Students' Subscribers Ranking of Mobile Network Operators Using Analytical Hierarchical Process

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Abstract. There have been rapid advancement and increase in the numbers of subscribers to services provided by different Mobile Network Operators (MNO) in Nigeria today. Hence, making the right choice among the available MNOs is a decision which many users especially students need to make intelligently. This study evaluates subscriber's satisfaction of quality of service provided by the four dominant MNOs in Nigeria which are MTN, GLO, AIRTEL and 9MOBILE. The assessment task is done by using Analytic Hierarchy Process model which is constructed base on some criteria so as to select the most suitable mobile network operator for users. Six criteria associated with MNO QoS were carefully selected for the study associated. Results obtained show that Customer care interaction & response is the most important criteria with a priority weight of 0.44985, while Network coverage, Promotion & Bonuses, Tariff Plan, Quality of calls and Internet speed and got the values of 0.24725, 0.11884, 0.11553, 0.04342, 0.02509 respectively in that order. Also, GLO is found to be the most preferable mobile network operator with a numerical weight of 0.45466 with 9mobile (0.24006), Airtel (0.18609) and MTN (0.08417) in 2nd, 3rd and 4th ranks respectively.

Keywords: Multi-criteria Decision Making · Quality of Service · Assessment

1 Introduction

Mobile Network Operator (MNO) is a telephone company that provides network services for mobile phone users. Other services provided by them include internet connectivity, voice and video calls, short message service (SMS) and many others services.

In Nigeria, there are majorly four MNOs which are MTN, Glo, Airtel and 9mobile. These MNOs have contributed favorably to Nigeria's economic progress in recent years as a result of unprecedented growth in the number of subscribers using the services over the years. This growth is partly due to the massive deployment of infrastructure by the four MNO in the country. However, this comes with a stiff competition in the country with each MNO trying to attract subscribers to use their services [1, 2]. As at February 2023, there are about 226 million subscribers in Nigeria with the statistics of their

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distribution shown in Fig. 1 [3] obtained from Nigeria Communication Commission. In order to satisfy and retain these teeming customers, the quality of service (QoS) provided by the MNOs must be excellent. In addition, for them to succeed in today's competitive marketing environment and enjoy customers patronage, it is imperative that the mobile telecommunication industry develop the ability to determine the critical needs of customers and thereby satisfy them. These may come in form of mobile network quality of service (QoS) preferences among existing MNOs.

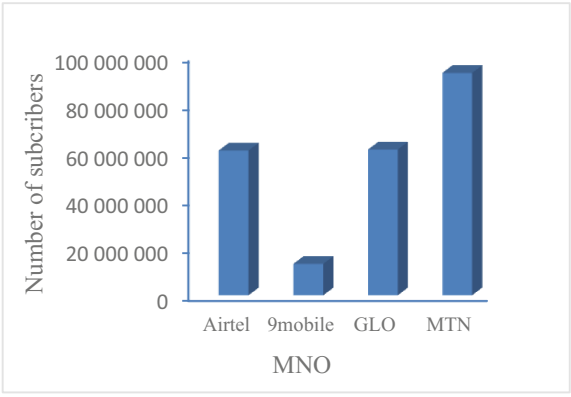

Fig. 1. Market share by MNOs.

In general, subscriber's satisfaction should be the ultimate goals of various MNO [4]. Many subscribers who are students have expressed one form of dissatisfaction or the other with services rendered them over the years. Some of the some challenges facing them include poor network coverage, epileptic internet access, communication breakdown, poor network, expensive tariff and data plans [4, 5]. This necessitates the need for serious decision making among subscribers on which MNO to choose and patronize. However, this decision-making process is a complex task which involves analysing and evaluating multiple parameters. The parameters in this case include network coverage, quality of call, speed of data, call price, customer care support and so on.

Subscribers are faced with making decision as to the choice of MNO is the face of competing organisations rendering competing services offered by different alternative MNOs. Selecting the best criteria on the part of the decision maker is another crucial decision that must be taken so as to get the best services. In this scenario, a lot of ambiguity and subjectivity are involved, hence the need to employ Multi-criteria Decision Making (MCDM) to tackle the problem [6, 7].

One way of solving the problem of selecting the best MNO base on service quality by subscribers is by using a variant of MCDM known as the Analytical Hierarchical Process (AHP) which is a mathematical technique. This approach have been applied in many telecommunication aspect [4, 8, 9]. The ultimate goal of AHP is to provide a rating of alternatives using pairwise comparisons as inputs, in accordance with the principle of relative measurement. The AHP belongs to the crossroads of decision analysis and

operations research. It has also proven to be widely accepted decision making tool [10, 11].

