

Improvement of Mobile Network Performance Ranking Using QoS KPI Index in Nigeria

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Abstract - This article introduces a novel approach to enhancing mobile network operator (MNO) performance ranking in Nigeria through the development and implementation of a Quality of Service Key Performance Indicator (QoS KPI) Index. As mobile technologies evolve and reliance on mobile services increases, the need for robust and comprehensible network performance metrics becomes critical. This study addresses gaps in current methodologies, which often assess Quality of Service (QoS) parameters independently, by aggregating multiple QoS Key Performance Indicators (KPIs) into a single comprehensive metric. By applying the Analytical Hierarchy Process (AHP), the research develops a QoS KPI Index that combines various network performance indicators into a unified ranking system. This index is validated against consumer complaints and empirical data to ensure its relevance and accuracy in reflecting the actual network performance experienced by users. Significant findings illustrate the utility of the QoS KPI Index in benchmarking MNOs' QoS performance, providing a clear empirical basis for ranking that can influence user choice and regulatory strategies aimed at enhancing network quality across Nigeria.

Keywords: QoS KPI Index, Mobile Network Performance, Quality of Service (QoS), Nigerian Telecommunications, Analytical Hierarchy Process (AHP), Mobile Network Operators (MNOs), Tower Companies (TowerCos), Network Performance Metrics, Regulatory Framework, Telecommunications Market Nigeria.

I. Introduction

In today's rapidly evolving telecommunications ecosystem, the quality of service (QoS) provided by Mobile Network Operators (MNOs) plays a crucial role in shaping user experiences and satisfaction. The introduction of new technologies and the proliferation of mobile devices have exponentially increased the demand for reliable and high-quality mobile network services. As such, the need for effective mechanisms to evaluate and rank the QoS delivered by MNOs has become paramount. This study introduces a

mechanism for improving mobile network performance ranking in Nigeria using the QoS KPI Index. This index amalgamates various QoS KPIs monitored and reported by the Nigerian Communications Commission (NCC) into a single, comprehensive metric for evaluating and ranking MNOs' voice service performance.

Table 1: Fundamental Scale for Pairwise Comparison

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities or criteria contribute equally to the objective
3	Moderate importance of one over another	One activity or criteria moderately favored over another
5	Essential or strong importance	One activity or criteria strongly favored over another
7	Very strong importance	An activity or criteria is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgements	When compromise is needed
Reciprocals	If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	

II. Background to the Study

The Nigerian telecommunications sector has experienced remarkable growth and transformation over the last twenty years, particularly following the licensing of GSM mobile

telecommunications providers. With the increasing adoption of mobile devices and the growing demand for data services, mobile operators face significant challenges in maintaining high QoS standards across their networks. The sector's rapid growth between 2001 and 2010 was driven by voice services on 2G networks. The prevalence of 2G services, due to widespread 2G network coverage and 2G-capable mobile devices in Nigeria, alongside the availability of 3G and 4G services, especially in urban and suburban areas, reflects the evolving telecommunications landscape.

According to NCC statistics (2023), the subscriptions to services on different technology generations as of November 2023 were: 2G services - 59.32%, 3G services – 9.81%, 4G services – 29.91%, and 5G services – 0.96%. Mobile telecommunications services constitute 99.79% of the total 223,220,009 subscriptions to telecommunications services in Nigeria (NCC 2023). The telecommunications industry is dominated by four major providers: 9mobile (6.27%), Airtel (27.51%), Globacom (27.62%), and MTN (38.59%).

The NCC, as the regulatory body overseeing the telecommunications industry in Nigeria, has been actively involved in monitoring and enforcing QoS regulations to ensure that subscribers receive satisfactory service (NCC Annual Report 2021). The NCC monitors and measures different network performance metrics for evaluating the network performance of operators. These metrics, published periodically on the NCC website, include four main QoS KPIs: Call Setup Success Rate (CSSR), Call Drop Rate (CDR), Standalone Dedicated Control Channel Congestion (SDCCH), and Traffic Channel Congestion (TCH). These KPIs measure the Accessibility (CSSR, SDCCH, TCH) and Retainability (CDR) of QoS dimensions for 2G services. Measures for other QoS perspectives (Availability, Mobility, and Integrity/Quality) are not currently published by NCC.

