FEDERAL GOVERNMENT OF NIGERIA

NIGERIAN COMMUNICATIONS COMMISSION

FINAL REPORT

for

MACHINE LEARNING AND DATA ANALYTICS FOR MOBILE COMMUNICATIONS NETWORK PLANNING (SRFP. NO. 001/NCC/RD-6/2022)

Submitted by

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ABSTRACT

This comprehensive study investigates the current and future landscape of machine learning (ML) and data analytics adoption in mobile communication network planning and optimization within Nigeria. Utilizing a cross-sectional approach, the research incorporates surveys, focus group discussions, and key informant interviews to uncover trends, challenges, and opportunities in the sector.

The findings highlight the diverse market segments of telecommunications companies, varying in size and geographical coverage. Despite employing a range of methodologies for network planning, including ML algorithms, the adoption of data analytics and ML remains modest at 42%. Challenges faced by companies encompass network congestion, capacity management, and adapting to urbanization.

Data collection methods are diverse, managed through various platforms. The study reveals that 69% of companies leverage ML and data analytics for planning, with challenges rooted in organizational culture and budget constraints. Companies employ multiple techniques for demand forecasting, with 68% reporting high accuracy. Recognized benefits include understanding market trends, but challenges involve budget constraints and staff literacy.

The research also concluded that performance evaluation in the industry involves diverse methods and key performance indicators, while collaboration and knowledge-sharing play a crucial role. Summarily, the study finds that ML and data analytics hold significant potential for network planning in Nigeria, recommending increased investment, staff training, collaboration, and exploration of emerging technologies. Further research avenues include network security impact, ethical considerations, and comparative analysis across regions.

ACKNOWLEDGEMENT

Pursuant to the execution of the contract of consultancy for the Study on the level of adoption of Machine Learning and Data Analytics for Mobile Communications Network Planning, and in fulfilment of the reporting requirements as deliverables, Hyjosam Integrated Service Limited hereby presents the Final Report on the project implementation to the Research and Development Department.

More so, the management of Hyjosam Integrated Service Limited greatly acknowledges the leadership of Honorable Minister of Communications and Digital Economy, Dr. Bosun Tijani, Executive Vice Chairman/CEO, Nigerian Communications Commission, Dr. Aminu Maida, and the entire Management Team for the opportunity to conduct this study that is intended to assess the impact of machine learning and data analytics in the telecom industry as well as extrapolate the benefits for network planning optimization and improved customer experience.

Furthermore, Hyjosam wishes to express its sincere gratitude to the Research and Development Department for their cooperation and assistance, especially in providing the needed technical support and interventions, which was of immense contribution towards the success of the project. The Procurement Department of NCC is also acknowledged for ensuring a transparent engagement and payment process.

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LIST OF ABBREVIATIONS AND ACRONYMS

AI- Artificial Intelligence
CAGR- Compound Annual Growth Rate
CSF- Critical Success Factors
DA – Data Analytics
EVC – Executive Vice Chairman
FGD- Focus Group Discussion
GDP- Gross Domestic Product
HM -Honorable Minister
Hyjosam- Hyjosam Integrated Service Ltd
IoT- Internet of Things
ISPs- Internet Service Providers
KII- Key Informant Interview
KPIs- Key Performance Indicators
ML- Machine Larning
MNOs-Mobile Network Operators
NCC- Nigerian Communications Commission
QoS- Quality of Service
RoI- Return on Investment
RoW-Wright of Way

EXECUTIVE SUMMARY

The research aimed to explore the current and future trends, challenges, and opportunities of machine learning and data analytics for mobile communication network planning and optimization in Nigeria. The study was based on a cross-sectional survey of telecommunications companies, as well as focus group discussions and key informant interviews with relevant stakeholders.

The study findings revealed that:

- Telecommunications companies have a wide range of market segments, covering enterprise solutions, national, regional, urban, and suburban areas. They also vary in size, with 47% being micro, 24% being small, 24% being medium, and 4% being large enterprises.
- The telecommunications companies use various methods to plan and optimize mobile communications network infrastructure, such as data analytics platforms, drive tests and simulation tools, terrain analysis and historical usage data, GIS data and predictive modelling, and machine learning algorithms. However, the adoption of data analytics and machine learning is relatively low, given their combined percentage of 42%.

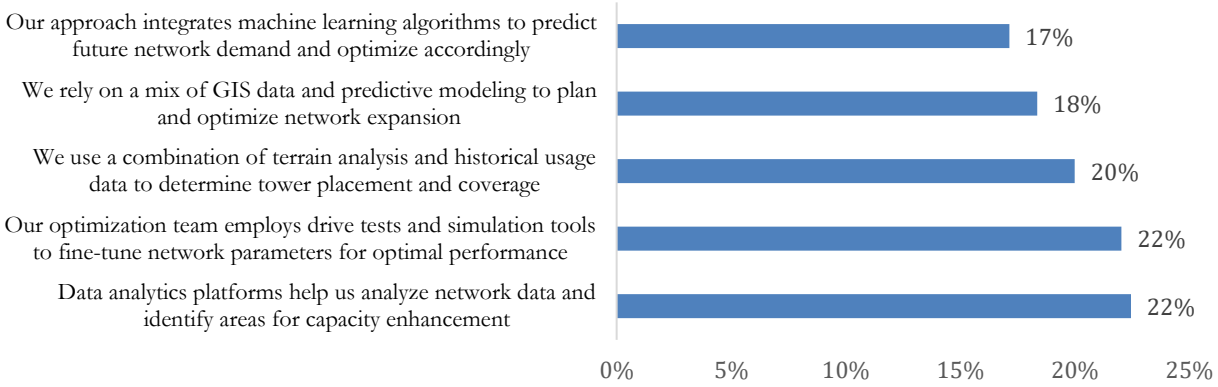

Figure 4.3: Methods Adapted to Plan and Optimize Mobile Communications Network Infrastructure

[Figure 4.3]

- The telecommunications companies face several challenges in network planning, capacity management, and optimization, such as identifying and mitigating network congestion points, balancing capacity needs with limited spectrum resources, adapting to rapid urbanization and fluctuating user behavior patterns,

and scaling infrastructure to meet growing data demands while maintaining quality.

- The telecommunications companies collect various types of data for network planning and optimization purposes, such as coverage maps and drive test logs, network load distribution and handover statistics, signal strength measurements and interference data, user behavior patterns and application usage trends, and call detail records and user session data. They also use various tools or platforms to store and manage the collected data, such as a centralized data warehouse with SQL-based querying, custom-built data repositories with APIs, cloud-based solutions for real-time data streaming and analytics, machine learning-powered data lakes, and big data platforms like Hadoop and Spark.
- Most of the telecommunications companies (69%) leverage machine learning and data analytics techniques for network planning and optimization, while the remaining 31% do not. Many of the telecommunications companies (65%) currently apply machine learning and data analytics techniques for network planning, capacity prediction, or optimization, while the remaining 35% do not. They also use various key performance metrics to evaluate the effectiveness of machine learning models for network planning, such as network capacity utilization and resource allocation efficiency, user experience metrics, prediction accuracy of future network demand, call drop rates and handover success rates, signal-to-noise ratio and mean opinion score, and quality assurance metrics.
- The telecommunications companies encounter various challenges or limitations in implementing machine learning for network planning and optimization, such as organization culture, and decision-making being based more on intuition than data, external constraints or regulations, a lack of data architecture and technology, and a lack of budget and other forms of organizational commitment.
- The telecommunications companies use various methods to forecast and predict the demand for mobile communication services, such as historical trend analysis of subscriber growth and data usage, hybrid models combining statistical methods with AI algorithms, machine learning models predicting future demands based on user behavior patterns, regression models considering external factors such as population growth, and time series analysis incorporating events and holidays. They also incorporate various external factors (e.g., events, holidays, population growth) into their demand forecasting models, such as historical event data using time-based correlation, statistical modelling to account

for seasonal variations and special events, machine learning algorithms detecting patterns in external data impact, external data sources to enhance predictive accuracy, and hybrid models combining event-driven data with user behavior insights.

- The telecommunications companies have different levels of accuracy of their demand forecasting models, with 68% being very accurate, 24% being moderately accurate, and 7% being slightly accurate. They also recognize the relevance of the adoption of data analytics in their network planning, such as understanding market trends, predicting peak network usage, customer centricity, attrition reduction, planning in line with customer preferences, and a cost-effective mechanism to structure the unstructured data. They also face various challenges in the adoption of data analytics in network planning, such as lack of funds to establish fully functioning big data analytics, high cost of purchase, lack of literacy on big data analytics among staff, and reluctance of staff to acquire more knowledge on big data analytics.
- The telecommunications companies use various methods for evaluating the performance of network planning and optimization efforts, such as network load distribution analysis and handover success rate evaluation, regular network audits and comparison with benchmarking standards, KPI tracking and analysis of user experience metrics, machine learning-powered anomaly detection, and continuous monitoring of network congestion points and capacity bottlenecks. They also consider various key performance indicators (KPIs) for network performance evaluation, such as call drop rate and handover failure rate, network utilization and resource allocation, data throughput and latency, signal quality and coverage area, and user satisfaction and customer churn rates. They also identify areas for network optimization and improvement through various sources, such as analysis of user complaints and service tickets, predictive analytics to detect future capacity bottlenecks, machine learning models to identify load distribution disparities, real-time network monitoring to trigger optimization actions, and heatmap analysis of network congestion and coverage gaps. They also measure the impact of network optimization on customer experience and satisfaction by various means, such as monitoring reductions in call drops and data stalls, conducting post-optimization user surveys, tracking improvements in user engagement metrics, measuring the decrease in customer

complaints and support inquiries, and using machine learning algorithms to quantify enhanced user experience.

- Most of the telecommunications companies (75%) actively collaborate with academia, research institutions, or industry partners in the field of machine learning and network planning, while the remaining 25% do not. They also use various methods to promote knowledge sharing and innovation within their organizations regarding machine learning and data analytics, such as allocating time for employees to pursue continuous learning and skill development, encouraging cross-functional teams to collaborate on analytics projects, hosting internal workshops and seminars on emerging technologies, partnering with external training providers to upskill employees in analytics, and establishing an innovation hub for exploring new analytics techniques.
- The telecommunications companies predict various future trends and advancements in machine learning and data analytics for mobile communication network planning, such as the integration of 5G capabilities for real-time analytics and response, a more advanced AI-driven autonomous network optimization, seamless integration of IoT data for dynamic network adjustments, predictive analytics for proactive resolution of network issues, and the evolution of hybrid cloud solutions for scalable data processing. They also face various challenges and obstacles in adopting and implementing advanced analytics techniques in their network planning processes, such as a lack of skilled data science professionals, managing the computational complexity of machine learning models, protecting the security and privacy of sensitive network data, combining different data sources from different vendors, and adapting to changing regulatory requirements.

The study concluded that machine learning and data analytics have significant potential and benefits for mobile communication network planning and optimization in Nigeria, but also face some challenges and barriers in their adoption and implementation. The study recommended that the telecommunications companies should invest more in data infrastructure and technology, train and upskill their staff in data science, collaborate and partner with other stakeholders in the field, and leverage the latest innovations and best practices in machine learning and data analytics for network planning and optimization. The study also suggested some areas for further research, such as the impact of machine learning and data analytics on network security and resilience, the ethical and social implications of machine learning and data analytics for network

planning and optimization, and the comparative analysis of machine learning and data analytics for network planning and optimization across different countries and regions.

CHAPTR ONE
INTRODUCTION

1.1 **Background and Context of The Study**

In recent years, Nigeria's telecommunications industry has experienced significant growth and transformation. As the largest economy in Africa and a country with a rapidly expanding mobile communications sector, Nigeria's telecom industry plays a crucial role in connecting millions of citizens and fostering economic development.

In terms of contribution to GDP, the telecommunications and information services sector in Nigeria in the first quarter of 2023, contributed N2.508 trillion in monetary value to the nation's gross domestic product (GDP), representing 14.13 per cent, which was an improvement to the 13.55 percent recorded in the last quarter of 2022. Meanwhile the sector achieved a record setting all-time high of contribution to GDP of 16.06 per cent in the second quarter, thereby surpassing the previous highest contribution record of 15 per cent achieved in the second quarter of 2022.

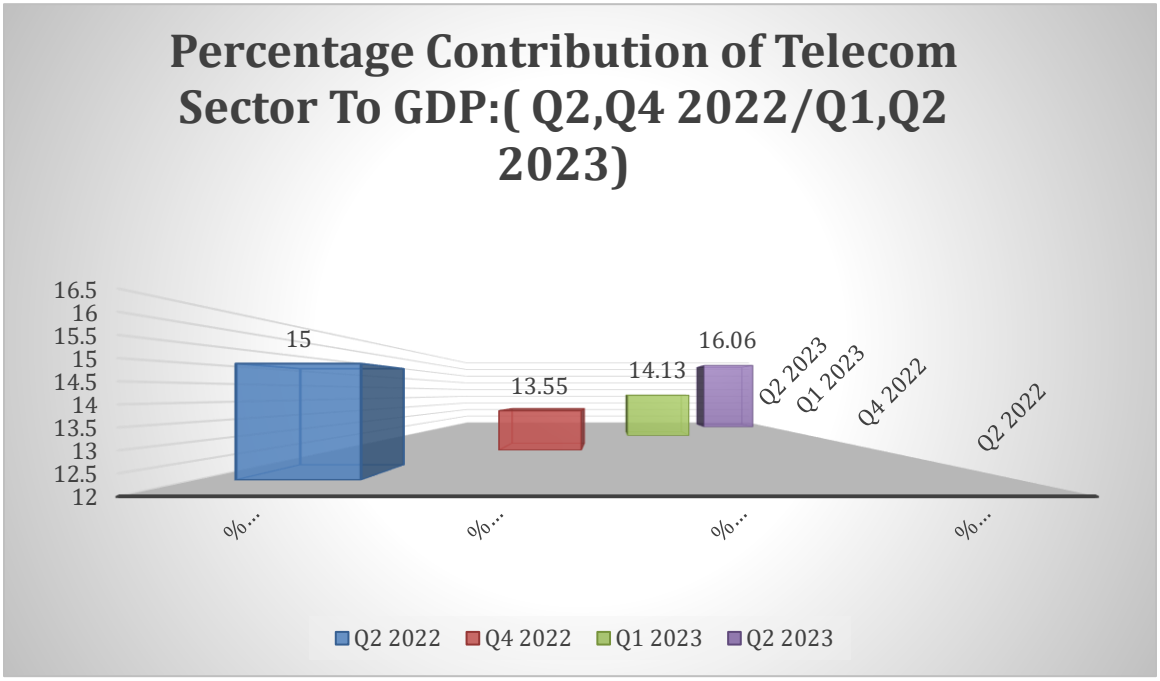

Chart 1.1: Telecom sector contribution to GDP (Q2, Q4 2022 – Q1, Q2 2023).
Source: NCC Industry Statistics & Reports.

When compared on a year-on-year basis, the growth showed a positive progression from 12.94 per cent in the first quarter of 2022, to the 2023 figure of 14.13 per cent in the first quarter of 2023, which is an approximate growth of 1.19 per cent. This is largely attributed to by the innovative and predictable telecom regulatory environment promoted and implemented by the Nigerian Communications Commission (NCC).

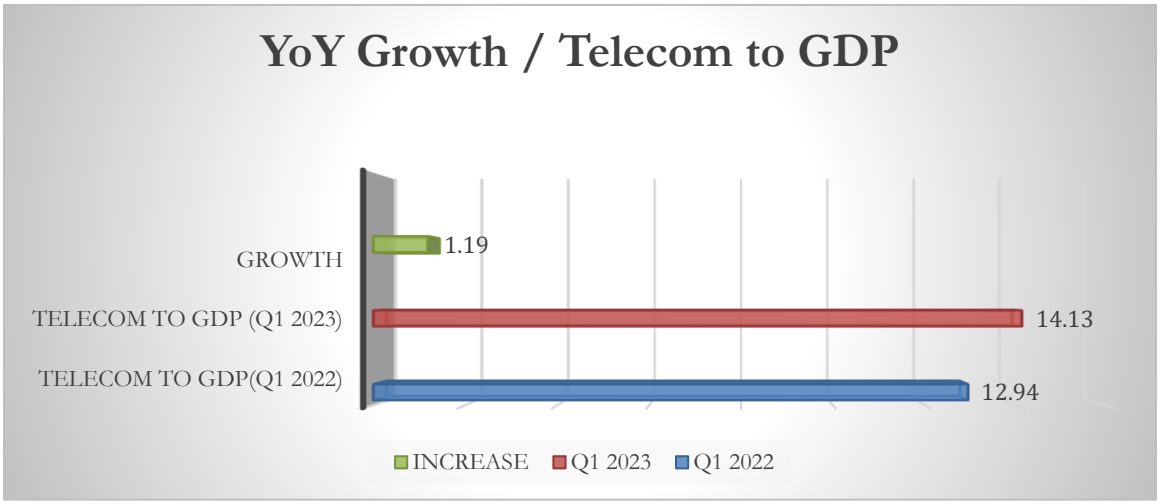

Chart 1.2: YoY Growth – Telecom to GDP (Q1 2022 – Q1 2023)

Market Dynamics

The mobile telecom sector in Nigeria is dominated by four Mobile Network Operators (MNOs), which are MTN, Globacom, Airtel and 9Mobile. The breakdown of the market share as of August 2023 shows that MTN has the lead, controlling 38.58%, followed by Globacom with 27.86% and Airtel coming third with 27.30% while 9 Mobile has 8.26%.