Thus, this research aims to develop an AHP model to assist subscribers to decide on the best MNO that fit their service preference based on some criteria. The paper focus on students of the Federal University of Technology Minna, Nigeria which is one of the leading specialized universities located in North Central Nigeria. Six unique criteria identified and used in the study are Tariff Plan (TP), Network Coverage (NC), Quality of calls (QC), Customer care response & interaction (CC), Promotion & Bonuses (PB) and Internet Speed (IS).

2 Multi-criteria Decision Making

MCDM is composed of Multi-attribute Decision Making (MADM) and Multi-objective Decision Making (MODM) [12]. AHP belongs to the class of MADM which is made of the alternatives, decision weights, multiple attributes and decision matrix. Each of these is described as follows:

i. **Alternatives** provide a limited set of options that enable a decision maker to act. These are further evaluated, prioritized, and ranked.
ii. **Decision weights**: These refer to the values given to the attributes in the order of importance. These weights are typically normalized to equal one.
iii. **Multiple attributes**: Attributes simply represent the various perspectives from which the alternatives can be evaluated. Large number of attributes are usually organized in a hierarchical manner comprising a number of sub-attributes
iv. **Decision matrix**: One way of expressing MADM is through matrix format. A decision matrix A is a $(M \times N)$ matrix where element A_{ij} implies how well alternative A_i performs when compared to decision criterion C_j (for $i = 1, 2, 3,\ldots, M$ and $j = 1, 2, 3,\ldots, N$). The decision maker is also assumed to have determined the relative performance weights of the decision criteria (W_j, for j $= 1, 2, 3,\ldots N$). Let $A = \{A_i$, for $i = 1, 2, 3,\ldots, M\}$ be a set of decision alternatives, and $G = \{g_i$, for $j = 1, 2, 3,\ldots, N\}$ be a set of goals for judging the desirability of an action. Determine which alternative A^* is the most desirable in terms of all relevant goals (see Fig. 2).

In general, MCDM Methods include the following steps:

1. Identifying the best alternative and criteria.
2. Using numerical values to determine the relative importance of the criteria and the effects of the alternatives on these criteria.
3. The numerical values are then processed to determine a ranking for each alternative.

2.1 AHP Model

Professor Thomas L. Saaty developed the Analytic Hierarchy Process (AHP), an MCDM method which is based on three principles viz: The identity and composition principle, the discrimination and comparative judgement principle, and the synthesis principle. It has been proven to be one of the most widely applied MCDM approaches in divers fields in engineering, technology, manufacturing, production, social science, health, etc. [8].

	Criteria				
	C_1	C_2	C_3	...	C_N
Alt.	W_1	W_2	W_3	...	W_N
A_1	a_{11}	a_{12}	a_{13}	...	a_{1N}
A_2	a_{21}	a_{22}	a_{23}	...	a_{2N}
A_3	a_{31}	a_{32}	a_{33}	...	a_{3N}
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
A_M	a_{M1}	a_{M2}	a_{M3}	...	a_{MN}

Fig. 2. An example of decision matrix.

The starting point is to identify the participants and subsequent briefing. This is followed by the first step of goal definition and outlining project scope, key criteria and alternatives. Next is creation of hierarchy. To determine their relative importance, or priorities, pairwise comparison with respect to the objective of the criteria has to be carried out. Thereafter, judgements of the users are subjected to consistency check. Lastly, each alternative is judged on each decision criterion. The AHP model used for this study is depicted in Fig. 3.