Table 2: Preference Scale for Pairwise Comparison

Preference Level	Numeric Value
Equally Preferred	1
Equally to Moderately Preferred	2
Moderately preferred	3
Moderately to Strongly Preferred	4
Strongly Preferred	5
Strongly to very strongly Preferred	6
Very strongly Preferred	7
Very strongly to extremely Preferred	8
Extremely Preferred	9

III. Conceptual Framework

The conceptual framework for the dissertation on "Improvement of Mobile Network Performance Ranking Using QoSKPI Index in Nigeria" integrates the foundational elements of Quality of Service (QoS) and Key Performance

Indicators (KPIs) in mobile telecommunications. It is based on the premise that a comprehensive assessment of mobile network performance can be achieved through the QoSKPI Index, which combines various performance indicators to reflect the service quality experienced by users.

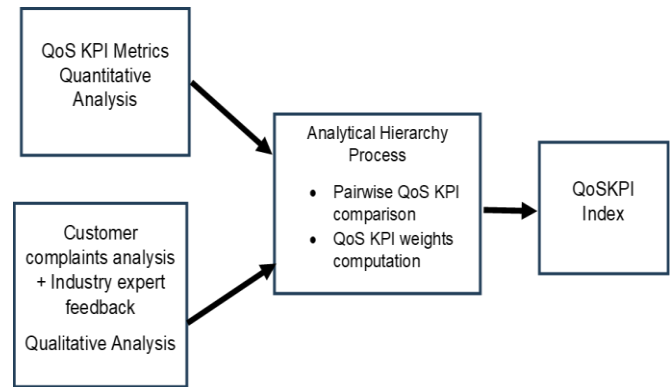


Figure 1: High Level QoS KPI Index Development Process

IV. Methodology

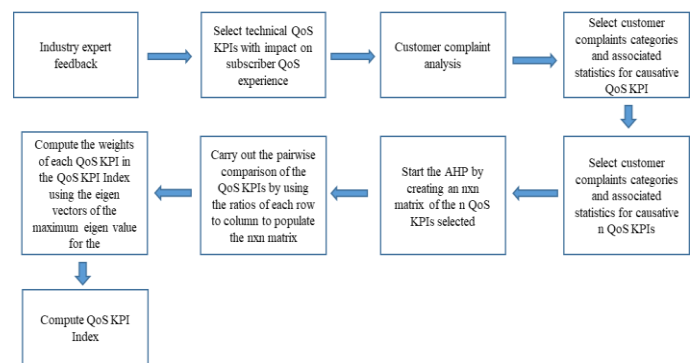


Figure 2: Detailed QoS KPI Index Development Process

This study adopts a mixed-methods approach, incorporating both qualitative and quantitative data collection and analysis methods. The research design includes the development of the QoS KPI Index through the Analytical Hierarchy Process (AHP), a structured technique for organizing and analyzing complex decisions. The AHP method was chosen for its ability to handle multiple criteria decision-making problems, allowing for a systematic comparison of the various QoS KPIs. The study area covers Nigeria as a whole where the four dominant MNOs operate. The stakeholders engaged during the study are MNOs, the regulator (NCC), Passive Infrastructure providers (TowerCos), and technology vendors.

