input-oriented approach based on CCR/CRS envelopment model is considered. This model determines the degree of efficiency of mobile networks against the best practice (efficient) and then, suggests how the inefficient mobile operators could attain efficiency so that they are also productive with their peers.

DEA Implementation Procedures

The following are the four main procedures for the DEA problem optimization and evaluation using OSDEA (OSDEA, [Online], 2019):

- **Formulation of DEA Problem:** The first step is to formulate a DEA problem. This involves the analysis of DMUs into inputs and outputs. The data set has been formulated and organized as in Table 6. The DEA tool provides an environment to present a new problem for DEA solver.
- **Import DEA Data:** To import DEA data, the 'Import Data' function is executed and the data are classified according to indexes types based on the resources available in the DEA problem. Note that the imported data must follow certain rules for proper execution. For instance, the data file must be in the 'CSV' format.
- **Configuring the DEA Variables (Resources) and Selection of Model Type:** After the DEA problem was imported into the solver, the configuration of problem variables and selection of appropriate model type is important before the problem is solved. An appropriate configuration of the variable problem is significant for the DMU transformation.
- **Solving the DEA Problem:** Once the DEA problem has been imported, correctly configured, and the model is appropriately selected, then, the next step is to solve DEA problems. The DEA provides its internal Excel file, which is also compatible with MS Excel. The DEA solution can be visualized or saved on this file for immediate and future references. The solution may be imported for analysis and interpretation. The solution includes objectives TE scores of each mobile operator, the weights, the slacks, and projections.

Analysis of Data Used

The main method of gathering the data used for the implementation of the envelopment model is through the analysis of data reported by the NCC in their database (NCC [Online], 2019). The data which have been reported are based on statistical central tendency good for effective performance measurement. In the DEA implementation, efficiency performance evaluation using the DEA solver is considered. The first approach is the analysis and transformation of data obtained from the NCC database using DMUs. The metrics or parameters are classified into inputs and outputs.

One of the unique characteristics of efficiency analysis is the consideration for all the variables and how they impact the entire operation of mobile operators. These variables were carefully examined, then classified into inputs and outputs for the DEA solver. Unlike the existing method, which considered the evaluation of variables separately to achieve operation effectiveness, the DEA method combined all the variables and collectively resolve them for performance evaluation. For example, the call setup success rate, 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) which are separately considered in the existing KPI model were combined in the proposed DEA model. 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 6 have been carefully analyzed. This data set represents the resources available for each mobile operator known as (DMU).

As presented in Table 6, the following are the inputs and outputs variables for the DMU transformation. To solve the DEA problem, each of the mobile operators (DMU) takes three input resources (metrics) and three output resources (metrics) simultaneously rather than a single entry in the case of KPI evaluation. The DMUs are varied for each mobile operator and the analysis ranges from the year 2014 to 2018. For example, MTN consists of five DMUs (MTN2014, MTN2015, MTN2016, MTN2017 and MTN2018). The same procedure applies to other mobile operators. The main function of DEA is to further optimize these resources (metrics) without affecting the established performance. This work is a combination of QoS, established by the NCC and TE evaluation to achieve productivity and sustainability. While the QoS is seeking to ensure customer satisfaction, the TE is seeking the sustainability and productivity of the mobile operators.

Table 6. Decision-Making Units (DMU) Table for input and output variables

Mobile Operators	Inputs			Outputs		
	DCR	SDCCH CONG	TCH CONG	% Market (GSM)	%Market (Internet)	CSSR
Airtel2014	0.76	0.15	0.31	19.70	18.36	98.15
Airtel2015	0.73	0.42	0.65	20.63	18.64	97.61
Airtel2016	0.73	0.18	0.32	21.88	19.15	98.31
Airtel2017	0.68	0.16	0.33	24.02	22.65	98.40
Airtel2018	0.58	0.16	0.49	25.33	25.86	98.36
9mobile2014	0.64	0.10	0.26	15.11	8.87	99.08
9mobile2015	0.51	0.16	0.23	15.54	14.45	99.19
9mobile2016	0.49	0.10	0.20	14.70	16.31	99.24
9mobile2017	0.53	0.11	0.18	12.59	13.35	99.00
9mobile2018	0.48	0.11	0.17	10.02	10.23	99.08
GLO2014	0.92	0.34	0.88	20.75	21.65	98.03
GLO2015	0.52	1.16	1.26	21.10	22.64	98.26
GLO2016	0.53	1.34	1.12	23.91	28.60	98.26
GLO2017	0.62	0.53	0.70	25.78	29.27	98.34
GLO2018	0.52	0.54	0.54	25.31	26.10	98.28
MTN2014	1.17	0.17	0.46	44.44	51.12	97.45
MTN2015	0.80	0.31	0.69	42.65	44.28	98.47
MTN2016	0.59	0.17	0.35	39.51	35.94	98.98
MTN2017	0.54	0.29	0.58	37.61	34.73	99.05
MTN2018	0.50	0.41	0.74	39.34	37.81	99.14