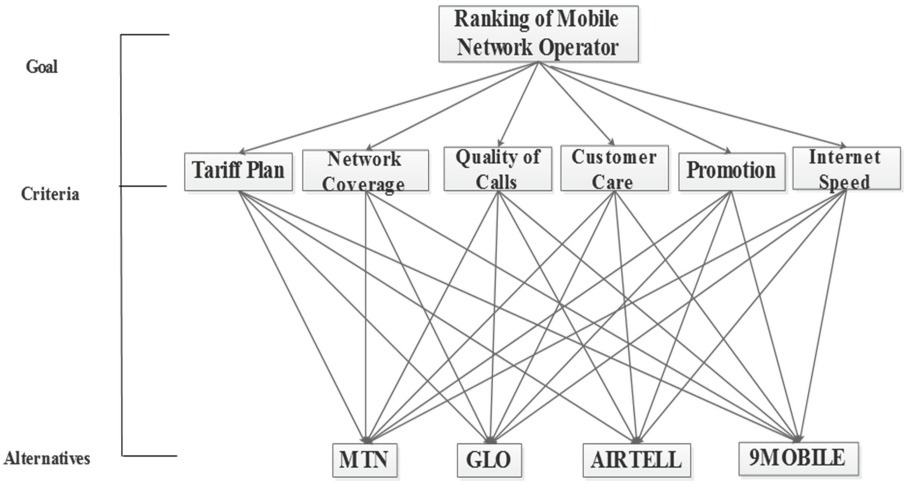

Fig. 3. The hierarchical model based on customers MNO preference.

To assess each alternative's relative performance in terms of each of the deciding criteria, the AHP uses a series of pairwise comparisons which sample is shown in Table 1.

Table 1. AHP Scale in relations to importance.

Scale of importance	Definition
1	Equally important
3	Fairly more important
5	Strongly important
7	Very strongly important
9	Extremely more important
2, 4, 6, 8	Intermediate values
Reciprocal of the values	If choice *a* is NOT preferred to choice *b*, but rather *b* to *a*, then the reciprocal value is used

The concepts of a consistency index (C_i) and a random consistency index (R_i) necessary so to obtain a measure of inconsistency. Based on the theory, if a given reciprocal matrix's consistency index C_i, is close to the consistency index R_i, of a large number of random reciprocal matrices with the same number of elements, the given matrix is as inconsistent as the average of the random matrices, or random [1].

To check the consistency of the judgments, the formula is given is Eq. (1).

$$C_i = \lambda_{\max} - (n/(n-1)), \tag{1}$$

where λ_{max} is the principal eigen value and n is the number of elements in the diagonal. The number of comparisons between the criteria's is determined by $n(n-1)/2$.

Where n is the number of criteria. That is, if there are 6 number of criterions, then the number of comparisons is 15.

Finally, the consistency ratio C_r, is calculated with the following Eq. (2):

$$C_r = C_i/R_i. \tag{2}$$

The process of synthesizing the information begins after the priority vector for each of the matrices in the analysis has been determined.

In summary, the use of AHP and its variants in evaluating users preference in divers areas have been on the increase in recent years [8, 13, 14]. Some of the areas in which it has been used over the years in choice making include library websites [15] course selection [16], telecom provider [5], e-commerce websites [17], subscribers preferences [1], power supply selection [18] among others. Most of these studies were generally focused on the general populace, but this study centers on university students' subscribers who are avarice users of telecommunication platform.

3 Research Methodology

Online survey questionnaire was deployed as a means of data collection for the research. The purpose and objectives of the study with proper briefings are contained in the introductory part. The survey consists of two parts viz; pairwise comparisons of quality

of service criteria and pairwise comparisons of alternatives of the mobile operators. The respondents numerically indicated the relevant importance on the 9-point comparison scale, which is the most commonly used scale. Thirty participants were randomly picked in the school to give their judgments. The questionnaire was distributed in the form of an online questionnaire. Out of these, only twenty responses that were filled correctly were used for the analysis. The AHP model structure used for the formulation of the study questions is shown in Fig. 3.

The first task is to define the goal and scope of the study. This is followed by clear identification of the key criteria and alternatives. The next step is creation of hierarchy. In order to determine the criteria importance or priorities, the criteria are compared pairwise with respect to the objective. Then consistency of the judgements by respondents is tested. Lastly, each alternative is then judged based on each decision criterion.

The criterions that affect the quality of service of the MNO as identified in this research are explained as follows:

i. Tariff plan: This refers to the tax charged by an MNO on services rendered to the users. These services may include voice calls and data subscription.
ii. Network coverage: This is simply the geographical area that a service provider's network covers. At times, there are may be good or poor network coverage.
iii. Quality of call: This describes the effectiveness and efficiency of calls made between two mobile network users. A phone call is said to be efficient and effective if the call made by a user to another connects quickly and it is clear.
iv. Customer care response and interaction: This depicts the communication between a user and a representative of user's network provider.
v. Promotion and Bonuses: These refers to special offers made available to the subscribers from time to time so as to attract patronage and retention by the MNO. It is also used to attract new customers or reward existing ones.
vi. Internet Speed: This is how fast the subscribers are able to access the services available on the internet services provided by the MNO.