S/N	MNOs	MARKET SHARE
1	MTN	38.58%
2	Globacom	27.86%
3	Airtel	27.30%
4	9Mobile	6.26%

Table 1.1 Market share of mobile telecommunications (August 2023)

Source: NCC Industry Statistics & Reports

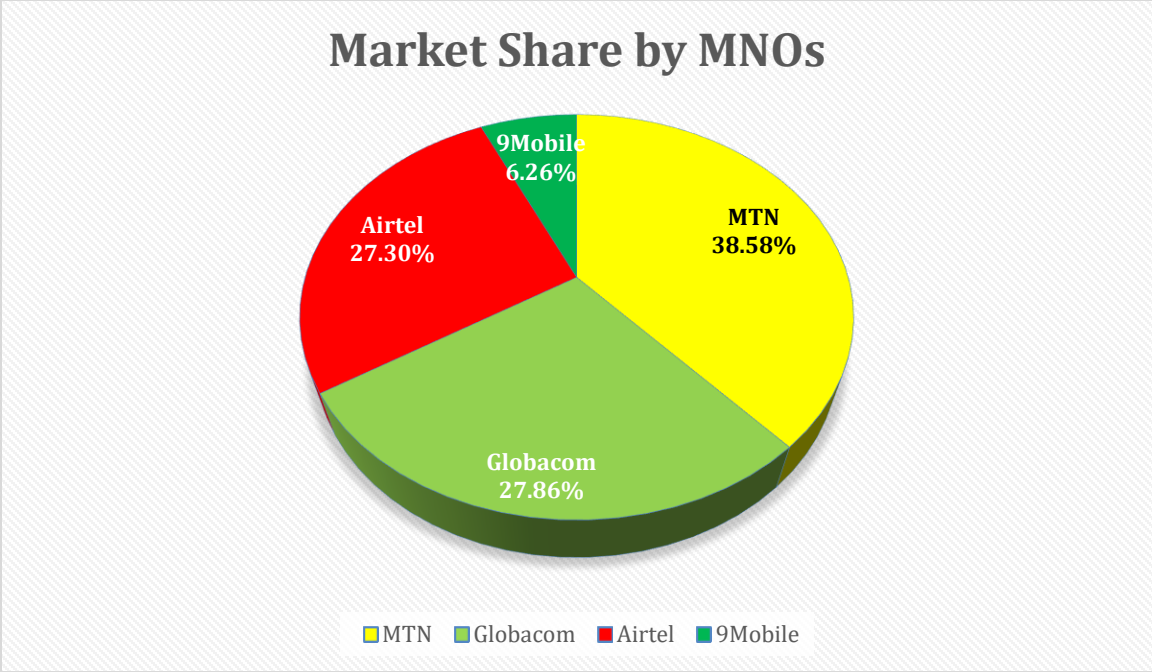

Chart 1.3 Market share of mobile telecommunications (August 2023)

Market Share by Mobile Phone Generation.

In terms of mobile phone generation currently deployed in Nigeria, the respective market share shows a dominance of 2G with 60.47%, followed by 4G with 29.135, while the 3G and 5G has 9.57% and 0.83% respectively.

S/N	GENERATION	MARKET SHARE
1	2G	60.47%
2	3G	9.57%
3	4G	29.13%
4	5G	0.83%

Table 1.2 Market share by mobile phone generation (August 2023)

Source: NCC Industry Statistics & Reports

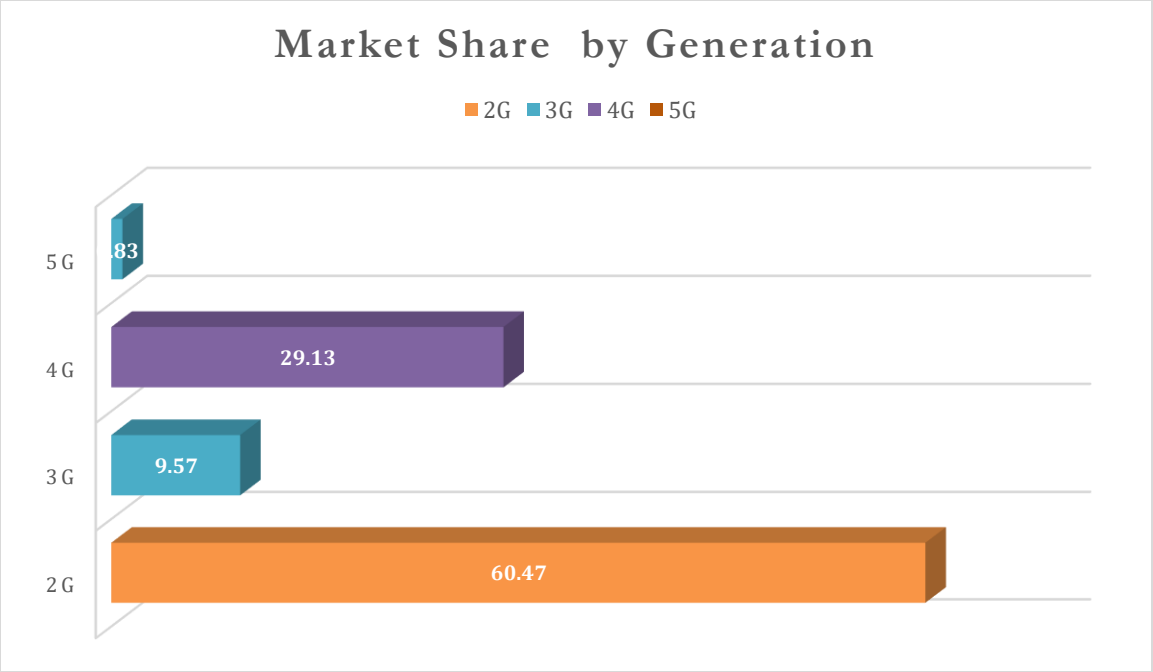

Chart 1.4 Market share by mobile phone generation (August 2023)

Source: NCC Industry Statistics & Reports

Revenue Insights

Based on available data, one of the key highlights of the telecom industry's performance within the period under review (2022 – 2023) was the generation of $820.8 million for the federal government from 5G spectrum licenses fees paid by three eventual winning operators, MTN, MAFAB and Airtel.

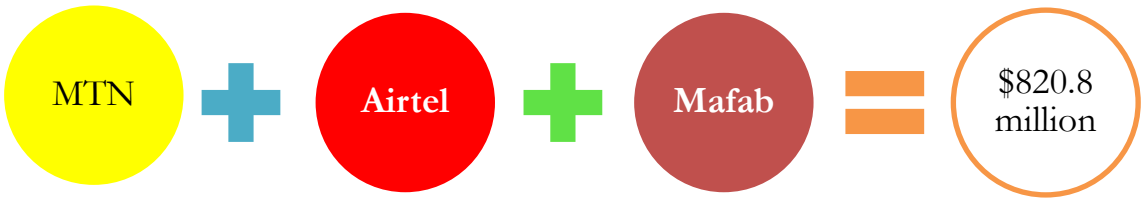

Figure 1.1 5G License Fees (2021/2022) (Source: NCC Briefings)

For instance, following the issuance of the licenses in December 2021 to MTN and MAFAB, both companies have launched 5G services. Airtel, which received its license in December 2022 has equally launched their services in June 2023. Another major development in the sector was the launch of Starlinks broadband services, a satellite-based wireless broadband service with potential nationwide coverage. This followed the issuance of a license to Elon Musk-owned SpaceX by the Commission making the services available in different parts of the country.

Additionally, the growth statistics of the telecom industry cannot be considered in isolation as records has shown that the growth and contributions of the telecom industry to the economy is driven by the number of phone subscribers which as of April 2023, stood at 223.6 million subscribers, scoring a tele density of 117 per cent. Internet subscribers for the same period were 157.6 million while Broadband subscriptions stood at 91.8 million, translating to 48 per cent broadband penetration in the country. However, this growth comes with its own set of challenges, including network planning and management, which are critical to maintaining service quality and expanding coverage.

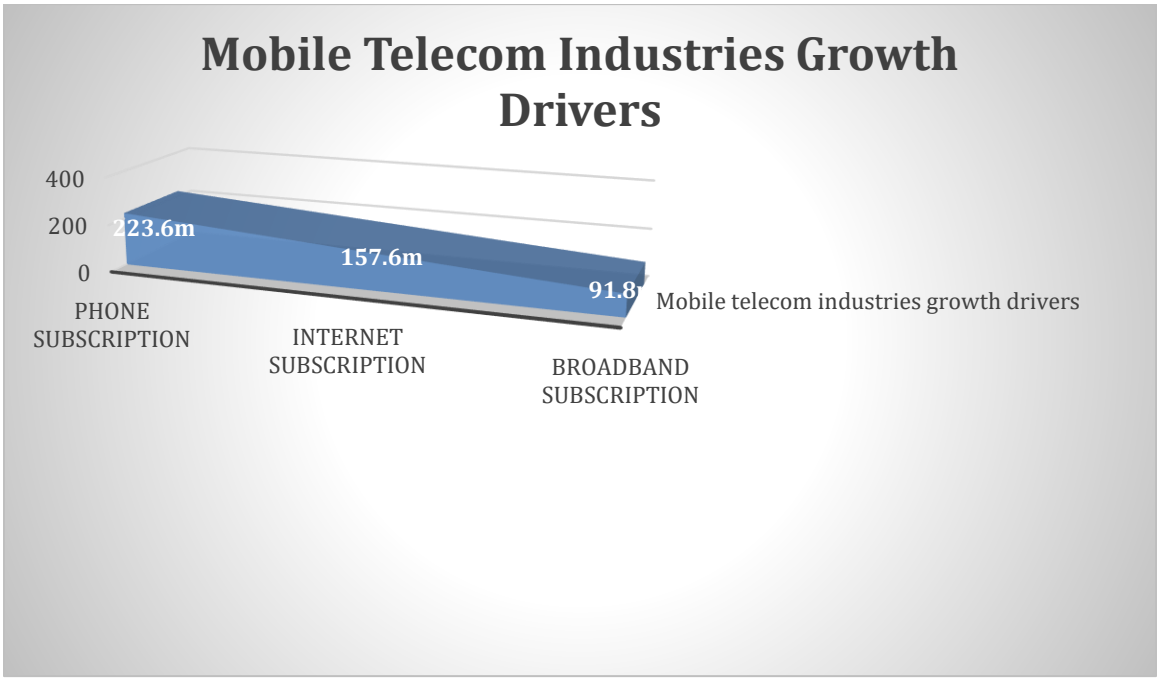

Chart 1.5 Mobile Telecom Growth Elements (April 2023)

Source: NCC Industry Statistics & Reports.

1.1.1 Impact on the Economy

It is evident that the growth of the telecommunications industry in Nigeria has had a significant impact on the economy. The industry has provided job opportunities for Nigerians and has contributed to the growth of the country's GDP. Another major aspect of the telecom industry that has had increasing impact on the economy is the increasing level of adoption of smartphone in Nigeria leading to increase in internet usage. With access to smartphones, Nigerians can connect to the internet more easily and conveniently. This has led to a rise in online activities such as social media usage, online shopping, and streaming of music and videos.

1.1.2 Impact on E-commerce

As mentioned above, the growth of the industry has also led to the rise of e-commerce in Nigeria. With the widespread use of smartphones, more people are now able to access the internet and conduct online transactions. This has led to the growth of e-commerce businesses, creating more job opportunities, and contributing to economic growth.

1.1.3 Financial Inclusion

Another impact of smartphone growth in Nigeria is the increase in financial inclusion. With the rise of mobile money and digital payments, Nigerians can access financial services more easily through their smartphones. This has helped to reduce the number of unbanked individuals in the country and has made financial transactions more efficient and secure.

1.1.4 Education

Smartphone growth in Nigeria has also had a significant impact on the education sector. With access to smartphones, students can access online learning resources and educational apps. This has helped to bridge the gap in access to quality education between urban and rural areas in Nigeria. With the availability of e-learning platforms, students are now able to access educational resources easily, resulting in the growth of online education and has made education more accessible to everyone.

1.1.5 Impact on Society and Social

The impact of smartphone growth rate on society in Nigeria cannot be overlooked. With the widespread use of smartphones, more people now have access to information and can connect with each other easily. This has led to the rise of social media and the use of social media platforms as a tool for communication and activism.

On the flip side, there have been concerns about the quality of telecom services provided in Nigeria. Issues such as dropped calls, poor network coverage, and slow internet speeds have been raised by consumers and industry observers. Critics argue that regulatory bodies should take a more proactive approach in enforcing quality of service standards and ensuring a better experience for users.

In effect, complaints about unsolicited messages, unfair billing practices, and inadequate dispute resolution mechanisms have been raised. Critics argue that regulatory bodies should enhance consumer protection measures and ensure effective enforcement of consumer rights.

The ever-increasing demand for high-quality mobile communication services necessitates a proactive and data-driven approach to network planning. With the increasing use of smartphones and other connected mobile devices, there has been a surge in the amount of data flowing through the networks of telecom operators that needs to be rapidly stored, processed to be able to extract useful insights from the available data.

This is because big data has become important in driving progress in the telecommunication industry. With the right data analytics approach, telecommunication companies can dramatically improve their services and make their subscribers happier. Companies and enterprises that implement big data analytics can reap several benefits such as informed decision-making, improved customer service, and efficient operations. Experts agree that machine learning and data analytics can serve as transformative technologies that can effectively address the current customer and cost challenges in the telecom industry. By harnessing the power of these technologies, telecom companies can optimize network performance, enhance user experiences, and adapt to changing market dynamics.

This survey therefore seeks to explore the current landscape of machine learning and data analytics implementation in Nigeria's telecom sector, specifically focusing on network planning and optimization. It aims to provide telecom industry stakeholders,

including service providers, policymakers, and technology vendors, with valuable insights into the extent to which these advanced technologies are leveraged and the potential for further adoption. Additionally, the survey will examine the perceived benefits, barriers, and prospects of integrating machine learning and data analytics into the telecom industry's network planning strategies.

The findings from this survey will not only offer telecom industry players insights into the current state of machine learning and data analytics integration but will also inform strategic decisions and investment priorities. It will serve as a valuable resource for industry leaders, policymakers, and technology providers as they work together to shape the future of Nigeria's mobile communication network planning, ensuring its continued growth and adaptability in a dynamic and competitive market.

1.2 Problem Statement and Research Objectives

Machine learning today is more advanced than machine learning of the past. It was born from pattern recognition and the theory that computers can learn without being programmed to perform specific tasks; researchers interested in artificial intelligence wanted to see if computers could learn from data.

The iterative aspect of machine learning is important because as models are exposed to new data, they can independently adapt. They learn from previous computations to produce reliable, repeatable decisions and results. It's a science that is not new – but one that has gained fresh momentum.

While many machine learning algorithms have been around for a long time, the ability to automatically apply complex mathematical calculations to big data – over and over, faster, and faster – is a recent development.

Below are a few examples of machine learning applications:

i. The heavily hyped, self-driving Google car? The essence of machine learning.
ii. Online recommendation offers such as those from Amazon and Netflix? Machine learning applications for everyday life.
iii. Knowing what customers are saying about you on Twitter? Machine learning combined with linguistic rule creation.
iv. Fraud detection? One of the more obvious, important uses in our world today.

By way of objective, this study aims to investigate and evaluate the use of Machine Learning (ML) and Data Analytics in network planning in the mobile communications sector. The following objectives have been set:

- To evaluate the level of adoption of machine learning (ML) and data analytics in mobile communications network planning.
- To exploit the information produced by and already available in the network to properly deploy, configure, and optimize network nodes.
- To investigate the level of Network Management (NM) challenges to operators of mobile communications.
- To analyze past relevant information gathered by the network with regards to future deployments.
- To exploit intelligent control decisions tools, offered by ML, based on learning and experience.
- To recommend best practices and ways in which the identified factors and challenges can be solved using the best solution framework or model.
- To enable complex and larger data to be processed and analyzed along with the desired results being achieved such as determining customer trends, detecting fraud, spotting buying trends and other primary objectives.
- To enable operators to keep up with those competitors already making the best use of their data to maximize business opportunities.

1.3 Scope and Limitations of the Survey

This study centered primarily on the Nigerian telecommunications industry, with a specific focus on network planning and optimization in Nigeria. The research will encompass urban, suburban, and rural areas, providing a comprehensive view of the diverse network planning challenges across the country.

The various stakeholders within the Nigerian telecom sector, including mobile network operators, internet service providers, and consumers were the main target of this research. This study was based on a well-rounded understanding of the ecosystem and its dynamics. The study explored the application of machine learning and data analytics in areas such as predictive maintenance, capacity planning, traffic and congestion analysis, and customer experience management in mobile communications network planning.

In the study, we have identified some limitation of this study to include the availability and accessibility of relevant data, which may be restricted due to proprietary constraints as well as the number of participants and their willingness to participate as documented in the field work section of this report. It is therefore important to point out that, while efforts have been made to obtain a representative sample, limitations in sample size could impact the study's generalizability.

1.3.1 Field Work/Survey

The field work activities were conducted in a logical manner that reinforces the key project deliverables and KPIs. The activities were strategically divided into three stages involving eight core activities as follows.

i. Identification and selection of sampled organizations
ii. Circularization and communication of sampled organizations
iii. First level engagement with key personnel of sampled organizations
iv. Nomination of research desk officers as enumerators
v. Administration of questionnaire/ research instrument
vi. Response data aggregation and preliminary analysis
vii. Focus Group Discussion (FGD)
viii. Key Informant Interview (KII)

This approach, in our determination, will be effective in ensuring maximum efficiency in the conduct of the fieldwork and enhancement of the credibility of the process as well as reliability of the outcome.