DISCUSSION OF RESULTS

The TE scores are processed from the solved problem document. The results of the model are analyzed and classified into efficient and inefficient mobile operators. The DEA tool uses the linear programming embedded within the DEA solver to resolve efficient mobile operators and compare the performance with other mobile operators. The efficient mobile operators are those that have the rating of their objective function (Θ) = 1. The inefficient DMUs are those that have a rating of less than 1 ($\Theta < 1$).

Table 7 presents the TE scores of all DMUs comprising four mobile operators evaluated by the DEA solver. Column two of Table 7 shows the results of TE scores of all the mobile operators. Column three of Table 7 presents the results of TE ratings (efficient and inefficient) of all the mobile operators. Column four of Table 7 shows the results of TE scores in their percentages while column five presents the efficiency gap of each DMU. Table 7 presents the results in which only 2 operators have DMUs with TE scores of 1; that is ($\Theta = 1$), and they are identified as efficient MNOs. That is, 9mobile2014, 9mobile2016, 9mobile2017, 9mobile2018, MTN2014, MTN2016, MTN2018 have 100% efficiency. As a result, these DMUs are considered as efficient DMUs for those years. The

Table 7. Efficiency scores and ratings of mobile operators based on CCR/CRS Model

Mobile Operators	Efficiency Scores	Efficiency Ratings	% Efficiency	Efficiency Gap
Airtel2014	0.75	Inefficient	75.2	24.8
Airtel2015	0.66	Inefficient	65.8	34.2
Airtel2016	0.75	Inefficient	74.5	25.5
Airtel2017	0.79	Inefficient	78.5	21.5
Airtel2018	0.91	Inefficient	91.4	8.6
9mobile2014	1.00	Efficient	100.0	0.0
9mobile2015	0.96	Inefficient	96.1	3.9
9mobile2016	1.00	Efficient	100.0	0.0
9mobile2017	1.00	Efficient	100.0	0.0
9mobile2018	1.00	Efficient	100.0	0.0
Glo2014	0.53	Inefficient	52.9	47.1
Glo2015	0.93	Inefficient	93.3	6.7
Glo2016	0.92	Inefficient	92.3	7.7
Glo2017	0.79	Inefficient	79.1	20.9
Glo2018	0.94	Inefficient	93.8	6.2
MTN2014	1.00	Efficient	100.0	0.0
MTN2015	0.87	Inefficient	86.9	13.1
MTN2016	1.00	Efficient	100.0	0.0
MTN2017	0.99	Inefficient	99.3	0.7
MTN2018	1.00	Efficient	100.0	0.0

Table shows the 7 occurrences of efficiency out of 20 DMUs. Two of the operators (9mobile and MTN) that are efficient have 4 efficient DMUs for 9mobile and 3 efficient DMUs for MTN. The remaining 13 DMUs have TE scores of less than 1 ($\Theta < 1$) but greater than 0, and therefore classified as inefficient DMUs or mobile operators. All the GLO and Airtel DMUs' are inefficient.

Column five of Table 7 presents the results in the percentage by which an inefficiency mobile operator deviates from the efficient frontier (100% efficient). For example, Airtel 2014 has an efficiency gap of 24.8%, meaning that the mobile operator can improve its TE score by reducing certain inputs up to 24.8% ($100 - 75.2$). Similarly, GLO2014 can do so with approximately 47.1% input reduction. However, 9mobile2014 and MTN2014 are already on the efficient frontier and needs not to perform input reduction. Note that it is possible to project the inefficient mobile operator unto the efficient frontier using the slack model. This is, however, outside the scope of this study.