V. Data Collection and Analysis

Data was collected from multiple sources, including NCC publications, MNO reports, and feedback from identified stakeholders. The primary QoS KPIs considered in this study

were CSSR, CDR, SDCCH, and TCH, which are crucial indicators of network performance impacting user’s quality of service experience. The AHP process was used and it involved the following steps:

1. Definition of the Problem and Criteria: The primary objective was to develop a comprehensive QoS KPI Index that accurately reflects MNO performance. The criteria for the index were the four main QoS KPIs.
2. Structure the Hierarchy: A hierarchical model was developed, with the overall goal (QoS KPI Index) at the top, followed by the main criteria (QoS KPIs), and finally, the sub-criteria representing the specific performance metrics for each KPI.
3. Pairwise QoS KPI comparison: The number of complaints for each complaint category for a day was utilised to determine the scale of importance of one impacted QoS KPI over the other in the pairwise comparison table. That is assuming KPI A has x complaints and KPI B has y complaints, then the scale of importance of KPI A over KPI B in the AHP matrix table will be $\frac{x}{y}$ and for KPI B over KPI A will be $\frac{y}{x}$. As the AHP scale is from 1-9, any ratios of complaints greater than or equal to 9 will be rounded to 9. All the KPI metrics identified are compared against each other to form a square nxn matrix. Where n is the number of QoS KPIs utilized in the pairwise comparison.

4. QoS KPI weights computation: The maximum Eigen value is computed using the “eig” function of MATLAB. The Eigen vectors that correspond to the maximum Eigen value are the weights of the various KPI metrics that make up the $n \times n$ square matrix realised from the pairwise comparison utilizing the AHP process.

Based on the above, the model below as derived:

$$\text{QoS KPI Index} = w_1 \times KPI_1 + w_2 \times KPI_2 + \dots + w_n \times KPI_n \quad [1]$$

Where:

$KPI_1, KPI_2, \dots, KPI_n$ are the different KPIs used to compute the QoS KPI Index

w_1, w_2, \dots, w_n are the weights of the KPIs utilised for computing the KPI index

5. Consistency Check: The consistency ratio was calculated to ensure that the pairwise comparisons were consistent. A consistency ratio of less than 0.1 was considered acceptable.
6. Aggregation of Weights: The final QoS KPI Index was calculated by aggregating the weighted scores of each KPI using Equation [1], providing a single comprehensive metric for evaluating MNO performance.

Table 3: Questionnaire shared with Stakeholders

S/N	Question in Questionnaire	Stakeholder Category Interviewed
1	How do you prioritize infrastructure investments to optimize QoS indicators such as signal strength and network uptime?	TowerCo, MNO, OEM, Industry Regulator
2	What infrastructure challenges most significantly impact KPIs like call drop rate from your perspective?	TowerCo, MNO, OEM, Industry Regulator
3	Which QoS KPIs do you believe are most directly influenced by the quality and distribution of masts and towers across different regions?	TowerCo, MNO, OEM, Industry Regulator
4	In areas with high user density, what KPIs should be weighted more heavily to ensure a consistent quality of experience for the maximum number of users?	TowerCo, MNO, OEM, Industry Regulator
5	How does the physical environment around mast and tower locations affect signal propagation, and what measures do you take to mitigate negative effects on KPIs?	TowerCo, MNO, OEM, Industry Regulator
6	Could you discuss the role of backup power solutions and their impact on QoS, particularly in terms of availability and reliability KPIs?	TowerCo, MNO, OEM, Industry Regulator
7	How do advancements in tower technology, like smart antennas and MIMO, change the prioritization of traditional QoS KPIs?	TowerCo, MNO, OEM, Industry Regulator
8	What are the most critical factors to consider when planning new tower sites to enhance network performance and user satisfaction?	TowerCo, MNO, OEM, Industry Regulator
9	How do you foresee the integration of small cells and DAS impacting the relative importance of different QoS KPIs in urban settings?	TowerCo, MNO, OEM, Industry Regulator
10	Can you provide insights into the future challenges that tower infrastructure might face with emerging technologies and services, and how should MNOs prepare to maintain QoS?	TowerCo, MNO, OEM, Industry Regulator
11	Which QoS KPIs have a direct impact on subscriber experience with respect to setting up calls, receiving calls, sending and receiving sms and signal availability	TowerCo, MNO, OEM, Industry Regulator
12	Prioritise the QoS KPIs identified in Question 11 above starting with the most critical in your view	TowerCo, MNO, OEM, Industry Regulator