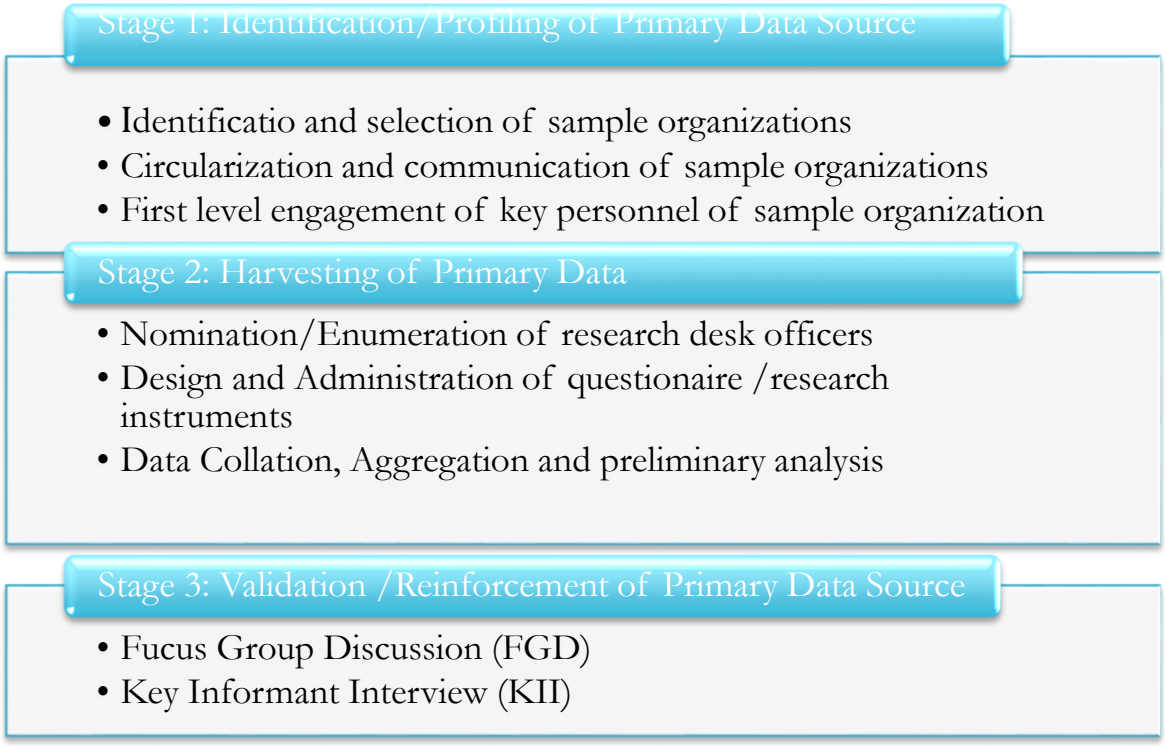

Figure 1.2: Stages of Field Work Activities

1.3.2 Identification and Profiling of Primary Data Source

The first stage of the field work and survey entails three preliminary activities relating to primary data source identification and profiling.

1.3.3 Identification/Selection of Sampled Organization

In consultation with the client (NCC, Research and Development Department) and understanding of the fragmentation of the Nigerian telecom sector, the Mobile Network Operators (MNOs) and Internet Service Providers (ISPs) were identified as key players in the sector whose operations have direct correlations with network planning in the mobile communication subsector, hence constituted the target population for the study.

Taking cognizance of the sample population, we adopted a case study method in which some sample organizations were carefully selected from the small population based on size, location, or market presence, while others were selected using simple random sampling method. Thereafter, we employed an extensive data collection mechanism,

encompassing designation of desk officers to serve as enumerators, interviews, surveys, reports, and observations within each chosen organization.

Suffice to state that the four major national mobile network operators, MTN, Globacom, Airtel and 9 Mobile and top twenty ISPs were seeded and given automatic slots for participation in the sampling process that produced the sample organizations that eventually participated in the study. Criteria such as number of connected and active customers, market segment in terms of domestic/home and corporate/business subscribers, regional spread as well as years of operation, etc. were used in arriving at the prioritized ISPs that featured in the study.

However about 258 licensed service providers in the telecom sector were given the chance of participating in the survey, either as one of the priority samples or through random sampling. A total of eighty (85) sample organizations, including the selected MNOs, were eventually selected for the study. This approach was designed to enhance the validity of the research findings as well as the credibility of the entire exercise.

1.3.4 Circularization and Communication of Sampled Organizations

Having arrived at the required sample organizations, we proceeded with the engagement of the sampled organizations through official written communication, outlining the purpose, expected benefits, modalities for participation and the roles which they are expected to play in the study. A letter of introduction was obtained from the NCC, introducing Hyjosam Integrated Service Ltd to the target sampled organizations and attached to our official letters to the respective organizations.

The letters were eventually delivered directly to the sampled organization by our research team and field staff at their operational office addresses which were obtained from the NCC website as recommended by the project coordinating team of the user department during the project inception meeting or through scouting methods.

Two basic considerations informed our decision to deliver the letters directly through our research team. First, the need to deal with issues of relocation of offices by some of the organizations without a corresponding forwarding address, a situation that defeated the objective of initially engaging professional courier companies for the purpose of delivering the letters to the sampled organizations.

Second, there was a need to have a first level engagement with key personnel of the organizations and secure further commitment and contact information for effective

follow-up. Hence getting our research team to deliver the letters was strategic and it eventually produced a better outcome irrespective of the extended time spent in the process. Nevertheless, the challenge of relocation from the primary operating addresses without a corresponding forwarding address by the sampled organizations remained a major setback in the study, in terms of reaching the target audience, despite the efforts of our research team and the enormous resources committed to the process.

1.3.5 Engagement of Key Personnel of Sampled Organizations.

As a measure for achieving some form of commitment towards the much-needed collaboration and technical partnership from the sampled organizations, our field officers and research team engaged their respective key personnel on a pre-survey interviews and discussions on the purpose and objectives of the study. In most cases, these key personnel were technical staff involved in network planning and monitoring as well as data management activities of the organizations. Such engagement proved helpful in further profiling of the organization in terms of accessibility and suitability, arousing of interest and enthusiasm, allaying some perceived apprehension, pessimism, and mistrust, and thereby boosting the participation level of the target audience in the study. Regrettably, we still could not secure the expected level of cooperation from most of the sampled organizations due to apathy and apprehension, irrespective of the fact that we presented the letter of introduction from the commission.

1.3.6 Harvesting of Primary Data

At the second stage of the field work and having secured the interest and initial commitment of some of the target sampled organizations for participation in the survey, we embarked on the three basic activities designed for the purpose of generating the primary data for the study.

1.3.7 Nomination of Research Desk Officers/ Enumerators

The nomination of designated staff as the research desk officer and enumerator is one of the modalities for the study, which was appropriately communicated to the sampled organizations as part of the participation process. Hence, based on our engagement with the sampled organizations through the letters and series of follow-up discussions, desk officers were nominated by some of the sampled organizations. These desk officers served as the survey enumerators and focal persons for the purpose of communications between the research team and the respective target organizations.

This approach was very effective in terms of getting prompt responses from the sampled organization on the various aspects of the survey activities without necessarily interrupting the office operational schedule and business processes.

1.3.8 Design and Administration of Questionnaire/Research Tools

A well-structured online questionnaire was designed to obtain the required information in the conduct of the study. The questionnaire was a combination of open and close ended questions developed based on empirical evidence emanating from the previous levels of research activities and preliminary engagement with key personnel of some of the sample organizations. The questionnaire was drafted in a manner that will provide information that can help in conducting relevant descriptive, diogenitic and prescriptive analytics, emphasis was placed on generating practical responses and insights that will sufficiently address the objective of the research, scope of the study and key deliverables of the exercise.

Evidently, the questionnaire was successfully administered to the sampled organizations, through the designated research desk officer, via their preferred medium, which is either email or whatsapp. It is important to note that the choice of online questionnaire was based on ethical consideration, flexibility and administrative convenience, anonymity, and to support ease of aggregation and accuracy of the analysis of response, enabling the use of compatible software tools and relevant technology, thereby enhancing operational efficiency and cost effectiveness.

Most importantly, while our dedicated team embarked on prompt follow-up to obtain the survey instrument / questionnaire responses from the target respondents, the responses rate and time were relatively low and did not meet our expectations. However, about 95% response rate was eventually achieved.

1.4 Significance and Relevance of the Study

That the study on the impact of machine learning and data analytics in the mobile communication sector in Nigeria's telecom industry holds paramount significance and relevance for various stakeholders cannot be overstated. It addresses critical areas such as network performance enhancement, operational efficiency, and fostering innovation and competitiveness within the industry.

Soothingly, with increased adoption of these technologies in the industry, regulatory authorities can benefit from informed policy development, while consumers stand to

gain from improved service quality and digital inclusion. The economic implications and the potential for future readiness are substantial, making this study essential for Nigeria's telecom industry's growth and adaptability to global best practices.

More so, in the context of a growing technology powerhouse like Nigeria, which may have legacy technologies and infrastructure in place, the study on the impact of machine learning and data analytics in the mobile communication sector becomes even more relevant and critical because legacy technologies often come with their set of challenges, including outdated infrastructure, limited scalability, and inefficiencies, technology risk, sustainability and business continuity impediments.

1.4.1 Optimizing Limited Resources:

Key market indicators have shown that one of the notable challenges in the telecom industry in Nigeria is largely increase cost of capital investments and without clear cut corresponding financial resources to invest in building entirely new communication infrastructure. To this end, machine learning and data analytics can help optimize the use of existing resources, making it cost-effective to enhance network performance, coverage, and quality thereby increasing investors interest in the sector.

1.4.2 Bridging the Digital Divide:

Legacy technologies can lead to a digital divide where urban areas have better network connectivity than rural regions. This study can provide insights into deploying machine learning and data analytics to bridge this gap, ensuring that remote and underserved areas have access to reliable mobile communication services in a manner that will boost broadband penetration and support the digital economy initiative of the federal government as well as the strategic vision plan of the NCC.

1.4.3 Enhancing Operational Efficiency:

In our engagement with stakeholders in the telecoms industry, we observed that operational costs are a significant concern for service providers. Interestingly, machine learning and data analytics is a more cost-effective tool for streamlining operations, reducing network downtime, monitoring network traffic and congestion, and predicting maintenance needs, thereby increasing the overall operational efficiency of the sector. This efficiency will translate into cost savings that can be reinvested in network expansion and service improvement, which is the essence of this study.

1.4.4 Attracting Investment:

Investors are keen on markets that show potential for growth and innovation. By harnessing machine learning and data analytics to improve mobile communication services, operators can attract foreign and domestic investment, which, in turn, drives economic growth and job creation.

1.4.5 Global Competitiveness:

To compete in the global market, especially within the African continent, the telecoms sector in Nigeria needs a robust and efficient telecom products and services. Embracing modern technologies like machine learning ensures that the operators can compete with nations that have already adopted these innovations.

1.4.6 Digital Transformation:

As the government pushes for increased broadband penetration and expanded digital technology adoption, this study can pave the way for broader digital transformation initiatives in various sectors of the economy. Better mobile communication infrastructure is a cornerstone for e-commerce, e-health, e-education, e-governance, and other digital services that drive economic progress.

CHAPTER TWO
LITERATURE REVIEW

2.1 Mobile Communication Sector in Nigeria

The Mobile Communications sector in Nigeria has witnessed remarkable growth and transformation since the introduction of the Global System for Mobile Communications (GSM) in 2001. Before then, suffice to state that the country had a limited and inefficient fixed-line network that could not meet the demand for telephony services. Therefore, the GSM auction, conducted by the Nigerian Communications Commission (NCC), opened the market to private operators and increased competition, innovation, and investment in the sector.

Notably, the first GSM licenses were awarded to MTN Nigeria, Econet Wireless (now Airtel Nigeria), and NITEL Mobile (now M-Tel). They were later joined by Globacom, Etisalat (now 9mobile), Visafone, Starcomms, and Multilinks. The GSM operators deployed their networks across the country, reaching both urban and rural areas, and offering voice, SMS, and data services.

While the number of mobile subscribers grew rapidly, from 270,000 in 2001, the latest industry statistics, according to the Nigerian Communications Commission (NCC) is put at 29 million in 2022 and a record high of 226.84 million as at July 2023. Also, mobile internet subscriptions grew to 156.42 million, with broadband penetration rising to 48.49 percent and subscriptions hitting 92.56 million in the same period under review, marking a significant increase in the number of people using mobile devices to access the Internet.

Overall, the mobile communications sector in Nigeria has also contributed significantly to the development of other sectors, such as banking, e-commerce, education, health, and entertainment. The emergence of mobile money and fintech platforms has enabled millions of Nigerians to access financial services and conduct transactions using their mobile phones. The growth of e-commerce platforms, such as Jumia and Konga, has equally been facilitated by the availability of mobile internet and delivery services in addition to increasing creation of digital content and services, such as music streaming, video-on-demand, online gaming, and social media.

The mobile communications sector in Nigeria has also faced some challenges over the years, such as inadequate power supply, security threats, multiple taxation, Right of Way (RoW), regulatory uncertainty, and quality of service issues. However, the sector has shown resilience and adaptability to overcome these challenges and continue to provide value to its customers and stakeholders. Suffice to state that the sector has also embraced new technologies and trends, such as 4G LTE, Internet of Things (IoT), Cloud Computing, Artificial Intelligence (AI), and 5G.

Statistically, the mobile communications sector in Nigeria is expected to grow further in the coming years, driven by increasing demand for data services, digital inclusion, and innovation. According to a report by Mordor Intelligence, the Nigeria telecom market size is expected to grow from USD 8.68 billion in 2023 to USD 10.92 billion by 2028, at a CAGR of 4.70% during the forecast period (2023 - 2028) while playing a key role in achieving the national development goals and vision of digital transformation in Nigeria.

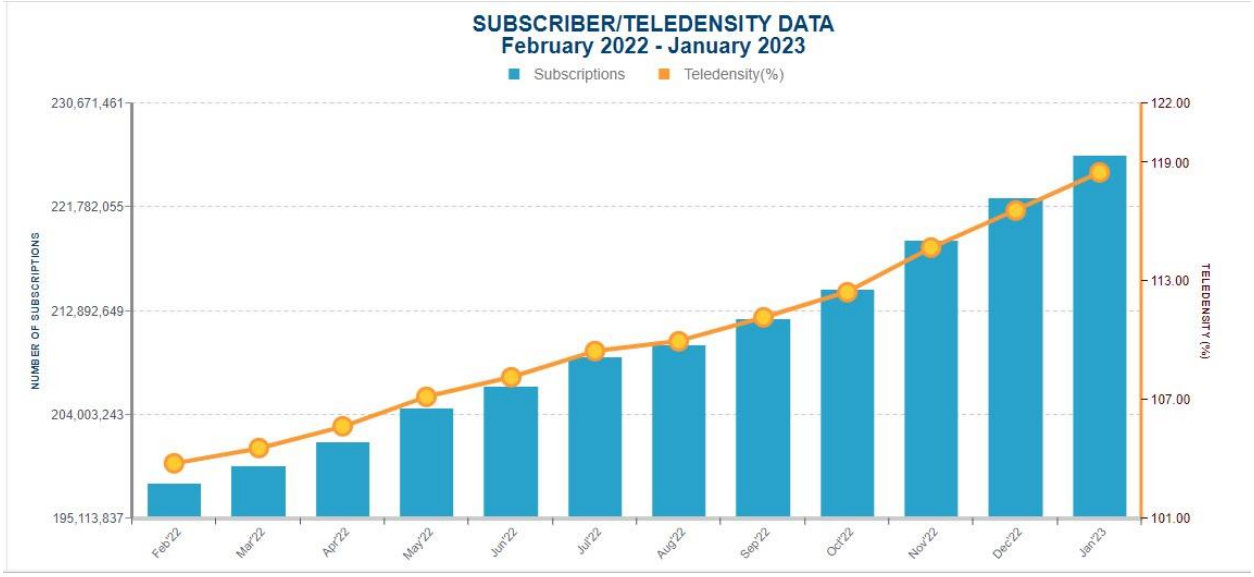

Chart 2.1 Subscriber/Teledensity (February 2022 – January 2023)
Credit: Nairametrics

2.1.1 Network Management in Mobile Communication

The Nigerian telecoms industry has come a long way from its early days of limited state-controlled services. Liberalization, the proliferation of mobile networks, the introduction of advanced technologies like 5G, and the focus on security and

sustainability have shaped the industry's evolution. Network planning and management have become increasingly essential to address the industry's unique challenges and capitalize on its growth and innovation.

Network management plays a pivotal role in the ever-evolving realm of mobile communication, serving as the backbone that supports the seamless flow of data, voice, and multimedia services. With the rapid proliferation of mobile devices, increased data consumption, and emerging technologies like 5G, the landscape of network management is undergoing a significant transformation.

2.1.2 Pre 2021 Telecommunications Era

In the early days of Nigerian telecommunications, services were primarily provided by the state-owned Nigerian Telecommunications Limited (NITEL). The infrastructure was limited, and services were often unreliable. There was little emphasis on network planning or management, resulting in poor service quality.

2.1.3 Liberalization and Mobile Revolution (Early 2000s):

The liberalization of the Nigerian telecoms industry in the early 2000s marked a turning point. Private operators like MTN, Glo, and Airtel (formerly Zain) entered the market, introducing competition and driving the expansion of mobile networks. Network planning became critical to meet the surging demand for mobile services.

2.1.4 3G and 4G Deployments (Mid-2000s to 2010s):

The mid-2000s witnessed the deployment of 3G networks, offering faster data speeds and mobile broadband services. Subsequent years saw the introduction of 4G technology. Network management gained significance as operators needed to ensure network reliability and quality of service, while also addressing issues like power instability and infrastructure vandalism.

2.1.5 The Rise of IoT, Edge Computing, A.I., Network functions virtualization (NFV) and software-defined networking (SDN) and 5G (Late 2010s to Present):

The late 2010s and early 2020s saw the emergence of the Internet of Things (IoT), with applications in agriculture, healthcare, and smart cities. Network planning became more complex, as providers had to accommodate a growing number of connected devices. The advent of 5G technology, Artificial Intelligence amongst other related technologies

presented new opportunities for successful deployment and optimization, high-speed, low-latency services, but it also necessitated significant investment in infrastructure.