Figure 1 presents the efficiency scores against each of the mobile operators in a particular year. Based on the CCR model with CRS assumption, it is easy to see that 9mobile has the average best performance in terms of efficiency followed by MTN. The observed average performance of 9mobile and MTN is very close. Airtel has the least average efficiency performance. To expand the distribution, achieving better visualization, appropriately rank all the DMUs of mobile operators, and observe the trends over five years, the cumulative efficiency is determined as shown in Figure 2. It is observed that 9mobile is still taking the lead followed by MTN while Airtel has the least cumulative performance over the year 2014 to 2018.

Already, papers that considered KPI and drive tests to evaluate the performance of MNOs in Nigerian were examined and analyzed. The results have shown that the most MNOs in Nigeria have failed to meet the requirements set by NCC in some cases, but acknowledged that 9mobile has a fair effective performance compared to other MNOs. The existing method that was reviewed and validated also corroborated this finding. However, the fact that an MNO achieves effective performance does not necessarily mean that such MNO is efficient. As discussed and shown in Figures 1 and 2, the analysis of the proposed model for the evaluation of mobile operators based on TE has presented as a better alternative to the KPI and drive test. As mentioned, the KPI and drive test are limited to

Figure 1. Distribution of technical efficiency scores based on input-oriented CCR/CRS model

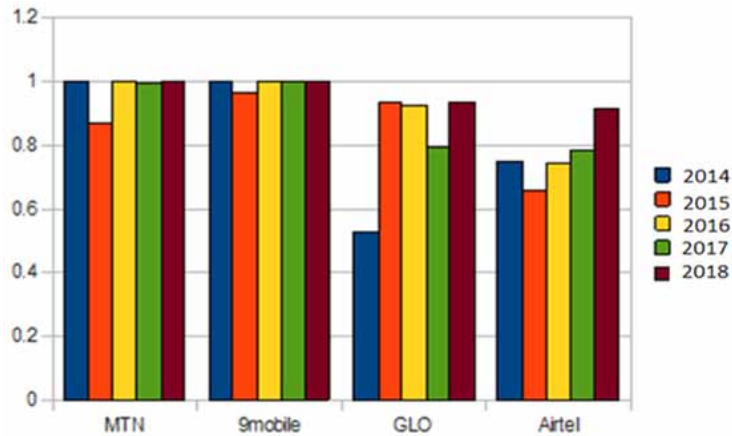
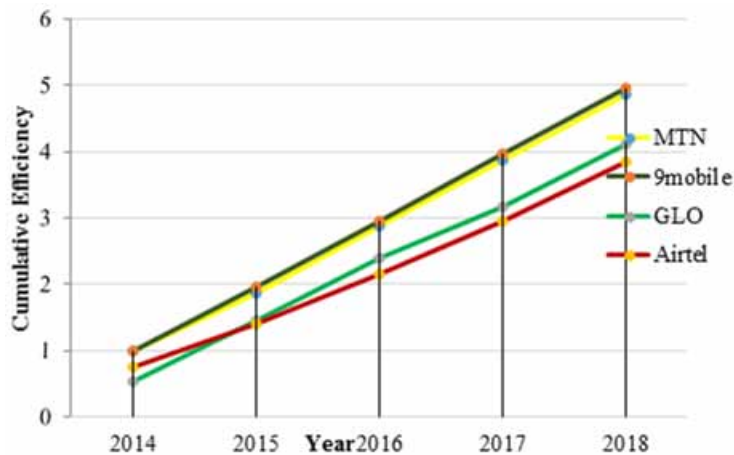


Figure 2. Cumulative efficiency scores based on input-oriented CCR/CRS model



effective performance evaluation while the DEA method can appropriately evaluate the efficiency of MNOs. The DEA method has shown how MNOs' resources could be optimized for productivity.

Contributions

The beginning of the paper is dedicated to the review of literature, an explanation of the existing methodology, and then discussed the proposed methodology. The major objectives and contributions of this thesis are summarized as follows.