In order to determine the relative importance of the six major criteria described above, a criterion pair-wise comparison matrix is carried out. To do this and obtain the first criteria pairwise comparison matrix, the questionnaire was asked to give their relative judgement on how important a criterion is in comparison to others. For example, Tariff plan in comparison to Quality of call. The decision maker will be asked to select a number from the comparison scale as shown in Table 1 that best represents their judgment.

For instance, if internet speed is strongly more important than the quality of call, then the response will be will be 5. The reverse comparison rating will be automatically 1/5. Because there are six criteria, there will be a total of 15 comparisons. i.e., from the formula given in Eq. (3):

$$Number\ of\ comparison = n(n-1)/2. \tag{3}$$

After completing the criteria pairwise comparison matrices, they are then asked to complete preference pairwise comparison matrices for the MNOs which are MTN, GLO, Airtel, and 9Mobile. After the preference pairwise comparison matrix is completed for each alternative, the datasets collected in the data entry matrix is then computed.

The process of synthesizing the information begins after a priority vector for each of the matrices in the analysis has been determined. There will be one priority vector for the overall objective's criteria and one priority vector for each criterion against which the alternatives are ranked.

Java was used to code the responses and generate the pairwise comparison matrix from the inputs, normalizes the matrix to calculate the priority eigen vectors and the priority eigen value, calculates the CR (consistency ratio), choose eligible cases (CR below 0.1). The algorithm used is shown in Table 2.

Table 2. Algorithm for criteria weights.

Input: users data obtained from online questionnaire	
Output: Criteria weight	
1.	*Begin*
2.	*WHILE i< c do where i = 0, c = number of criteria*
3.	*Input range of the criteria*
4.	*Enter the input data row by row from the pairwise comparison*
5.	*Convert to pairwise comparison matrix*
6.	*Add the columns of the matrix*
7.	*Normalize the weight by dividing each element by the sum of its column*
8.	*Obtain the principal eigen vector for respective rows by adding the elements of the respective row and dividing by the range of the criteria.*
9.	*IF rows and columns are equal in step 7*
10.	*Compute the principal eigen value by adding the product of the eigen vectors and the sum of column of the normalized matrix.*
11.	*ELSE*
12.	*ENDWHILE*
13.	*End*

4 Results and Discussion

4.1 Criteria Weights

First, local weight scores for the first and second layer of the AHP model were calculated. Consequently, global weight scores were yielded by multiplying the first layer weights and the second layer weight scores. The pairwise comparison and priority weight (PV) for the six criteria used in the study is shown in Table 3.

The priority score of the criteria is checked using Eqs. (1)–(3). The consistency ratio obtained is 0.0673 which is <0.1 and the principal eigenvalue is 6.337. The results indicated that Customer care response & interaction (CC) with Priority (PV) of 0.44985 was the most important evaluation factor for MNO quality of service assessment. This is followed by Network Coverage (NC), Promotion & Bonuses (PB), Tariff Plan (TP), Quality of calls (QC) and Internet Speed (IS) in the 2nd, 3rd, 4th, 5th and 6th positions respectively.

Table 3. Pair-wise comparison and priority of the criteria based on AHP.

	TP	NC	QC	CC	PB	IS	PV	Rank
TP	1	0.25	3	0.17	1	7	0.11553	4th
NC	4	1	3	0.5	3	8	0.24725	2nd
QC	0.33	0.33	1	1	6	9	0.04342	5th
CC	5.88	2	1	1	1	7	0.44985	1st
PB	1	0.33	0.17	1	1	7	0.11884	3rd
IS	0.14	0.13	0.11	0.14	0.14	1	0.02509	6th

4.2 Alternative Priority

The priority among the alternatives is computed by using the global criteria weights (*WC*) of each factor obtained from above and the four alternatives' local weight scores (LCW) for the six criteria. The sum of the product index becomes the final weight of an alternative. The local scores for each alternative's in terms of the six evaluation factors are presented in Table 4.

Table 4. Alternative priority weight.

	TP	NC	QC	CC	PB	IS	PV	Score	Rank
MTN	0.083	0.091	0.057	0.128	0.064	0.071	0.051	**0.08417**	4th
GLO	0.716	0.603	0.520	0.522	0.064	0.609	0.176	**0.45466**	1st
AIRTEL	0.149	0.256	0.124	0.128	0.254	0.251	0.161	**0.18609**	3rd
9MOBILE	0.051	0.048	0.297	0.221	0.617	0.067	0.256	**0.24006**	2nd

Each value of PV per alternative was obtained by formulating the pairwise comparison matrix our alternatives based on each of the criteria. For example, Table 5 shows the comparison matrix base on Tariff Plan (TP) by using the AHP algorithm to derive the priority vector (PV), principal eigen vector (PEV) and the consistency ratio (CR).