2.1.6 Current Challenges and Regulatory Framework:

Throughout history of telecoms industry in Nigeria, the industry has faced various challenges. Security concerns, such as fraud and privacy issues, have persisted. Infrastructure challenges, including power shortages and theft, have required continuous attention. The regulatory framework evolved, introducing licensing requirements, quality of service (QoS) standards, and spectrum management to ensure fair competition and protect consumer interests. As a result of this evolving dynamic landscape, the effective management of mobile communication networks is essential to meet the demands of an increasingly connected world including the following.

2.1.7 Security Concerns:

As mobile networks become more complex and data-intensive, security threats escalate. Protecting networks from cyberattacks and ensuring the privacy of user data is an ongoing challenge.

2.1.8 Network Congestion:

The increase in data traffic often leads to network congestion. Managing this congestion while maintaining quality user experience is a significant challenge.

2.1.9 Interoperability:

Ensuring seamless interoperability between different generations of networks (2G, 3G, 4G, 5G) can be complex. Network managers need to ensure a smooth transition.

2.1.10 Resource Allocation:

Allocating network resources efficiently is crucial. Overlooking resource allocation can lead to network underutilization or overloading.

2.1.11 Compliance and Regulation:

Mobile communication networks must adhere to strict regulatory and compliance standards. Keeping up with these standards and implementing necessary changes is challenging.

2.1.12 Scaling for Future Growth:

Anticipating and preparing for future network growth and user demand is essential as scalability is a constant concern.

2.2 Concepts and Definitions of Machine Learning and Data Analytics.

2.2.1 Concept of Machine Learning and Data Analytics

In the era of big data and technological advancement, the domains of Machine Learning (ML) and Data Analytics have emerged as transformative fields, pivotal to our understanding and utilization of data. Machine Learning, a subset of artificial intelligence, empowers systems to learn from data and improve their performance over time, without being explicitly programmed. It harnesses algorithms and statistical models to unearth patterns, make predictions, and automate decision-making processes.

Data Analytics, on the other hand, focuses on examining, cleaning, transforming, and interpreting data to derive actionable insights and facilitate informed decision-making. Both ML and Data Analytics share a common goal of extracting valuable knowledge from large datasets, yet they employ distinct methodologies and tools.

Machine Learning (ML) and Data Analytics (DA) have become essential tools in the telecom industry, transforming operations and services. Predictive maintenance techniques allow for proactive network maintenance by predicting equipment failures, reducing downtime, and optimizing maintenance schedules.

2.2.2 Machine Learning (ML):

Machine Learning is a subset of artificial intelligence that focuses on the development of algorithms and statistical models, enabling computer systems to learn from and make predictions or decisions based on data without being explicitly programmed. It involves the use of patterns and information extracted from data to improve the performance of tasks, such as classification, regression, clustering, and recommendation.

2.2.3 Data Analytics (DA):

Data Analytics refers to the process of examining, cleaning, transforming, and interpreting data to discover meaningful patterns, relationships, and insights. It involves using various techniques and tools to extract valuable information from data, which can aid in informed decision-making and problem-solving.

2.2.4 Data Mining:

Data Mining is the practice of discovering previously unknown, non-trivial, and potentially valuable patterns and knowledge from large datasets. It involves various techniques like clustering, association rule mining, and anomaly detection to reveal hidden insights within the data.

2.2.5 Supervised Learning:

Supervised Learning is a type of Machine Learning where the algorithm is trained on a labeled dataset, meaning it is provided with input-output pairs. The goal is to learn a mapping from inputs to outputs, enabling the model to make predictions on new, unseen data.

2.2.6 Unsupervised Learning:

Unsupervised Learning is a Machine Learning paradigm where the algorithm is given an unlabeled dataset. It aims to identify patterns or structures in the data, often through clustering or dimensionality reduction techniques, without explicit guidance.

2.2.7 Regression Analysis:

Regression Analysis is a statistical method used in Data Analytics to model the relationship between a dependent variable and one or more independent variables. It is commonly employed to make predictions about continuous numeric outcomes.

2.2.8 Classification:

Classification is a Machine Learning task where data is assigned to predefined categories or labels. It is widely used for tasks like spam email detection, sentiment analysis, and image recognition.

2.2.9 Clustering:

Clustering is an Unsupervised Learning technique that groups similar data points together based on their inherent patterns or characteristics. It is useful for tasks such as customer segmentation and anomaly detection.

2.2.10 Feature Engineering:

Feature Engineering involves the process of selecting, transforming, or creating new features (variables) from the raw data to improve the performance of machine learning models. It requires domain knowledge and creativity.

2.2.11 Data Visualization:

Data Visualization is the presentation of data in a graphical or visual format, making it easier to understand, analyze, and communicate insights. It includes charts, graphs, and dashboards to represent data effectively.

2.2.12 Overfitting:

Overfitting is a common issue in Machine Learning where a model performs well on the training data but poorly on new, unseen data. It occurs when a model becomes too complex and captures noise in the data, rather than the underlying patterns.

2.2.13 Big Data:

Big Data refers to datasets that are extremely large and complex, often beyond the capabilities of traditional data processing methods. Machine Learning and Data Analytics techniques are frequently employed to extract valuable information from such datasets.

2.3 Previous Studies and Existing Research

Available research reviewed so far shows that businesses are leveraging the power of machine learning methods to help them extract better quality information, increase productivity, reduce costs, and extract more value from their data. As the amount of data continues to grow along with the processing power of technology, businesses will continue to incorporate ML into their business. Researchers have found different AI / ML adoption rates. In one study, adoption rate of ML Methods was 10%; in a 2020 study by Mckinsey, adoption rate of AI was 50%. Still, another study found that 42% of companies were currently using AI and 40% of companies were planning on using AI in the next two years. Another 2020 study found that 59% of enterprises have machine learning initiatives either in production or at a proof-of-concept stage.
However, a worldwide survey of data professionals by Kaggle showed that the rate of adoption of machine learning methods varied by country with Israel (63%), Netherlands (57%) and the United States (56%) showing the highest and Egypt (31%), Morocco (24%) and Nigeria (23%) showing the lowest adoption rate. ML adoption also varied by company size, with larger companies having higher adoption rates (61%) than medium (45%) and small (33%) companies.

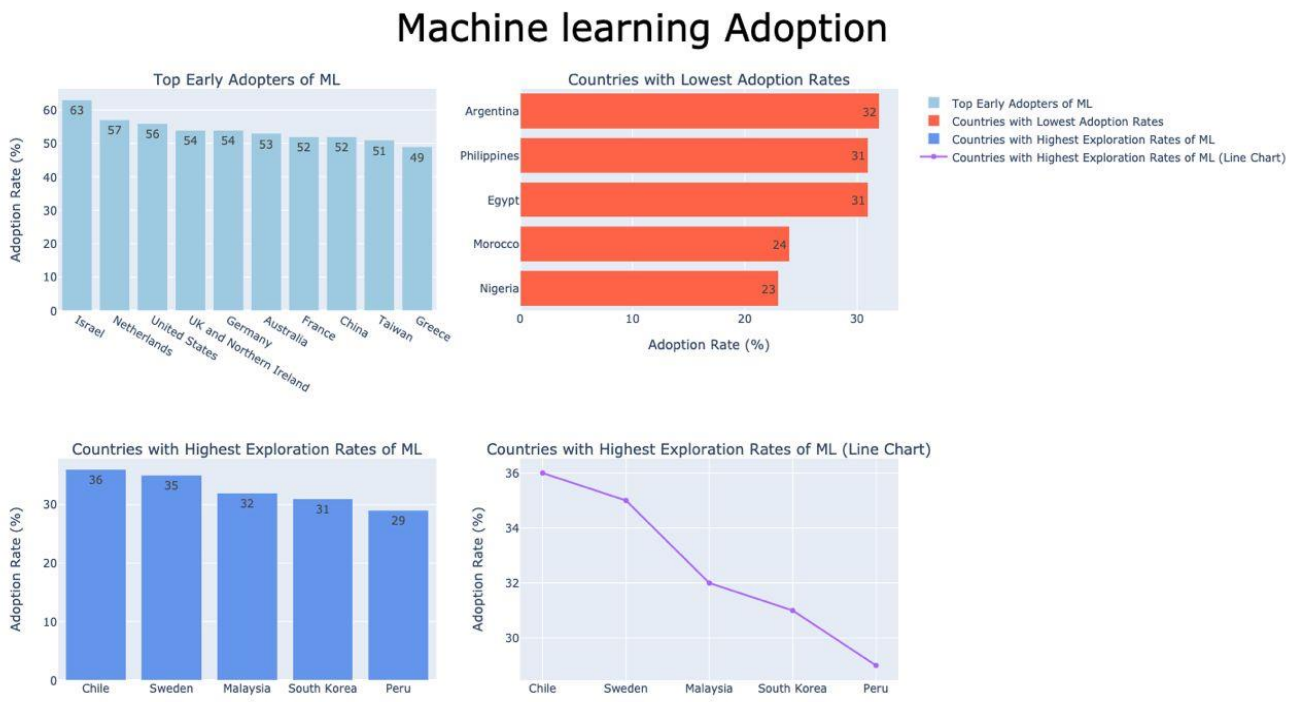

Chart 2.2: Machine Learning Adoption Rate Across Regions.

2.3.1 More so, the integration of Machine Learning (ML) and Data Analytics (DA) in network planning within the mobile communications sector in Nigeria has garnered significant attention from researchers and practitioners alike. A review of previous studies and existing research reveals a growing body of work dedicated to understanding, enhancing, and optimizing the application of these technologies.

In a research titled enhanced predictive data mining algorithm for fraud detection and churn behavior modelling in telecommunication systems, authored by Promise Elechi, Iwok Odudu-Abasi Michael, aimed at identifying and predicting losses in the telecommunications industry, it was revealed that using ML and DA capable of analyzing large amount of data through a complicated network architecture that retains derived patterns in the cloud back-end for analytics was able to provide a prediction threshold for fraud attrition that was superior to Decision Tree (DT) and Logical Regression(LR) in terms of its level of reliability. Therefore, an application running Enhanced Neural Discriminant Analysis (ENDA), which is responsible for the installation of an algorithm on the servers that are part of the Fog Mobile Switching Service (FMSS) layer of the Telecommunication Service Provider (TSP) infrastructure will ensure that an initial fraud alert is sent to users whenever a subscriber who is predicted to be fraudulent makes a call.

M.E. Nwanga, E.N. Onwuka, A.M. Aibinu and O.C. Ubadike in their paper, titled, Impact of Big Data Analytics to Nigerian Mobile Phone Industry concluded that big data analytics can make increasing impact on customer service and revenue generation of mobile phone industry, stating that these technologies in a number of ways holds many opportunities to influence how the telecommunication industry will grow and develop for the better by adding huge data insight for customer services. By deploying these technologies, insightful decision via real-time analytics will help to guide the communication service providers to have business platform that satisfy individual customer needs, reduces operational expenses, and considerably improves revenue. The innovations and strategies derived from investing in big data and analytics generate high Return on Investment (ROI) for the operators. The proper correlations of data help to reveal more complete and deeper insight of customer needs, thus enriching the operators with more revenue. This process translates to advanced ways of capturing and retaining customers with identifiable churn reduction, the authors concluded.

Another research conducted by Busayo Temitayo, Igbekoyi Olusola E. (Ph.D.), Oluwagbade Oluyinka I. (Ph.D.) , Adewara Yink , Dagunduro Muyiwa and Boluwaji Yinka, entitled, Artificial Intelligence and Service Quality of Telecommunication Firms in Nigeria, with the aim of examining the combined impact of artificial intelligence (AI) on the service quality of telecommunications firms in Nigeria revealed that the independent variables collectively had a significant effect on the dependent variable, stating that data mining (DM) was found to have a positive and significant influence on service quality, while machine learning (ML) showed a negative and significant effect. The research concluded that implementing data mining can enhance service quality in telecommunications firms, aligning with existing previous research, this implementation not only improves customer service but also positively impacts firm performance and customer loyalty. On the other hand, machine learning was found to have a negative influence on service quality, contradicting some previous studies. However, variations in specific components of machine learning's impact were observed. Finally, the study confirms that chatbots positively affect service quality, consistent with existing literature and further recommended that telecommunications firms in Nigeria should consider adopting data mining techniques to enhance service quality and achieve better business outcomes.

Instructively, while existing research has made notable strides in understanding and implementation of ML and Data Analytics in network planning within the Nigerian mobile communications sector, several opportunities and challenges remain,

necessitating the need to understand the level of adoption of these technologies by operators in the industry. Therefore, the ever-evolving technology landscape and the need for continuous adaptation present exciting avenues for further research.

2.4 Theoretical Framework

The mobile communications sector has been experiencing significant growth due to a rising urban population and increasing adoption of smartphones. The Nigerian telecom market size is expected to grow from USD 8.68 billion in 2023 to USD 10.92 billion by 2028 at a CAGR of 4.70% during the forecast period (2023-2028). However, increasing cost pressures driven by high energy costs, rising inflation, local currency depreciation and scarcity of foreign currency remain a challenge for operators in this sector, resulting in contested Quality of Service (QoS) in the industry. To address these challenges, the Nigerian Communications Commission is optimistic that increasing adoption of Machine Learning and Data Analytics will enhance operators' capabilities in becoming more competitive and in turn offer better QoS to customers and increase their revenue.

2.4.1 **Objectives**

The objectives of this research paper are as follows:

1. To evaluate the level of adoption of machine learning (ML) and data analytics in mobile communications network planning.
2. To exploit the information produced by and already available in the network to properly deploy, configure, and optimize network nodes.
3. To investigate the level of Network Management (NM) challenges to operators of mobile communications.
4. To analyze past relevant information gathered by the network with regards to future deployments.
5. To exploit intelligent control decisions tools, offered by ML, based on learning and experience.
6. To recommend best practices and ways in which the identified factors and challenges can be solved using the best solution framework or model.
7. To enable complex and larger data to be processed and analyzed along with the desired results being achieved such as determining customer trends, detecting fraud, spotting buying trends and other primary objectives.

8. To enable operators to keep up with those competitors already making the best use of their data to maximize business opportunities.

2.4.2 **Expected Outcomes**

This research paper will use a mixed-methods approach that combines qualitative and quantitative research methods. The qualitative research method will involve conducting interviews with key stakeholders in the mobile communications sector in Nigeria. The quantitative research method will involve collecting data from secondary sources such as academic journals, customer data, industry reports, government publications, and other relevant sources.

To this end, the expected outcomes of this research will include the following:

1. A comprehensive evaluation of the level of adoption of machine learning (ML) and data analytics in mobile communications network planning.
2. A set of best practices for exploiting the information produced by and already available in the network to properly deploy, configure, and optimize network nodes.
3. An analysis of Network Management (NM) challenges faced by operators of mobile communications.
4. An analysis of past relevant information gathered by the network with regards to future deployments.
5. A set of recommendations for exploiting intelligent control decisions tools offered by ML based on learning and experience.

CHAPTER THREE
METHODOLOGY

As a strategy for getting exhaustive participation of the sampled organizations in the survey process and obtaining as much data as will be necessary for the study, a structure of three levels of engagement was adopted as methodological approach. The three level of engagement was strategically designed to secure a progressive participation and enthusiasm from the sampled organizations as well as providing the window to fill any void created at the previous level in terms of supply of critical information and data.

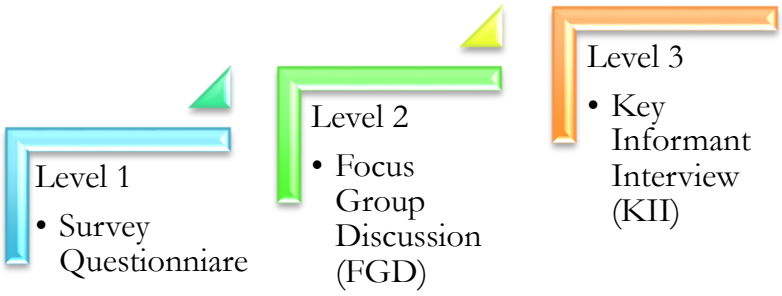

Figure 3.1: Data Sourcing/Stakeholder Engagement Structure

3.1 Research design

The research design adopted for this study is a **mixed-method** approach that combines both qualitative and quantitative data and relies significantly on field survey to answer the research questions. The mixed-method design will enable us to explore the perceptions, experiences, and challenges of using machine learning and data analytics in network planning, as well as to measure the impact, performance, and benefits of these techniques on the mobile communications sector in Nigeria. Most importantly, this approach, will enable us to triangulate the findings from different sources and methods, and to validate the results with empirical evidence.

The specific type of mixed-method design that will be used in this study is the convergent parallel design, which involves collecting and analyzing both qualitative and quantitative data separately and then merging them in the interpretation and discussion stage to enable us to compare the findings from different methods and to corroborate or complement them with each other.

3.2. Data Collection Methods

The data collection methods deployed for this study are:

3.2.1 **Surveys:**

The lack of increased interest on the part of the sampled organizations affected the timeline for the conduct and administration of survey tools. Therefore, currently, we are still awaiting response from the **structured questionnaire** administered to a sample of mobile network operators, service providers, and customers in Nigeria. The questionnaire consists of both **closed-ended** and **open-ended** questions that aim to measure the **awareness, adoption, usage, satisfaction, and challenges** of machine learning and data analytics in network planning. The questionnaire will also collect some **demographic** and **contextual** information from the respondents. The survey data is being collected through an online platform such as Google Forms.

3.2.2 **Focus Group Discussion**

As a key element of the research design and methodology, a focus group discussion was conducted in a virtual format, using zoom meeting platform. The choice of the virtual mode was informed by the need for flexibility, cost effectiveness, administrative convenience, and most essentially, minimizing the interruption of operational and other business schedule of the target audience. More than thirty-two (32) representatives of the sampled organization, especially the MNOs and ISPs as well as randomly nominated mobile communication service users drawn from targeted segments and sectors of the economy, participated in the discussion.