As an important part of efficiency evaluation, the existing methodology used by the NCC to evaluate the performance of the MNOs was investigated, analyzed, and reported. For instance, in Table 1, the NCC used Call Setup Success Rate (CSSR) to compare the performance of the MNOs in which 9mobile and GLO met the set standard of CSSR threshold $> 98\%$. First, this result is an example of KPI that is only good for effective performance evaluation. To evaluate the efficiency performance evaluation, there is a need to know the level of inputs used by the MNO to meet the set standard. The results presented in Figures 1 and 2 are the evidence that Glo for instance, uses more input resources

to achieve the CSSR. Therefore, Glo needs to reduce a certain number of input resources to have a balance and achieve efficiency. Similarly, Airtel needs to reduce a certain number of input resources to be efficient. However, it should be noted that this performance evaluation is based on CCR/CRS model. Thus, the result can change under different models and DMUs.

In terms of Drop Call Rate (DCR), as presented in Table 2, all operators met the set standard, except MTN that was defaulted in 2014 and therefore ineffective. Interestingly, the same ineffective MTN in the year 2014 using KPI is efficient using the DEA. The KPI result shows that GLO is effective in terms of DCR while the DEA TE performance shows that Glo is only 53% efficient. Only MTN and 9Mobile attain efficient frontier in 2014. Similarly, Traffic Channel Congestion (TCH CONG), as presented on Table 4, it is observed that all the operators met the set standard for all the observed years and there is no single defaulter. However, none of the operators achieved 100% efficiency for all the observed years. The closest is the 9Mobile with an average efficiency of 99.2% followed by MTN with an average efficiency of 97.2 while Airtel is the least with the average efficiency of 77.2%. It is interesting to know that the Airtel-Tanzania that is among the leading operators in Tanzania in terms of DEA efficiency is ranked lowest in Nigeria. This suggests that the Airtel-Nigeria is using more resources to catch up with the standard set by the NCC.

Another effective result presented in Table 5 shows the market share of mobile operators. The MTN has the highest market share and 9mobile has the least. However, the 9mobile has the highest efficiency followed by MTN while Airtel has the least efficiency. This suggests that the 9mobile and MTN are concerned about how well their operations are done while trying to meet the regulatory standards.

The main objective of this work is to identify the MNO that are inefficient and to make recommendations so that the inefficient MNOs also achieve efficiency. For inefficient MNOs to become efficient, a strategic plan can be developed to improve the input use of resources and to manage the output results. For instance, Table 7 has presented the percentage efficiency as well as the deviation, which is the efficiency gaps. This means that inefficient MNOs can achieve the same outputs while reducing the inputs. The deviation is a good requirement for the strategic plan to guide and control the input resources used to achieve the outputs. Therefore, it is important to know that the model considered can be used to evaluate the degree of efficiency of mobile networks against the best practice (efficient) and then, suggests how the inefficient mobile operators could attain efficiency so that they have also become productive. However, this model is limited to CRS assumption and TE evaluation. The Variable Return to Scale (VRS) assumption and the slack model, which are beyond the scope of this work may be explored for more flexibility and projection of the inefficient MNOs unto their efficient frontier.

CONCLUSION

This paper has considered DEA which is a better alternative methodology compared to the KPI that is widely used to evaluate the performance of MNOs in Nigeria. This study is focused on the technical efficiency evaluation of mobile operators in Nigeria using an input-oriented envelopment model that is formulated based on the CCR/CRS assumption. The TE achieved by mobile operators using CCR/CRS assumption means that all mobile operators are operating at an optimal scale. Based on this, the TE results were obtained to identify which mobile operators are efficient and which are inefficient. Also, the model was able to rank the MNOs and suggest how the inefficient mobile operators could attain efficient frontier through the analysis of efficiency gaps. Specifically, four major MNOs were examined: MTN, 9mobile, Glo, and Airtel. Considering the CCR/CRS model, the efficiency distribution has shown that 9mobile is the most efficient mobile operator followed by the MTN with a close margin. The Glo is the third while and Airtel is the last. The average and cumulative efficiency results also showed similar performance.

Furthermore, this paper has shown that the DEA method based on CCR/CRS model provides an excellent alternative approach to the KPI and the drive test in terms of resource utilization, and efficiency. It is a recommended model for the policymaker such as NUC to make a good decision and to advise the MNOs appropriately. It is not enough to set a threshold but to set a standard that includes quality of service, productivity, and sustainability. For instance, MNOs that meet the threshold but not productive will be out of operation. This will not only affect the GDP of the nation but may result in losses of jobs. The results have shown that some DMUs are operating with certain TE gaps. Therefore, it is recommended that those DMUs consider their inputs wastage and minimize accordingly so that they become efficient. Other DMUs may need to benchmark with the DMUs that are efficient to learn about resource utilization.