Table 5. Evaluated alternatives based on Tariff Plan (TP).

	MTN	GLO	AIRTEL	9MOBILE	PV	PEV	CR
MTN	1	0.14	1	0.25	0.083	3.87	0.0124
GLO	7	1	7	9	0.716		
AIRTEL	1	0.14	1	4	0.149		
9MOBILE	4	0.11	0.25	1	0.050		

From the results obtained in Table 5, the alternatives ranking shows that GLO was the most preferred mobile network provider with a weight of 0.46566, followed by 9mobile, Airtel and MTN which have weight of 0.24706, 0.18609 and 0.08775 respectively. This is presented in chart in Fig. 4. From the analysis, the subscribers considered Tariff Plan (TP), Network Coverage (NC), Quality of calls (QC), Customer care response & interaction (CC), Promotions & Bonuses (PB) and Internet Speed (IS) as almost equivalently important factors when assessing the quality of service assessment of mobile network operators.

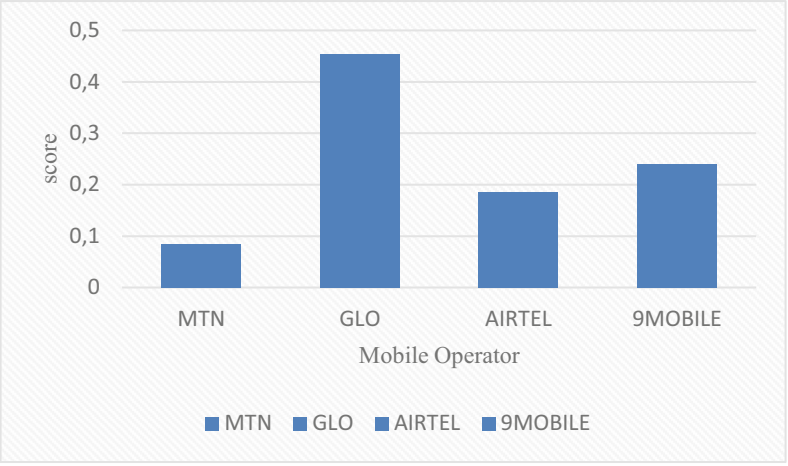

Fig. 4. Pie chart representation of the alternative ranking.

Nonetheless, CC was found the most important factor among the six criteria which accounts for almost half of the value (44%). This implies that this particular set of users takes customers care response and interaction very serious. It was surprising that CC is perceived not as pivotal as Internet speed. This could be explained by relative emphasis on the quick fix and response to demands and needs of users, also the ease of relationship between users and their mobile network operators.

Besides Customer care response & interaction, Network coverage (NC) was found slightly more important than Quality of calls (QC) when evaluating quality of service assessment of mobile network operators. Particularly. This is logical, since the availability of a network coverage equals the quality of the calls made and somewhat determines the internet speed, which ranks next to quality of calls in that particular area coverage.

5 Conclusion

This study evaluates mobile network operator quality of service assessment by utilizing the AHP model. By using six criteria; Tariff Plan (TP), Network Coverage (NC), Quality of calls (QC), Customer care response & interaction (CC), Promotions & Bonuses (PB) and Internet Speed (IS) was proposed as the first layer criteria for the model. Four

Nigeria mobile network providers were selected as the alternatives: MTN, GLO, Airtel and 9Mobile. The results indicated that customer care response & interaction, promotion & bonuses and network coverage were the prominently important factors when evaluating the quality of service assessment of mobile network operators. Taking the pairwise comparison of the alternatives and the individual weights of each criteria into consideration, GLO, was the most preferred mobile network provider, 9Mobile, Airtel and MTN ranked second, third and fourth respectively.

The following conclusion and recommendation can be drawn from the study based on the results obtained: CC contributes approximately twice (44%) to NC and thrice to TP and PB. This implies subscribers are more concerned with timely response to their request and challenges than any other factor. The least factor here is internet speed which means they are more comfortable with network coverage and other things. It may be due to the fact that generally the internet speed is low across different network So available may be of utmost priority to them. Also, taking into consideration the subject of the study who are mainly students, the preferences on the choice of criteria is not surprising. Future work can be done by extending to other type of subscribers and also employ the use of other MCDM techniques.

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