VI. Results and Discussion

The QoSKPI Index developed in this study integrates various network performance indicators into a comprehensive metric. The validation of this index against consumer complaints and empirical data confirms its relevance and accuracy. In addition, the reliability and applicability of the QoS KPI Index, was compared with the QoS KPI Index based on the Boulmaf and others (2008) QoS Index. The results demonstrate that the QoSKPI Index provides a clear and empirical basis for ranking MNOs utilizing consumer complaints as a basis for determining importance of one QoS KPI metric against another. The outcome of the study can influence user choices and regulatory strategies aimed at enhancing network quality across Nigeria. The study's findings emphasize the importance of adopting the QoSKPI Index as a standard tool for regulatory and operational purposes to elevate the quality of mobile services and enhance user satisfaction.

Impact of QoS KPI Index on Regulatory and Consumer Decision-Making

The adoption of the QoSKPI Index by telecom regulators can significantly enhance the regulatory framework for monitoring and enforcing QoS standards. By providing a unified and transparent metric for evaluating MNO performance, the QoSKPI Index can facilitate more effective regulatory interventions and promote competition among MNOs to improve their service quality. Additionally, the QoSKPI Index can empower consumers with reliable information to make informed decisions when choosing their mobile service providers, thereby driving market competition and incentivizing MNOs to continuously enhance their network performance.

Figure 3 and 4 shows outcome with an MNO as well as combined industry data respectively.

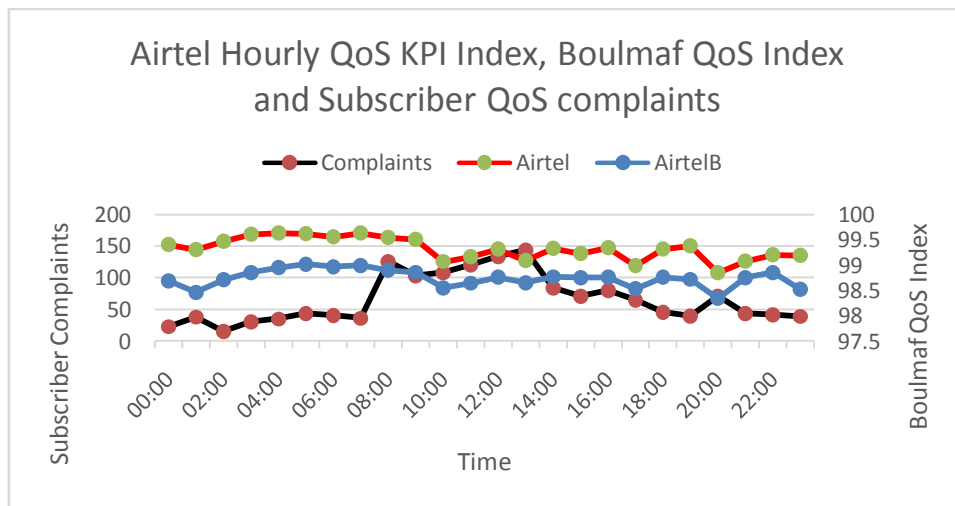


Figure 3: Graph of Hourly QoS KPI Index (Airtel), Boulmaf QoS Index (AirtelB) and Subscriber Complaints for Airtel