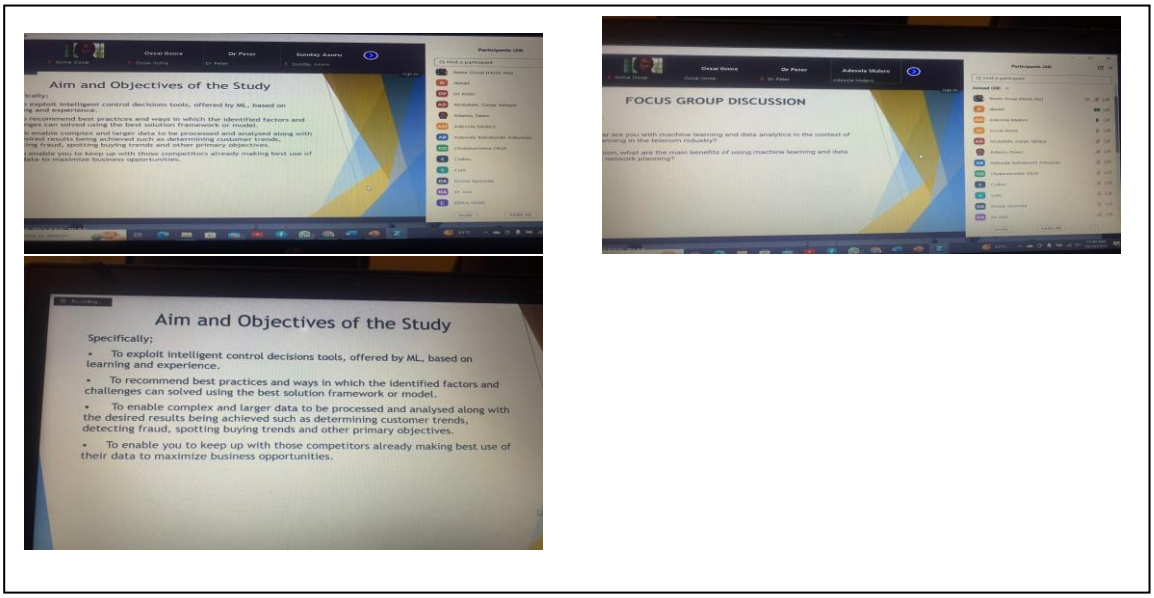

Figure 3.2: Extract of FGD Outline

While the forum offered our research team the opportunity to obtain further insight into the various issues involved in the practical adoption of machine learning and data analytics in the mobile communication sector in Nigeria, it equally afforded the participants, especially mobile communication operators and internet service providers, the avenue for experience sharing as well as gaining more understanding on some of the intricacies of ML and DA in the mobile communication business. Participants expressed consensus views on several issues relating to the practical adoption of ML and DA in the mobile communication industry. Pending our final analysis and interpolation of the data for this research, some of the issues identified and deliberated on during the FGD to include are being presented as follows.

- The mixed level of awareness and familiarity of machine learning and data analytics in the context of network planning in the telecom industry.
- Greater level of understanding of the associated benefits of using machine learning and data analytics in network planning.
- Average rate of success in the application of machine learning and data analytics in network planning in Nigeria.
- Practical challenges or limitations are being encountered while implementing machine learning and data analytics in network planning in Nigeria.

- Mobile communication service users' assessment of network services quality, in terms of accessibility, affordability and reliability is trending neutral.
- The customer satisfaction/dissatisfaction index across the mobile network operators and respective services is trending negative.
- The prospect of machine learning and data analytics in transforming network planning in the future is agreeably high.
- The key opportunities for leveraging machine learning and data analytics to improve network planning in Nigeria will include government support.
- Enterprise risk management and business continuity planning in relation to the technology of machine learning and data analytics in mobile communication sector.

Furthermore, the articulated views of the participants and outcome of the forum will be juxtaposed with the feedback from the questionnaires by way of interpolation during data presentation, analysis, and interpretation of the research findings, which will be appropriately documented in the draft and final report.

3.2.3 **Key Informant Interviews:**

Again, owing to the challenges encountered during stakeholder engagement, we are still conducting **semi-structured interviews** with a subset of the survey respondents who are willing to participate in further discussions. The interviews will be based on a guiding protocol that covers the same topics as the survey, but in more depth and detail. The interviews will also allow us to probe into the motivations, opinions, expectations, and recommendations of the interviewees regarding machine learning and data analytics in network planning. The interviews are being conducted either face-to-face or through a video conferencing tool such as Zoom

Picture 1: KII session

Key quotes from some of the KII engaged in so far.

"I think the potential for increasing efficiency through the adoption of ML and DA is notable, however, the high cost of mobile telecom infrastructure and foreign exchange challenges is strangulating".

"I should point out that some form of incentives and technical interventions from government and regulatory agencies could help facilitate increase in adoption".

"Our organization is quite big on ML and DA but recent limitations on budgetary provisions to adequately fund the required ICT infrastructure and maintain the professional workforce required for ML and DA technology is a factor".

"For us, lack of good funding mechanisms and high cost of borrowing from the conventional banks has impacted our ability to accelerate adoption".

"I think NCC is extremely good at innovations and is able to drive strategic plan implementation for the sector, however, their extreme focus on the big players has blindsided them on the challenges faced by the small to medium players in the industry".

3.2.4 **Data Extraction:**

We will obtain and analyze some secondary data from various sources such as mobile network operators, service providers, regulators, industry reports, academic publications, and online databases. The secondary data will include some **quantitative indicators** such as network coverage, quality, capacity, traffic, revenue, cost, customer satisfaction, churn rate, etc., as well as some **qualitative information** such as policies, strategies, standards, best practices, case studies, etc. The secondary data will be used to complement and validate the primary data collected from the surveys and interviews.

3.3 Data Sources and Sample Selection

The data sources for this study are:

3.3.1 Mobile network operators:

These are the entities that own and operate the mobile networks in Nigeria. They are responsible for planning, deploying, managing, and optimizing the network infrastructure and services. They are also the main users of machine learning and data analytics techniques for network planning purposes. The mobile network operators in Nigeria include MTN Nigeria, Airtel Nigeria, Globacom, 9mobile, etc.

3.3.2 Internet Service Providers:

These are organizations licensed by the NCC to provide internet access to both corporate and domestic users in the country through multiple means such as dial-up, DSL, cable, wireless and fiber optics connections. This data source category constitutes

a greater proportion of the sample population in the study. Notable among them are Spectranet, Layer 3 Ltd, Backbone Connectivity Network Ltd, 5M Telecom Ltd, Giafra Wireless Network Ltd, ipNX Nigeria Ltd, STL Fiberco Ltd, Access and Content Ltd, VDT communications Ltd, etc.

3.3.4 `**Service Providers:**

These are the entities that provide various services to mobile network operators or customers such as data analysis, cloud computing, software development, consulting, etc. They are also involved in developing and implementing machine learning and data analytics solutions for network planning purposes. Some examples of service providers in Nigeria are IBM, Google, Microsoft, Huawei, Ericsson, etc.

3.3.5 **Regulators:**

These are the entities that regulate and oversee the mobile communications sector in Nigeria. They are responsible for setting and enforcing the rules, standards, policies, and guidelines for the sector. They are also interested in monitoring and evaluating the performance and impact of machine learning and data analytics techniques on network planning outcomes. The main regulator in Nigeria is the Nigerian Communications Commission (NCC).

3.3.6 **Customers:**

These are the end-users of the mobile communications services in Nigeria. They are affected by the quality and availability of the network services provided by the mobile network operators. They are also potential beneficiaries of machine learning and data analytics techniques that can improve network planning efficiency and effectiveness. The customers in Nigeria include individuals, households, businesses, organizations, etc.

3.3.7 **Sampling Procedure/ Sample Selection**

The sample selection for this study is based on a combination of **probability sampling** and **purposive sampling** techniques.

3.3.8 Probability sampling is used to select a representative sample of survey respondents from each data source category based on some criteria such as size, location, service type, etc.

3.3.9 Purposive sampling is used to select a specific sample of interviewees from each data source category based on some criteria such as expertise, experience, involvement, etc. The sample size for each data source category will be determined based on the **confidence level**, **margin of error**, and **population size** of the target population.

3.3.10 **Sample Size Determination.**

Having carefully defined the target population, as highlighted in the previous sections of this report, we adopted appropriate statistical tools and procedures in determining the sample size.

Essentially, the population for the study comprised 258 licensed ISPs as well as the MONs licensed under Unified Access Services. A total of eighty (85) sample organizations were eventually selected for the study, using a combination of purposive and simple random sampling procedure.

3.4 Data Analysis Techniques

The data analysis techniques for this study are:

3.4.1 **Descriptive Analysis:** This involves summarizing and presenting the data using some **statistical measures** such as mean, median, mode, standard deviation, frequency, percentage, etc., and some **visual tools** such as tables, charts, graphs, maps, etc. The descriptive analysis will help the researcher to understand the **general characteristics** and **patterns** of the data and to answer some basic research questions such as who, what, when, where, how, etc.

3.4.2 **Inferential Analysis:** This involves testing and drawing some **statistical inferences** from the data using some **hypothesis testing** and **correlation analysis** techniques such as t-test, ANOVA, chi-square test, Pearson's r, Spearman's rho, etc. The inferential analysis will help the researcher to examine the **relationships** and **differences** among the variables and to answer some advanced research questions such as why, how much, how often, etc.

3.4.3 **Machine Learning Models:** This involves applying some **supervised learning** and **unsupervised learning** algorithms to the data such as linear regression,

logistic regression, decision tree, random forest, k-means clustering, principal component analysis, etc. The machine learning models will help the researcher to explore the **hidden patterns**, **predictive factors**, and **latent variables** in the data and to answer some complex research questions such as what if, what next, etc.

3.5 Major Stakeholder Engagement Experience

As with most research of this nature, the major stakeholder engagement during the field survey proved to be a key limiting factor in the timely execution and expected level of participation of the target population.

Four main challenges were encountered in engaging the target audience.

3.5.1 Physical Location of Operating Addresses of Sampled Organizations.

The issue of difficulties encountered in finding the physical location and operational base of the sampled organization was a key challenge in the research exercise. As part of our implementation strategies, physical meetings with key stakeholders, especially the executive management of the sampled organizations, at the initial stage of engagement, was a critical and primary factor in achieving the success of the research. In fact, our designed research methodology required securing of the buy-in of key stakeholders for effective collaboration and technical partnership. A situation whereby we are not able to physically locate the operational base of most of the sampled organizations at the respective addresses obtained from the commission's website created a huge challenge in terms of effective communication and important first level engagement.

However, our team had to depend on online visibility, personal contacts, and other public domain channels such as the website of the sampled organizations and google map and GPS app as well as telephone contact extracted from the respective website to get across to most of the target organizations. This approach, apart from being time consuming and capital intensive, created a huge gap in terms of the actual number of participants in the study and the deliverable timelines as well as the entire project cycle.

3.5.2 Delay in Nomination of Desk Officers for Research.

Based on our research design and execution process, research desk officers of the sampled organization, who will serve as the enumerators and interface between our research team and the sampled organization are a key component of the research modalities. The delay in nominating the desk officers as a focal person in the study, by

most of the sampled organizations affected the timely administration of questionnaire, and as expected, the receipt of responses.

All the same, being that we are not directly in control of this organizations, we had to deploy the relevant tools of persuasion, appeal, and multiple follow-up processes to get them to provide the needed support, which proved to be very effective in the engagement process. Ultimately our team had to settle for their timing and convenience as much as possible, while keeping the project objectives and timelines on track.

3.5.3 Poor Response to the Research Questionnaire.

Contrary to our projection, the response level to the questionnaire by the sampled organizations has been generally poor at this interim stage. We had to embark on a series of follow-ups via multiple channels such as telephone calls, WhatsApp messages and e-mail. In some instances, our research team had to physically visit the target audience to get them to complete and submit the questionnaire. No doubt, while these experiences have negatively affected our research efforts, thereby resulting in the stretching of the research completion time frame, we are confident that the objectives of the research will be achieved, as we intensify the use of persuasive mechanism and value incentives to arouse their interest.

In a nutshell, we are optimistic that the next stage of activities involving data aggregation, presentation, analysis, and interpretation will commence soon. This will also enable us to submit the draft report, accordingly.

3.5.4 General Apathy and Apprehension on the Part of Sampled Organization.

Generally, the attitude of most of the sampled organizations has been that of apathy and lack of interest in the study. This reflects the low level of commitment of several organizations to research and development, as indicated in previous studies. There was also a high-level apprehension with regards to divulging classified information and data which can be used by competition and other third parties. The entire research efforts in this study are largely undermined by this unimpressive behavior of the sampled organization, which will ultimately affect the objective adversely. However, using persuasive tools and mechanisms and reassurance of research ethics of confidentiality and non-disclosure, our research team were able to achieve reasonable measure of success as now being reported.

3.6 Ethical Considerations

The ethical considerations for this study are:

3.6.1 Informed Consent: The researcher will obtain the informed consent of the participants before collecting any data from them. The informed consent will include information about the purpose, scope, methods, risks, benefits, confidentiality, anonymity, and rights of the participants. The participants will have the option to withdraw from the study at any time without any penalty.

3.6.2 Data Protection: The researcher will protect the data collected from the participants from any unauthorized access, use, disclosure, modification, or destruction. The researcher will use encryption, password protection, anonymization, pseudonymization, and other security measures to safeguard the data. The researcher will also comply with the relevant data protection laws and regulations such as the Nigeria Data Protection Regulation (NDPR).

3.6.3 Data Quality: The researcher will ensure the quality of the data collected from the participants by using valid and reliable instruments, avoiding bias and error, checking for accuracy and completeness, cleaning and coding the data properly, and reporting any limitations or challenges encountered in the data collection process.

3.6.4 Data Ownership: The researcher will respect the ownership rights of the data sources and acknowledge their contributions in the study. The researcher will also obtain permission from the data sources before using or sharing any of their data with others. The researcher will also cite any references or sources used in the study according to the appropriate citation style.

CHAPTER FOUR

FINDINGS / RESULTS

4.0 Introduction

This section presents the results of the analysis of the cross-sectional data gotten from the telecommunications companies (telecommunication companies) across Nigeria. The results were interpreted accordingly with appropriate result triangulations using excerpts from the focus group discussion and key informant interview. The section was presented systematically in line with the objectives of the study.

4.1 **Institutional Attributes of The Firms**

4.1.1 Market Segments

Figure 4.1

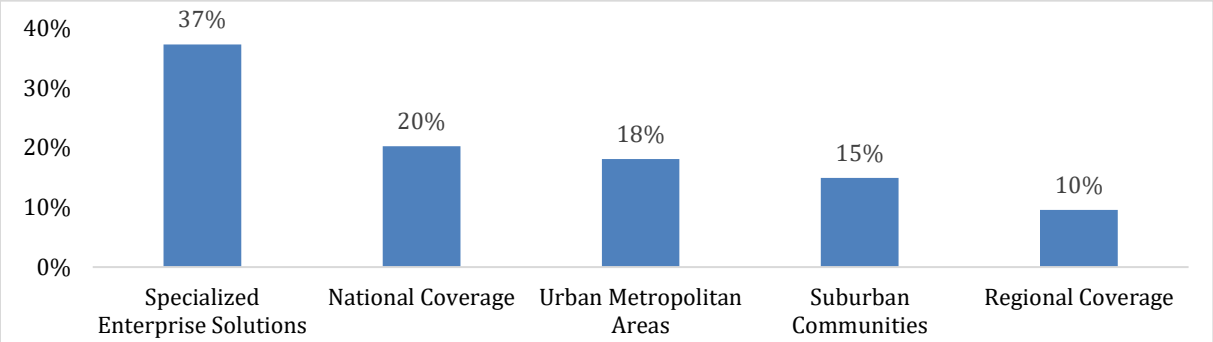

Figure 4.1: Market Segment

Source: NCC Field Survey (2023)

4.1.2 Number of Employees in the Organization

Figure 4.2

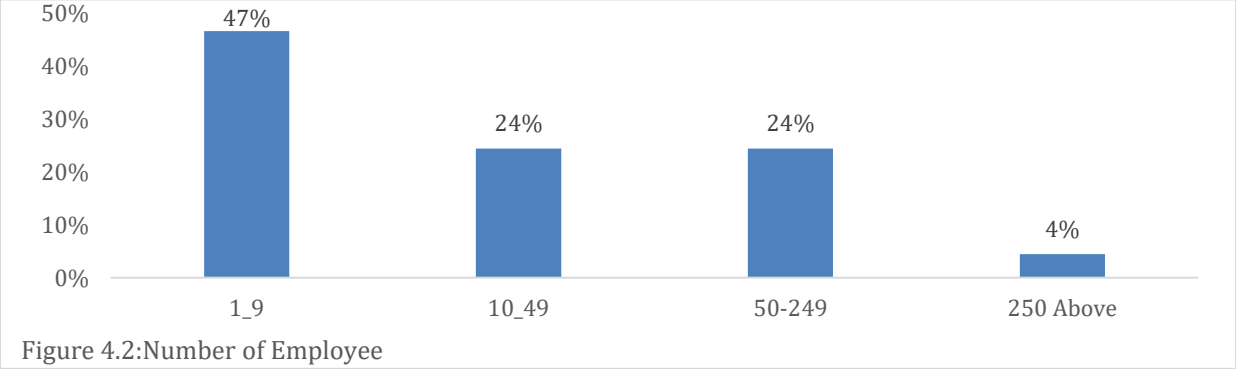

Figure 4.2:Number of Employee

Source: NCC Field Survey (2023)

4.2 Network Planning and Optimization

4.2.1 Methods Adopted to Plan and Optimize Mobile Communications Network Infrastructure

Figure 4.3

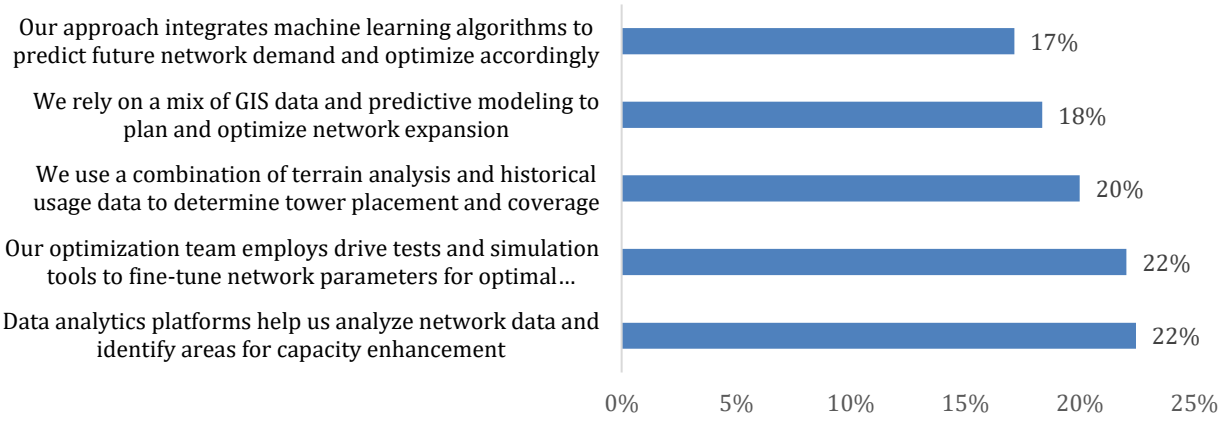

Figure 4.3: Methods Adopted to Plan and Optimize Mobile Communications Network Infrastructure

Source: NCC Field Survey (2023)

FGD

From the FGD, the respondents posited they were familiar with data analytics and machine learning in network planning. According to one of the Participants "I am familiar with data analysis and machine learning because I had the opportunity to do some courses in data analytics and machine learning and during my M.S.C program and also I have a working understanding of data analysis and machine learning" (Source: FGD Excerpts).