Future work is encouraged to consider the BCC/VRS model that is based on its assumption on the scale of operation rather than optimal scale, and the result may be compared with these findings. Besides, future research may consider the slack model for appropriate projection of inefficient DMUs or operators, and the extension of the DMUs to the recent year may be considered. The research work may also consider international mobile operators to obtain a completely different efficient DMU and new benchmarks. This may be necessary for international competitions. It is important to note that the DEA methodology is a black box and do not design to capture the upper limit. It compares the relative efficiency of the available DMUs. A change in the DMUs results in a change of efficiency. Also, it is not sensitive to erroneous DMUs. Thus, it is important to be careful in dealing with the DEA dataset.

REFERENCES

- Ajibesin, A. A. (2018). Efficient Frontier and Benchmarking Models for Energy Multicast in Wireless Network Coding. In *Network Coding*. IntechOpen.
- Ajibesin, A. A., Ventura, N., Chan, H. A., & Murgu, A. (2014). Service Productivity in IT: A Network Efficiency Measure with Application to Communication Systems. *International Series in Operations Research and Management Science*, 2015, 241–261. Advance online publication. doi:10.1007/978-3-662-43437-6_14
- Aldamak, A., & Zolfaghari, S. (2016). A Two-Stage Prediction Model for DEA Efficiency Scores. *Proceedings of the 13th International Conference on Data Envelopment Analysis*.
- Aliyu, O., Okpo, U. O., Anene, E. C., & Abraham, U. U. (2016). Traffic Congestion Analysis in Mobile Macrocells. In *International Conference on Information and Communication Technology and Its Applications*. The Federal University of Technology, Minna, Nigeria.
- Alwaddood, Z., Noor, N. M., & Kamarudin, M. F. (2011). Performance Measure of Academic Departments Using Data Envelopment Analysis. *IEEE Symposium on Business, Engineering, and Industrial Applications*. doi:10.1109/ISBEIA.2011.6088844
- Ayo-BeUo, O. A., Aibinu, A. M., & Onwuka, E. N. (2014). Call Setup Success Rate in GSM Network Using Citizen Sensing Approach: A proposal. *11th International Conference on Electronics, Computer and Computation*.
- Budu, J., & Boateng, R. (2015). Richard Mobile Service Capabilities: Evidence from a Ghanaian Mobile Service Provider. *International Journal of E-Services and Mobile Applications*, 7(3), 1-17.
- Charnes, A., Cooper, W., & Rhodes, E. (1978). Measuring the efficiency of decision-making units. *European Journal of Operational Research*, 2(6), 429–444. doi:10.1016/0377-2217(78)90138-8
- Eli-Chukwu, N. C., & Onoh, G. N. (2017). Improving Service Accessibility (CSSR) In GSM Network using an Intelligent Agent-Based Approach. *International Journal of Computer Engineering in Research Trends*, 4(11), 478-486.
- Emuoyibofarhe, O. N., Oyetunji, K., Awokola, J. A., & Oladeji, A. E. (2015). Performance Analysis of Traffic Control Congestion Management in Mobile Wireless Communication in South West of Nigeria. *Journal of Multidisciplinary Engineering Science and Technology*, 2(7).
- Fagbohun, O. O., & Adetan, D. O. (2017). Assessment of the effectiveness of telecommunication delivery among operators of GSM in Ekiti State. *International Journal of Scientific and Technology Research*, 6(11), 170–175.
- Galadanci, G. S. M., & Abdullahi, S. B. (2018). Performance Analysis of GSM Networks in Kano Metropolis of Nigeria. *American Journal of Engineering Research*, 7(5), 69–79.
- Ifeoma, N. (2015). Evaluation of the Quality of Service of Global System for Mobile Telecommunication (GSM) Operators in Nigeria. *Journal of Multidisciplinary Engineering Science and Technology*, 2(7), 1686–1694.
- Kayisire, D., & Wei, J. (2016). ICT adoption and usage in Africa: Towards an efficiency assessment. *Information Technology for Development*, 22(4), 630–653. doi:10.1080/02681102.2015.1081862
- Kehinde, A. I., Lawan, S., Adunola, F. O., & Isaac, A. I. (2017). GSM quality of service performance in Abuja, Nigeria. *International Journal of Computer Science. Engineering and Applications*, 7(3-4), 29–40.
- Meza, L. A., de Mello, J. C. C. B. S., Gomes Júnior, S. F., & Moreno, P. (2018). Evaluation of Post-graduate Programs Using a Network Data Envelopment Analysis Model. *Dyna*, 85(204), 83–90. doi:10.15446/dyna.v85n204.60207
- Moreno, P., Andrade, G. N., Angulo-Meza, L., & Soares de Mello, J. C. C. B. (2015). Evaluation of Brazilian electricity distributors using a network DEA model with shared inputs. *IEEE Latin America Transactions*, 13(7), 2209–2216. doi:10.1109/TLA.2015.7273779
- NCC. (2019). Available: <https://www.ncc.gov.ng/statistics-reports/research-reports>
- Nigam, V., Thakur, T., Sethi, V. K., & Singh, R. P. (2012). Benchmarking of Indian Mobile Telecom Operators Using DEA with Sensitivity Analysis. *Benchmarking*, 19(2), 219–238. doi:10.1108/14635771211224545