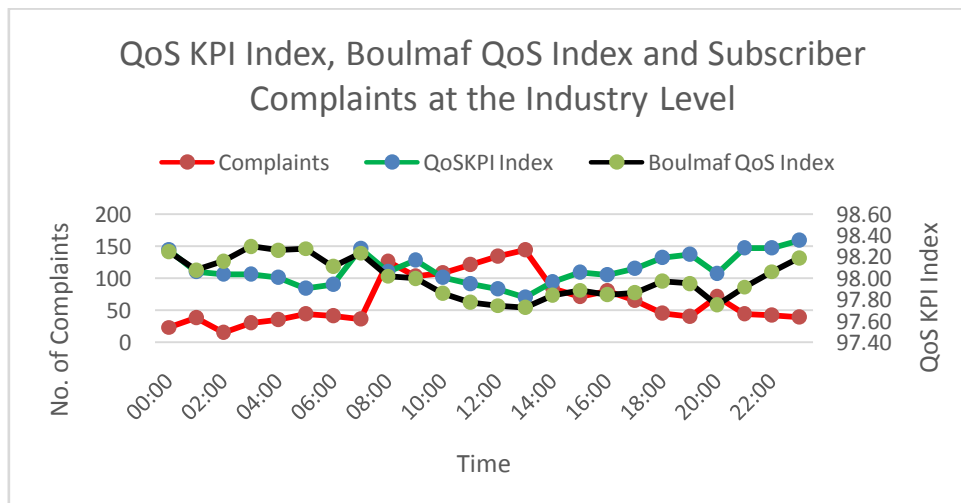


Figure 4: Graph of Combined MNOs Average QoS KPI Index, Boulmaf and Others (2008) QoS Index and Number of Subscriber Complaints

VII. Case Studies and Validation

Several case studies were conducted to validate the QoS KPI Index. Combined data from the regions and various MNOs were analyzed to test the robustness and reliability of the index. The case studies revealed that the QoS KPI Index accurately reflected the variations in network performance across different MNOs and closely tracks the subscriber complaints trends and trends. For instance, in regions where MNOs had invested significantly in network infrastructure, the QoS KPI Index showed higher scores, indicating better performance. Conversely, in areas with reported consumer complaints about poor network quality, the QoS KPI Index scores were lower, corroborating the empirical data. This can be seen from Figure 3 and Figure 4.

VIII. Challenges and Limitations

While the QoS KPI Index provides a comprehensive and effective tool for evaluating MNO performance, several challenges and limitations were identified during the study. One major challenge is the availability and reliability of data, as inconsistencies in data reporting by MNOs can affect the accuracy of the index. Additionally, the current scope of the QoS KPI Index is limited to voice services on 2G networks. Future research should aim to expand the index to include other services, such as data and messaging, and other network technologies, such as 3G, 4G, and 5G.

IX. Conclusion

The introduction of the QoS KPI Index represents a significant advancement in the evaluation and ranking of mobile network performance in Nigeria. By providing a comprehensive and customer-centric metric, the QoS KPI Index can enhance the understanding of mobile network performance and support the improvement of service quality in the telecommunications industry. The adoption of this index by regulatory bodies and MNOs can lead to improved network performance, greater user satisfaction, and a more competitive telecommunications market in Nigeria.

X. Recommendations

1. Adoption by NCC: The NCC should adopt the QoS KPI Index as a standard tool for evaluating and ranking MNO performance. This will ensure a more transparent and effective regulatory framework for monitoring and enforcing QoS standards.
2. Utilization by MNOs: MNOs should utilize the QoS KPI Index to identify areas for improvement in their network performance. By focusing on the key performance indicators, MNOs can implement targeted strategies to enhance their service quality.

3. Expansion of the Index: Future research should explore the application of the QoS KPI Index in other regions and for other types of services beyond voice. This will provide a more comprehensive assessment of mobile network performance.
4. Data Accuracy and Reporting: Efforts should be made to ensure the availability and reliability of data used in the QoS KPI Index. Standardized data reporting protocols should be established to maintain consistency and accuracy.

CONTRIBUTIONS TO KNOWLEDGE

This study contributes to the field of telecommunications by providing a methodological framework for assessing and improving mobile network performance through a customer-centric lens. The QoS KPI Index offers a holistic approach to evaluating QoS, which can drive regulatory and operational improvements in the telecommunications industry. By integrating multiple QoS KPIs into a single comprehensive metric, the QoS KPI Index provides a clear and empirical basis for ranking MNOs, influencing both regulatory strategies and consumer decisions. This study underscores the importance of adopting innovative approaches to enhance the quality of mobile services, ultimately benefiting consumers and promoting a competitive telecommunications market in Nigeria.

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