4.2.2 Challenges faced in network planning, capacity management, and optimization

Figure 4.4

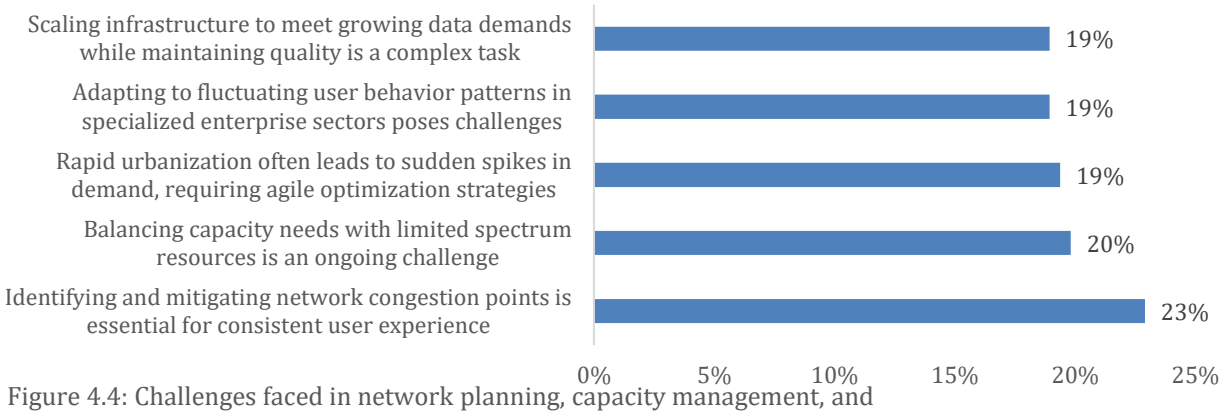

Figure 4.4: Challenges faced in network planning, capacity management, and optimization

Source: NCC Field Survey (2023)

4.2.3 METHOD OF DATA COLLECTION AND ANALYZES RELATED TO NETWORK PERFORMANCE, COVERAGE, AND CAPACITY

Figure 4.5

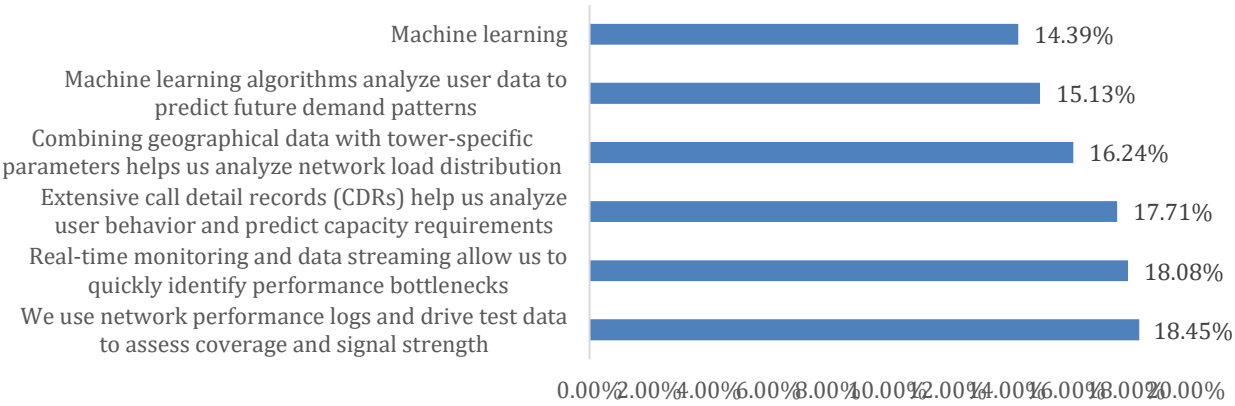

Figure 4.5: Method of data collection and analyzes related to network performance, coverage, and capacity

Source: NCC Field Survey (2023)

4.2.4 LEVERAGING MACHINE LEARNING AND DATA ANALYTICS TECHNIQUES FOR NETWORK PLANNING AND OPTIMIZATION

Figure 4.6

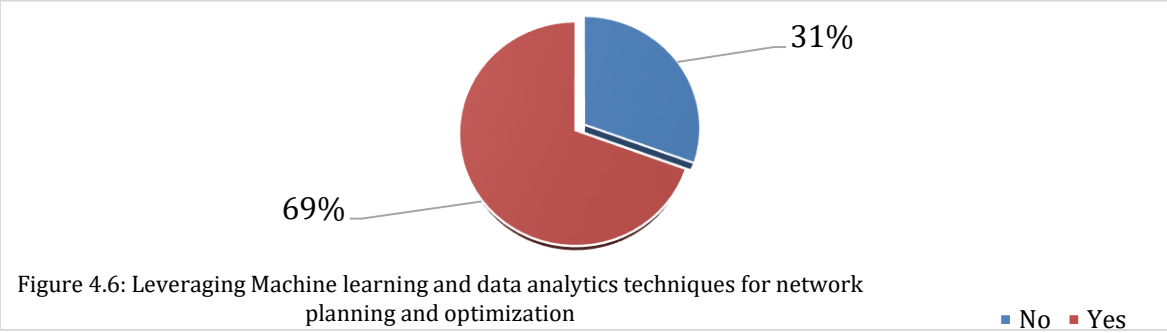

Figure 4.6: Leveraging Machine learning and data analytics techniques for network planning and optimization

Source: NCC Field Survey (2023)

4.3 Level of Adoption of Machine Learning and Data Analytics in Mobile Communication Network Planning

4.3.1 Application machine learning in your network planning, capacity prediction, or optimization

Figure 4.7

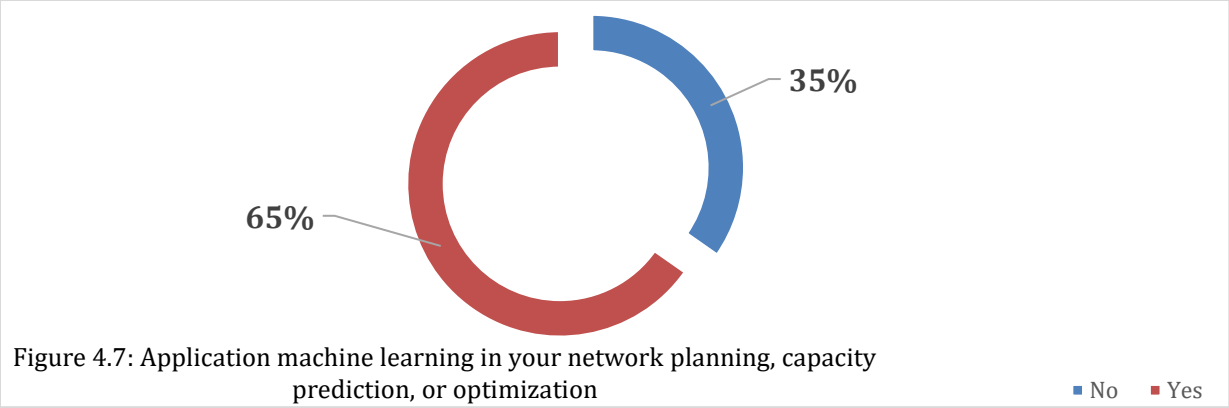

Figure 4.7: Application machine learning in your network planning, capacity prediction, or optimization

Source: NCC Field Survey (2023)

FGD,

> *Yes, we are currently using machine learning in network planning, capacity prediction, or optimization. According to a participant in the FGD, "there are cases right now where you can sit in your office and be able to see the user experience in a particular location without sending anyone to go there and test (Source: FGD Excerpts).*

KII,

"Yes, we are adopting machine learning at the basic level. We conduct network planning for optimal neighbour relations, a feature called Automatic Neighbour Relation (ANR), like 4G, where the system studies the neighbours, optimises them, and generates new neighbours. It's embedded in a standard feature, but not on a large scale. It helps in customer retention, network dimensions, and proper resource allocation." (Source: KII Excerpts).

KII,

"The adoption rate at the moment is still low, and we are not convinced that this incremental investment in the use of these machine tools can bring us a return on investment" *(Source: KII Excerpts).*

4.3.2 Key Performance Metrics Considered when evaluating the effectiveness of machine learning models for network planning

Figure 4.8

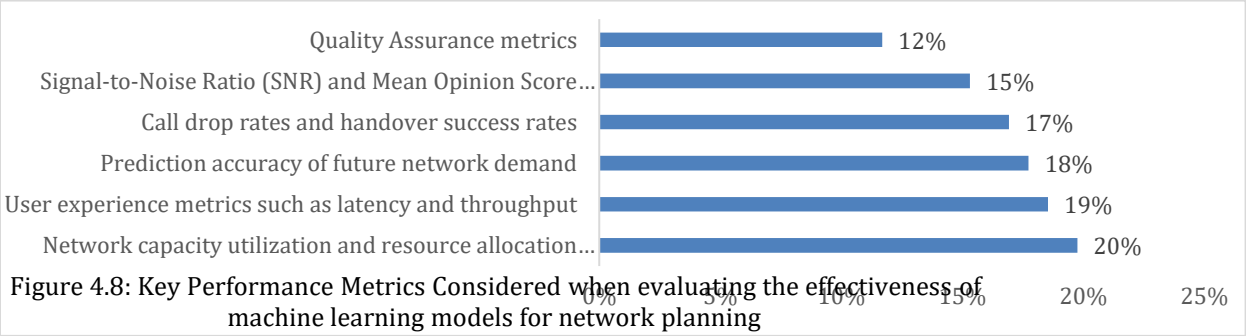

Figure 4.8: Key Performance Metrics Considered when evaluating the effectiveness of machine learning models for network planning

Source: NCC Field Survey (2023)

4.3.3 Challenges or limitations in implementing machine learning for network planning and optimization

Figure 4.9

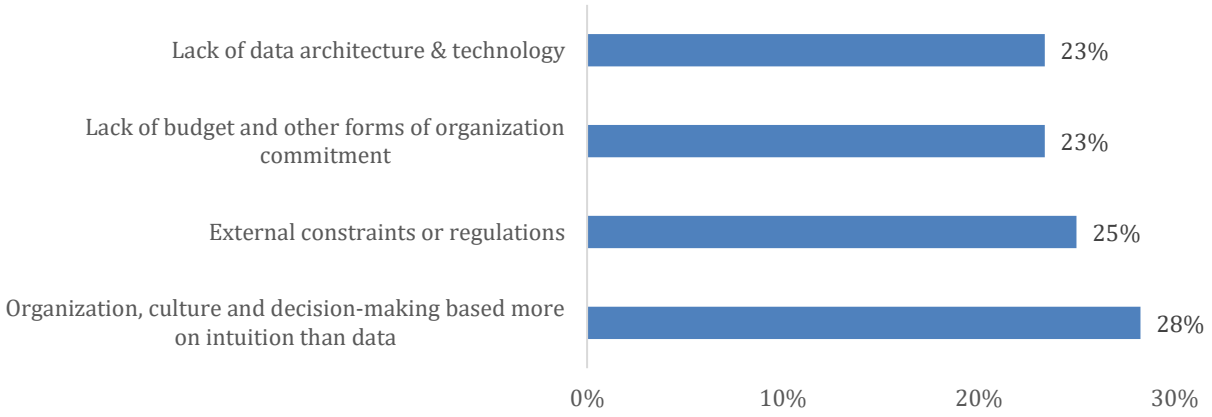

Figure 4.9: Challenges or limitations in implementing machine learning for network planning and optimization

Source: NCC Field Survey (2023)

FGD,

From the FGD, the participants highlighted a few challenges, such as

- *Storage: there is a lot of data that can be used for machine learning. Storage of data that has been collected over the years, and generally, in telecom, you have a lot of data and need to do a valid study."*
- *Most organisations don't have the institutional capacity to do the actual work they need to do when processing data.*
- *Lack of required skill: a lot of people are not skilled in using this, but most people are learning it, which is another challenge.*
- *Privacy issues.*
- *Accuracy of data collected: For instance, it is difficult to get actual or accurate population data. (Source: FGD Excerpts).*

4.4 Data Collection and Management

4.4.1 TYPES OF DATA COLLECTED FOR NETWORK PLANNING AND OPTIMIZATION

Figure 4.10

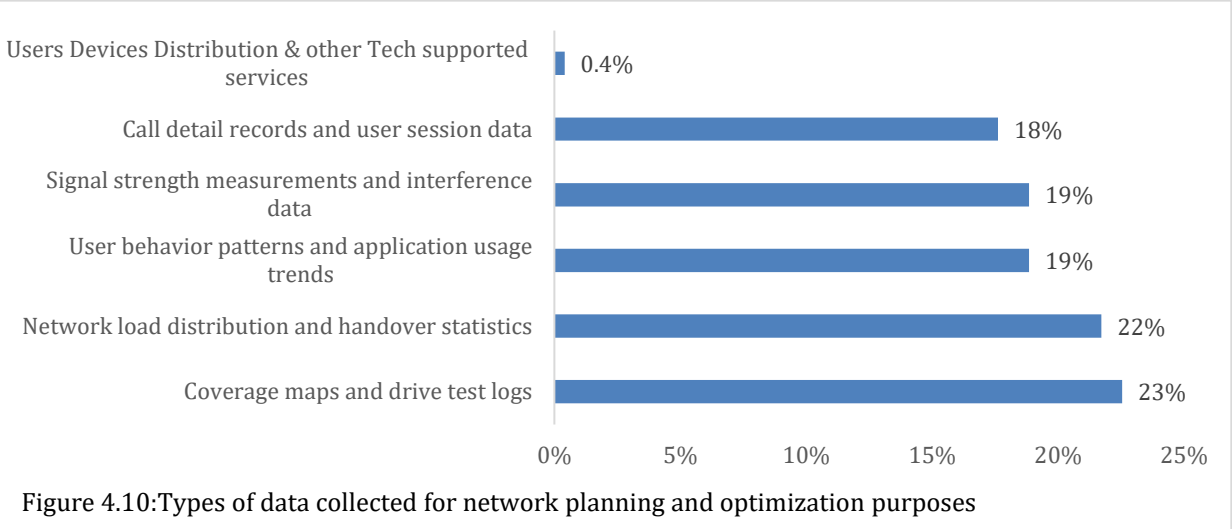

Figure 4.10:Types of data collected for network planning and optimization purposes

Source: NCC Field Survey (2023)

4.4.2 TOOLS OR PLATFORMS USED TO STORE AND MANAGE THE COLLECTED DATA

Figure 4.11

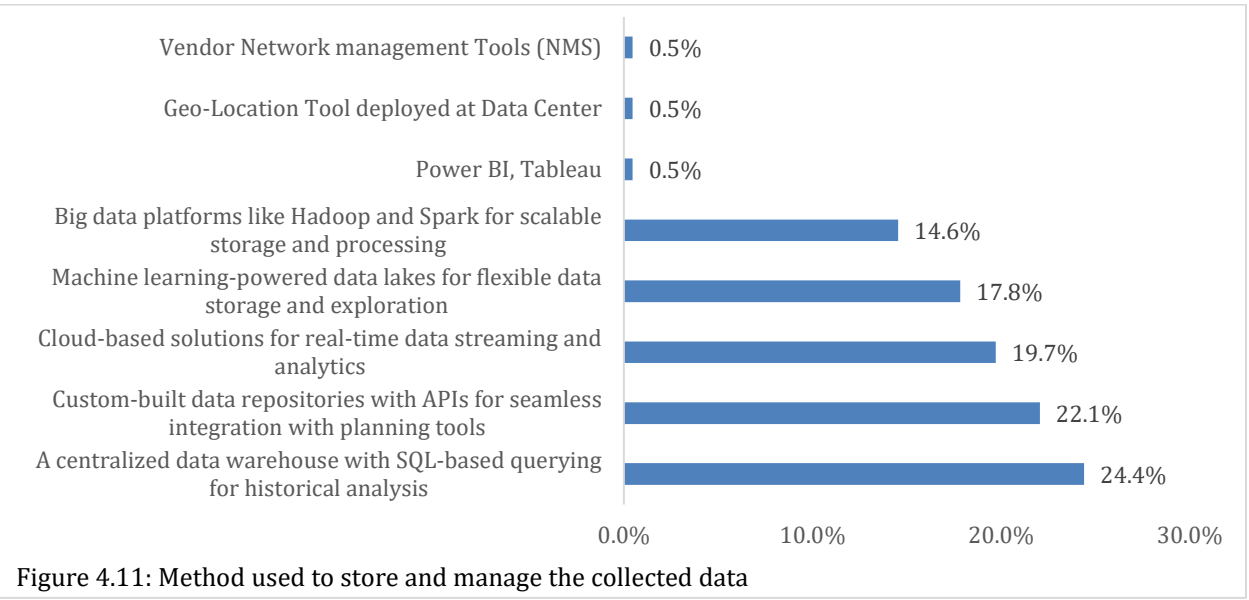

Figure 4.11: Method used to store and manage the collected data

Source: NCC Field Survey (2023)

4.5 Data Analytics for Demand Forecasting

4.5.1 Methods used to forecast and predict the demand for mobile communication services

Figure 4.12.