- Ononiwu, G., Akinwale, B. O. H., Agubor, C., & Onojo, J. (2016). Performance Evaluation of Major Mobile Network Operators in Owerri Metropolis of Nigeria. *International Association of Scientific Innovation and Research*, 16(304).
- OSDEA. (2019). Available: <https://opensourcedea.org/>
- Paço, C. M. L., & Pérez, C. J. M. (2015). Assessing the Impact of Information and Communication technologies on the Portuguese Hotel Sector: An Exploratory Analysis with Data Envelopment Analysis. *Tourism & Management Studies*, 11(1), 35–43.
- Papadimitriou, A. C., & Prachalias, C. P. (2009). Estimating the Efficiency of Marketing Expenses: The Case of Global Telecommunication Operators. *Journal of Economics and Business*, 12(2).
- Segun, I. P., Aderemi, A. A., Nasir, F., & Joke, A. B. (2018). Data on the Key Performance Indicators for Quality of Service of GSM Networks in Nigeria. *Elsevier Data in Brief*, 16(C), 914–928. PMID:29541680
- Sulaiman, M. S., Hemed, N. S., & Wei, J. (2018). Evaluation of Telecommunication Companies Using Data Envelopment Analysis: Toward Efficiency of Mobile Telephone Operator in Tanzania. *International Journal of e-Education, e-Business, e-Management Learning*, 8, 174–182.
- Tarkaa, N. S., & Pahalsan, C. A. D. (2019). Analysis of Drop- Call Probability: A Study of Mobile Telecommunication Network (Apapa Lagos, Nigeria). *International Journal of Research and Innovation in Applied Science*, 4(7).
- Tella, A., Adetoro, N., & Adekunle, P. A. (2009). A Case Study of the Global System of Mobile Communication (GSM) in Nigeria. *European Journal of Marketing Upgrade*, 10(2), 54–59.
- Toloo, M., Emrouznejad, A., & Moreno, P. (2015). A linear relational DEA model to evaluate two-stage processes with shared inputs. *Computational & Applied Mathematics*, 36(1), 1–17. doi:10.1007/s40314-014-0211-2
- Upadhyay, R. K., Singh, V. K., & Kumar, R. (2014). Performance Analysis of GSM Network. *International Journal of Advanced Research in Science and Engineering*, 3(5).
- Usman, A. U., & Ozovehe, A. (2015). Performance Analysis of Gsm Networks in Minna Metropolis of Nigeria. *Nigerian Journal of Technology*, 34(2), 359–367. doi:10.4314/njt.v34i2.21
- Vandana, K., & Sudhakar, M. (2019). Quality of Service Parameters Evaluation for Real Time Traffic in Cellular Networks. *International Journal of Recent Technology and Engineering*, 8(1S4).
- Zhang, H., Song, W., Peng, X., & Song, X. (2012). Evaluate the Investment Efficiency by Using Data Envelopment Analysis: The Case of China. *American Journal of Operations Research*, 2(02), 174–182. doi:10.4236/ajor.2012.22020

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