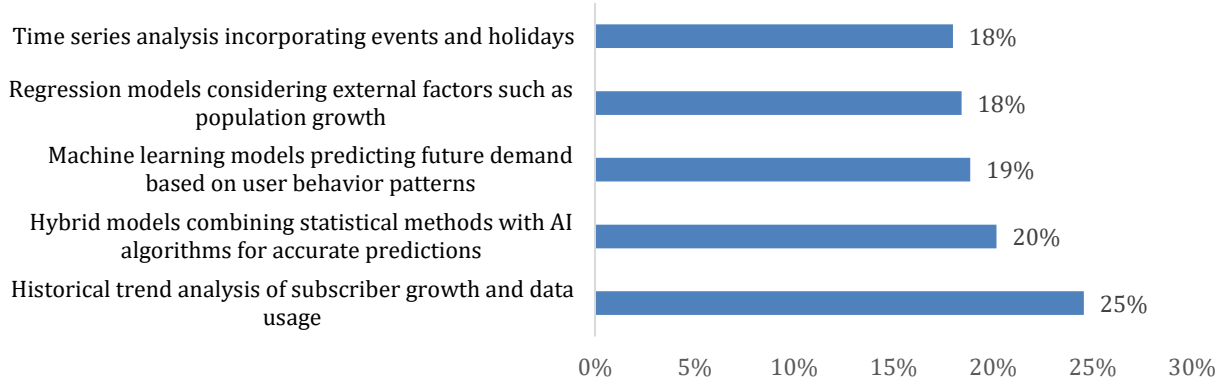

Figure 4.12: Method currently adopted to forecast and predict the demand for mobile communication services

Source: NCC Field Survey (2023)

4.5.2 Data Analytics Techniques to Analyze Historical Data for Demand Forecasting

Figure 4.13

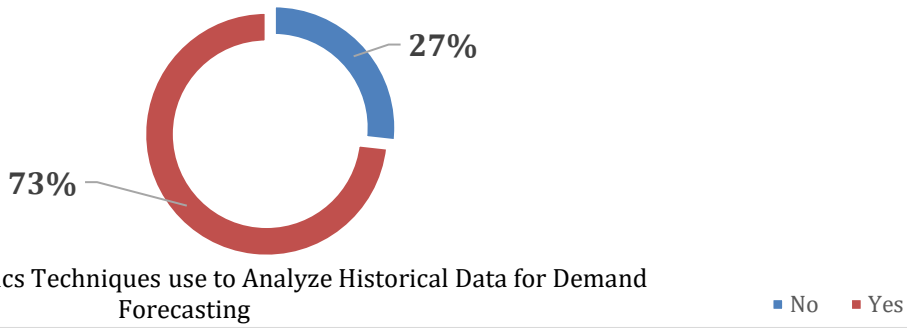

Figure 4.13: Data Analytics Techniques use to Analyze Historical Data for Demand Forecasting

Source: NCC Field Survey (2023)

4.5.3 External factors (e.g., events, holidays, population growth) incorporated into demand forecasting models

Figure 4.14

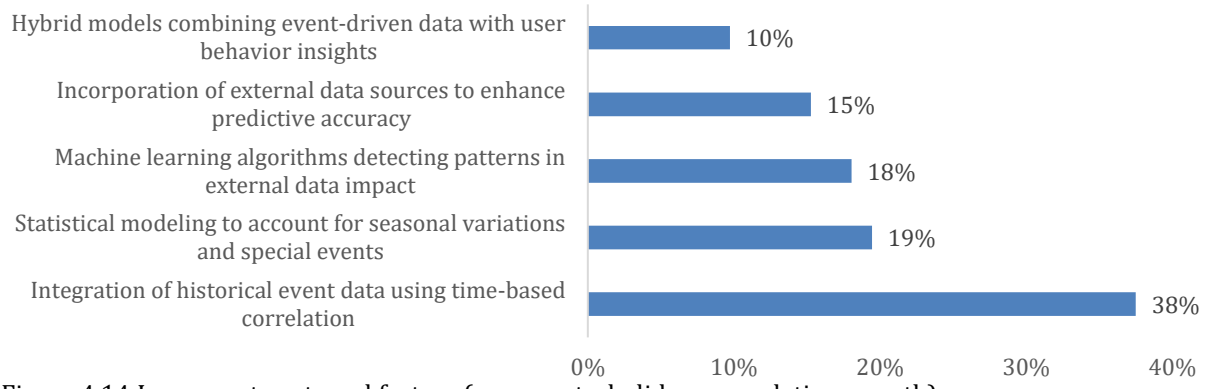

Figure 4.14:Incorporate external factors (e.g., events, holidays, population growth) into your demand forecasting models

Source: NCC Field Survey (2023)

4.5.4 ACCURACY OF DEMAND FORECASTING MODELS

Figure 4.15

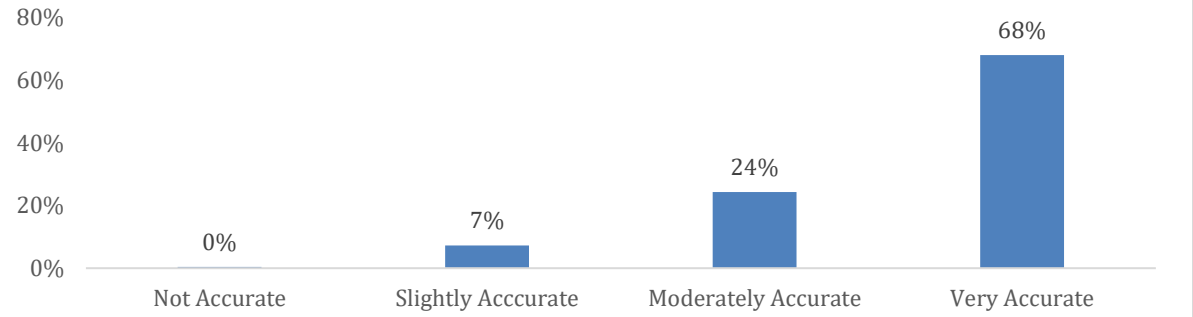

Figure 4.15: Accuracy of demand forecasting models

Source: NCC Field Survey (2023)

4.5.5 RELEVANCE OF THE ADOPTION OF DATA ANALYTICS IN YOUR NETWORK PLANNING

Figure 4.16

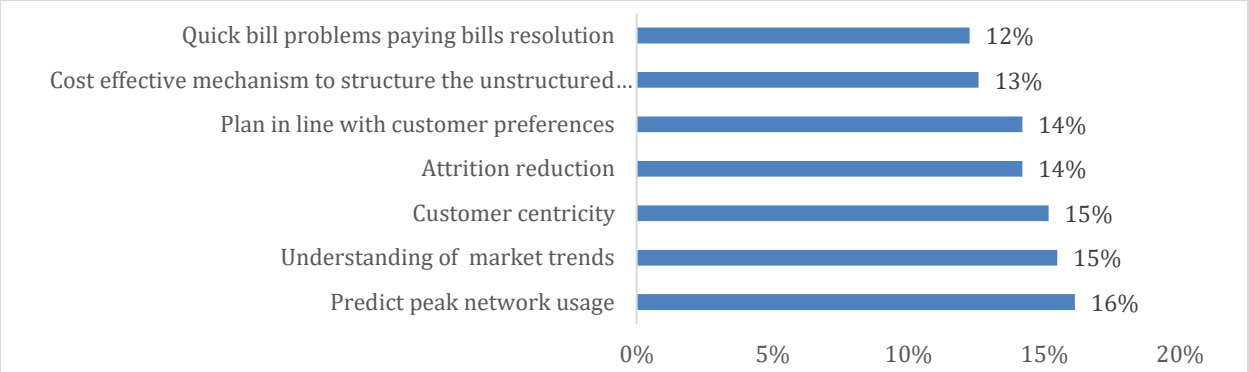

Figure 4.16:Relevance of the adoption of data analytics in your network planning

Source: NCC Field Survey (2023)

FGD,

According to participants in the FGD, machine learning and data analytics help reduce costs, save time, and improve customer satisfaction. A participant posited that, "for instance, when you have a customer complain, what we need is to send someone to do a dry test, but with machine learning and data analytics, it is just to check what the user experience is, and you are able to do investigation and analysis, so that reduces your time of investigation and you will be able to resolve the problem in time, and you also have to send someone to the location of your customer to do investigation" (Source: FGD Excerpts).

4.5.6 CHALLENGES FACE IN ADOPTION OF DATA ANALYTICS IN NETWORK PLANNING

Figure 4.17

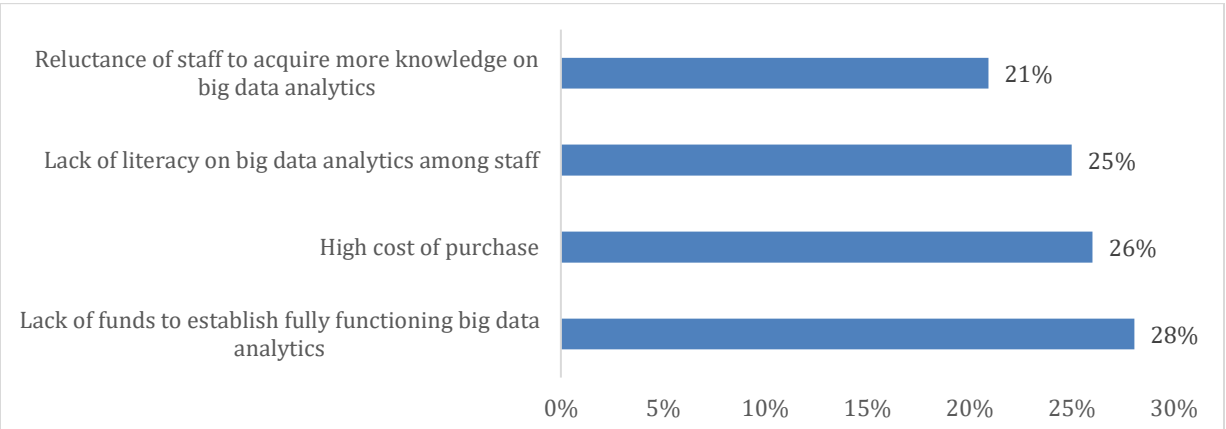

Figure 4.17: Challenges faced in adoption of data analytics in network planning

Source: NCC Field Survey (2023)

4.6 Level of Network Management Challenges to Operators of Mobile Communication

Table 5.1: Network Management Challenges to Operators of Mobile Communication	
Limitation of available work tool and required skilled workers	Fiber vandalism
Government policies-Stringent regulatory processes and policy	Drop Calls
Issues with energy generation to power major equipment	Los
Insufficient Coverage at other locations	Dead Spots
Wide spread of insecurity	Finding the right people with adequate skills
Limited Spectrum Bandwidth	High Operational cost
Network sabotage frequent damage to infrastructure	Lack of stable and reliable infrastructure in the country
Network congestion/Bad Network/managing traffic congestion	Fault detection and correlation
Patches	Network Inventory
Clogedness	IT and OT convergence
Aridity	High cost of taxation
Optimizing network capacity	Capacity over-utilization
Ever-changing landscape of technology. New devices, operating systems, and applications are released on a regular basis, and operators must be able to configure, manage, and support these new technologies	
Source: NCC Survey 2023	

4.7 Performance Evaluation and Optimization

4.7.1 Evaluation of the performance of network planning and optimization efforts

Figure 4.18

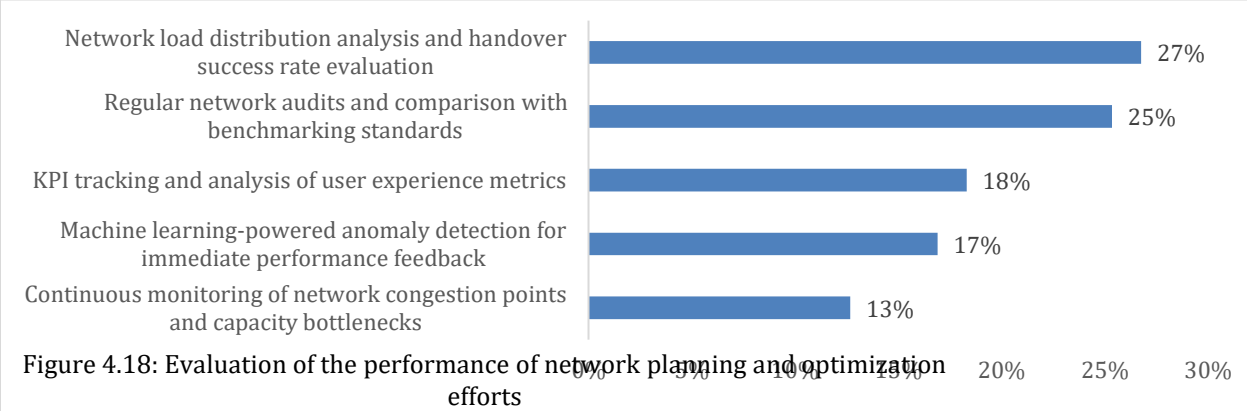

Figure 4.18: Evaluation of the performance of network planning and optimization efforts

Source: NCC Field Survey (2023)

4.7.2 Key performance indicators (KPIs) do you consider for network performance evaluation

Figure 4.19

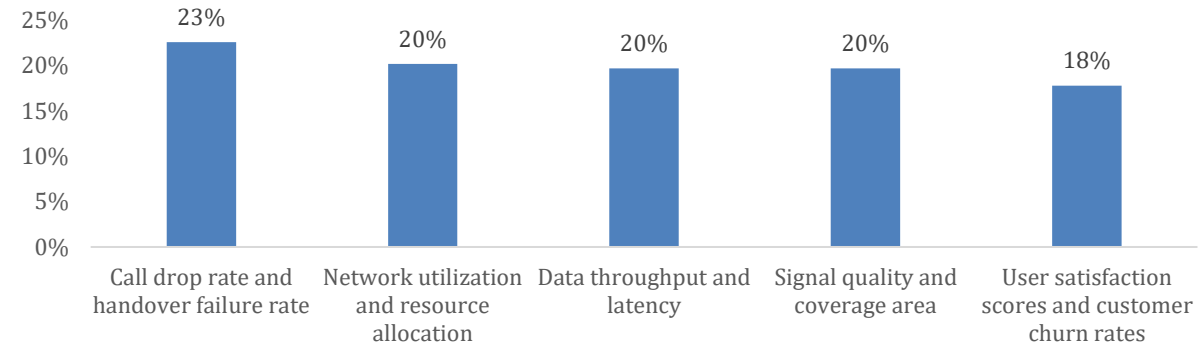

Figure 4.19:Key performance indicators (KPIs) do you consider for network performance evaluation

Source: NCC Field Survey (2023)

FDG,

Users of the network were asked to vet the performance of service providers. According to a participant, "I can say there is a kind of improvement, but still, I will say this is quite relative based on the location and the service provider.

I went to a rural community, and then I could not access my network, but when I was around the urban area, things were going fast. Sometimes it depends on the area where you are, but you can have good coverage. I believe most of the time, in rural settings, there is less coverage compared to when you are around the city. For instance, people in rural areas can't access data until they are in the city due to the poor network in the area. But I believe there could be improvement in that area as well. They should extend their broad band into areas that have poor network services."(Source: FGD Excerpts).

4.7.3 AREAS FOR NETWORK OPTIMIZATION AND IMPROVEMENT

Figure 4.20

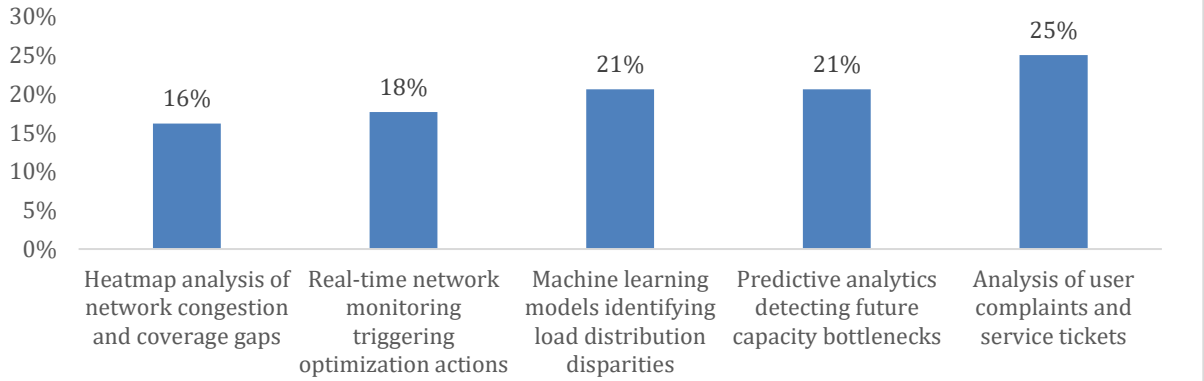

Figure 4.20: Areas for network optimization and improvement

Source: NCC Field Survey (2023)

4.7.4 IMPACT OF NETWORK OPTIMIZATION ON CUSTOMER EXPERIENCE AND SATISFACTION

Figure 4.21

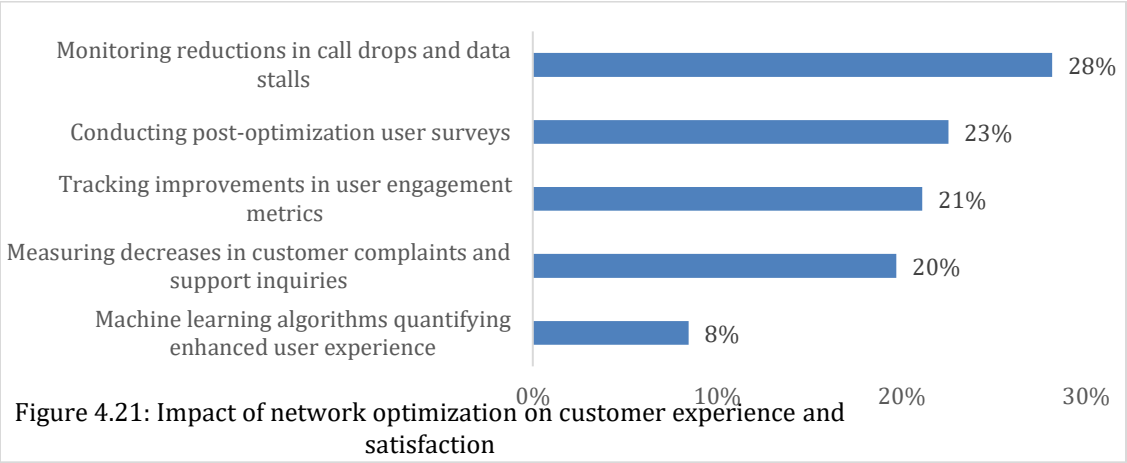

Figure 4.21: Impact of network optimization on customer experience and satisfaction

Source: NCC Field Survey (2023)

FGD,

> *Costumers were asked what they were satisfied with the mobile network services and what their dissatisfaction was with the internet service. One of the participants affirms that over the years, the network for mobile usage has been very poor, particularly with difficulty hearing the caller at the other end of the phone. Also, when one tries to work with data, you will discover what they give you is not what you have paid for, and at the end of the day, even after you complain to network providers through emails or websites, they don't respond to it. For a layman, how can he complain after he doesn't know about emails?" (Source: FGD Excerpts).*

4.8 Future Trends and Challenges

4.8.1 FUTURE TRENDS AND ADVANCEMENTS IN MACHINE LEARNING AND DATA ANALYTICS FOR MOBILE COMMUNICATION NETWORK PLANNING

Figure 4.22

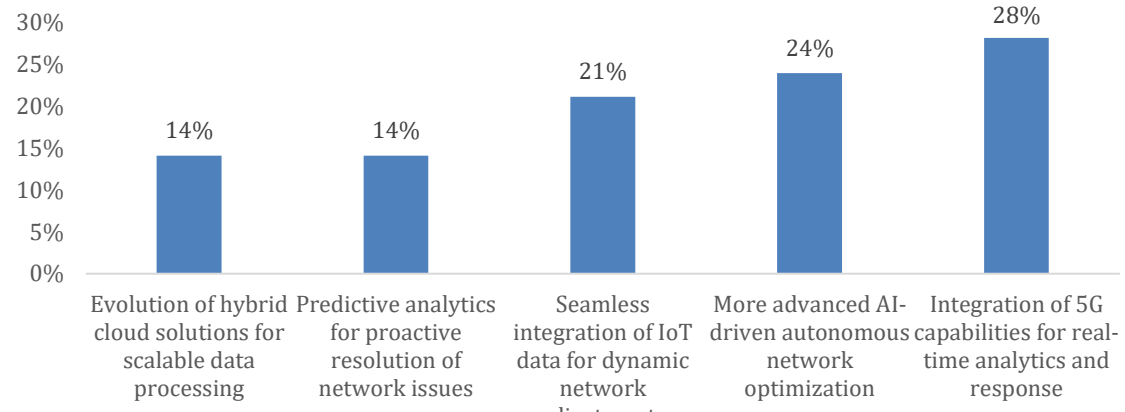

Figure 4.22: Future trends and advancements in machine learning and data analytics for mobile communication network planning

Source: NCC Field Survey (2023)

FGD,

According to the participants, the importance of machine learning and data analytics cannot be overemphasized. One of the participants posited that data analytics is used to analyse future trends and make recommendations. Both can help us in the sense that from data analytics you can extract more specifically from our data, specifically subscriber level and application level, and these are the directions we are going in the future because we will be planning for different loads, different applications, different subscribers, and a lot of different things. (Source: FGD Excerpts).

4.8.2 Challenges and obstacles in adopting and implementing advanced analytics techniques in your network planning processes

Figure 4.23

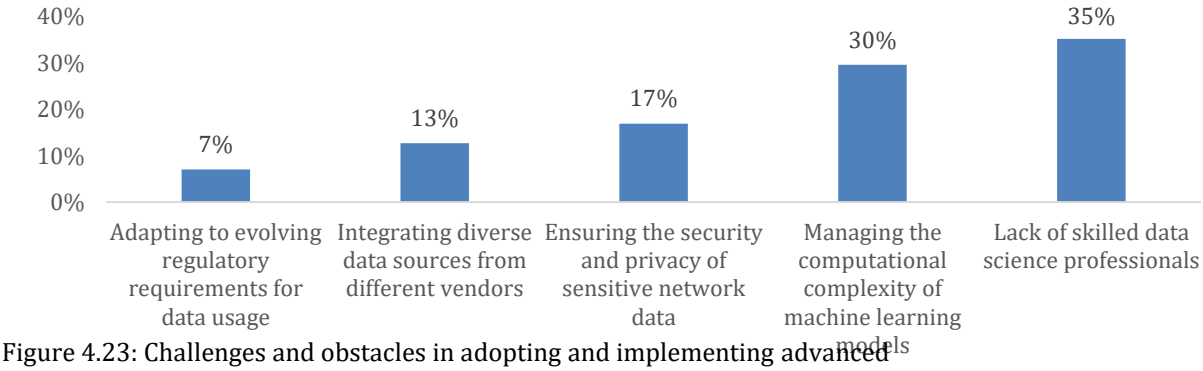

Figure 4.23: Challenges and obstacles in adopting and implementing advanced analytics techniques in your network planning processes

Source: NCC Field Survey (2023)

4.8.3 SPECIFIC AREAS OR ASPECTS OF NETWORK PLANNING WHERE YOU BELIEVE MACHINE LEARNING AND DATA ANALYTICS CAN BRING SIGNIFICANT IMPROVEMENTS

Figure 5.24

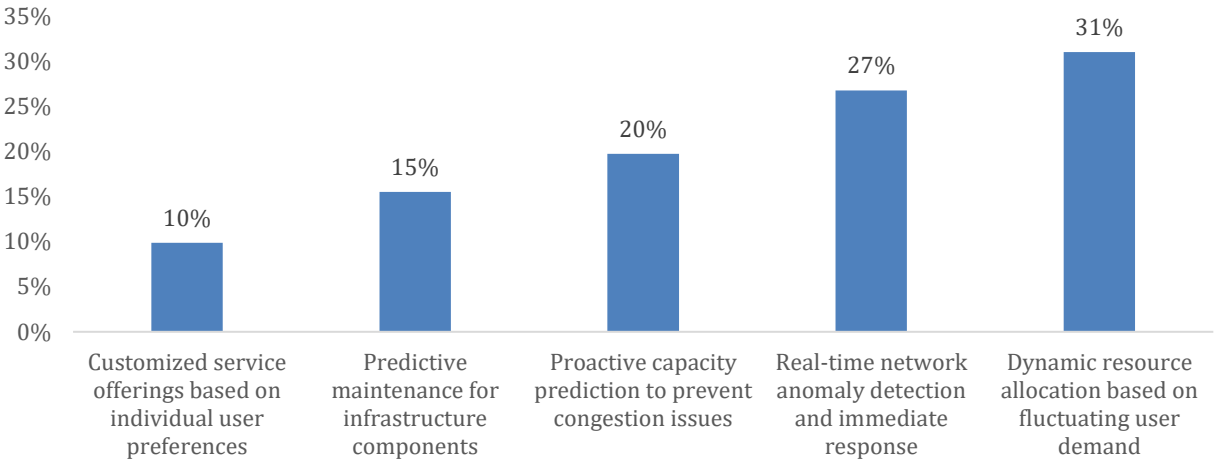

Figure 4.24: Specific areas or aspects of network planning where you believe machine learning and data analytics can bring significant improvements

Source: NCC Field Survey (2023)

FGD,

> *According to the participants, one of the most significant areas in which machine learning is important is predictive analytics. Because network planning is all about major networks, like coverage analysis and network capacity, machine learning will help in predictive analytics to identify and be able to bring out the events you are planning (Source: FGD Excerpts).*

4.9 Collaboration and Knowledge Sharing

4.9.1 LEVEL OF COLLABORATION WITH ACADEMIA, RESEARCH INSTITUTIONS, OR INDUSTRY PARTNERS IN THE FIELD OF MACHINE LEARNING AND NETWORK PLANNING

Figure 4.25

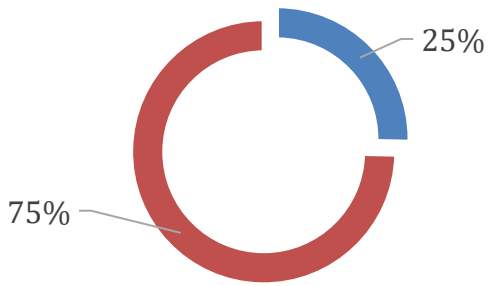

Figure 4.25: Level of collaboration with academia, research institutions, or industry partners in the field of machine learning and network planning

Source: NCC Field Survey (2023)

4.9.2 METHOD USED TO PROMOTE KNOWLEDGE SHARING AND INNOVATION WITHIN ORGANIZATION REGARDING MACHINE LEARNING AND DATA ANALYTICS

Figure 4.26

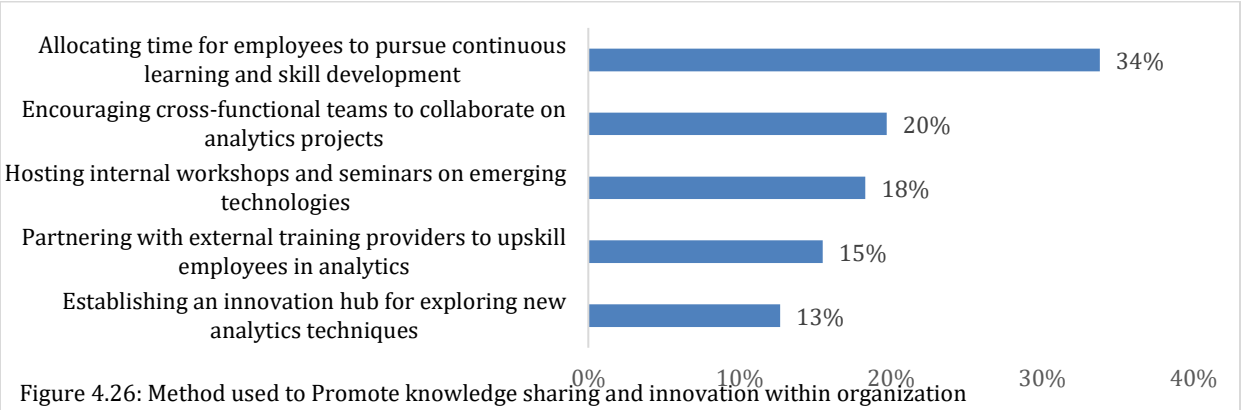

Figure 4.26: Method used to Promote knowledge sharing and innovation within organization regarding machine learning and data analytics

Source: NCC Field Survey (2023)

CHAPTER FIVE

INTERPRETATIONS AND DISCUSSIONS

The study findings are based on a cross-sectional survey of telecommunications companies in Nigeria, as well as focus group discussions and key informant interviews. The study aims to explore the institutional attributes of the firms, their network planning and optimization methods, and the challenges they face in network planning, capacity management, and optimization.

Below are further interpretations and discussions of the findings of the study.

5.1 Attributes of the Industry

- Telecommunications companies have a wide range of market segments, covering enterprise solutions, national, regional, urban, and suburban areas. This implies that they have different customer segments and service offerings. [Figure 4.1]
- The telecommunications companies vary in size, with 47% being micro, 24% being small, 24% being medium, and 4% being large enterprises. This suggests that they have different levels of resources, capabilities, and competitiveness. [Figure 4.2]

5.2 Network Planning and Optimization

- The telecommunications companies use various methods to plan and optimize mobile communications network infrastructure, such as data analytics platforms, drive tests and simulation tools, terrain analysis and historical usage data, GIS data and predictive modelling, and machine learning algorithms. However, the adoption of data analytics and machine learning is relatively low, given their combined percentage of 42%. This indicates that there is room for improvement in leveraging data-driven and intelligent approaches to network planning and optimization. [Figure 4.3]
- Operators face several challenges in network planning, capacity management, and optimization, such as identifying and mitigating network congestion points, balancing capacity needs with limited spectrum resources, adapting to rapid urbanization and fluctuating user behavior patterns, and scaling infrastructure to meet growing data demands while maintaining quality. These challenges require

innovative and agile solutions that can cope with the dynamic and complex nature of mobile communications networks. [Figure 4.4]

The study findings also show that the respondents from the focus group discussion are familiar with data analysis and machine learning in network planning, as some of them have done courses or have a working understanding of these concepts. This suggests that there is some awareness and interest in data analysis and machine learning among the telecommunications companies, which can be leveraged to enhance their network planning and optimization capabilities.

Specifically, the study revealed that telecommunications companies in Nigeria employ a variety of methods for planning and optimizing mobile communications network infrastructure. The key network planning and optimization steps adopted by these companies include:

- Data Analytics Platforms:
  Utilizing advanced data analytics platforms to analyze large volumes of data related to network performance, user behavior, and other relevant metrics.
- Drive Tests and Simulation Tools:
  Conducting drive tests to assess network coverage, signal strength, and overall performance in real-world scenarios while using simulation tools to model and predict network behavior under different conditions.
- Terrain Analysis:
  Analyzing the geographical terrain to understand its impact on signal propagation and coverage as well as considering landscape features to optimize the placement of cell towers and network infrastructure.
- Historical Usage Data:
  Examining historical data on network usage patterns to identify areas of high demand and using past usage trends to anticipate future network requirements and optimize capacity.
- GIS Data and Predictive Modeling:
  Leveraging Geographic Information System (GIS) data for spatial analysis and mapping of network elements. Employing predictive modeling to forecast network performance and identify areas for improvement.

- Machine Learning Algorithms:
  Implementing machine learning algorithms for intelligent data analysis and decision-making in network planning. Enhancing optimization strategies by incorporating algorithms that can adapt to changing network conditions.

In practice, the type of machine learning algorithms employed for network planning and optimization can vary based on the specific use cases and challenges faced by the telecom companies and dependent on the nature of the data, the objectives of the optimization, and the preferences of the telecom companies. However, common types of machine learning algorithms spotted from the research include Regression Algorithms; Clustering Algorithms; Classification Algorithms and Anomaly Detection among others.

The study findings also reveal that:

- Telecommunications companies use various methods to collect and analyze data related to network performance, coverage, and capacity, such as network performance logs and drive test data, real-time monitoring and data streaming, call detail records (CDRs), geographical data and tower-specific parameters, and machine learning algorithms. However, the adoption of machine learning algorithms is relatively low, given its percentage of 14.39%. This indicates that there is potential for more data-driven and intelligent solutions to enhance network performance, coverage, and capacity. [Figure 4.5]
- Most of the telecommunications companies (69%) leverage machine learning and data analytics techniques for network planning and optimization, while the remaining 31% do not. This implies that most of the telecommunications companies surveyed have recognized the benefits of machine learning and data analytics techniques for network planning and optimization, such as improving network efficiency, quality, and reliability. [Figure 4.6]

5.3 Level of adoption of machine learning (ML) and data analytics in mobile communications network planning

- Many of the telecommunications companies (65%) currently apply machine learning and data analytics techniques for network planning, capacity prediction, or optimization, while the remaining 35% do not. This suggests that most of the telecommunications companies surveyed have implemented machine learning

and data analytics techniques for network planning, capacity prediction, or optimization, such as automatic neighbor relation, network load distribution, and future demand prediction. [Figure 4.7]

- The telecommunications companies use various key performance metrics to evaluate the effectiveness of machine learning models for network planning, such as network capacity utilization and resource allocation efficiency, user experience metrics, prediction accuracy of future network demand, call drop rates and handover success rates, signal-to-noise ratio and mean opinion score, and quality assurance metrics. These metrics help to measure the impact of machine learning models on network performance, quality, and reliability. [Figure 4.8]

The study findings also show that the respondents from the focus group discussion and the key informant interviews are familiar with machine learning and data analytics techniques in network planning, capacity prediction, or optimization. Some of them have used machine learning to assess user experience, optimize neighbor relations, and allocate resources. However, some of them are not convinced that the incremental investment in machine learning can bring them a return on investment. This suggests that there is some awareness and interest in machine learning and data analytics techniques among the telecommunications companies, but also some challenges and barriers to their adoption and implementation.

The research findings also reveal that:

- The telecommunications companies encounter various challenges or limitations in implementing machine learning for network planning and optimization, such as organization, culture, and decision-making being based more on intuition than data, external constraints or regulations, a lack of data architecture and technology, and a lack of budget and other forms of organizational commitment. These challenges hinder the adoption and implementation of machine learning for network planning and optimization, and require solutions that can address organizational, technical, and regulatory barriers. [Figure 4.9]

Specifically, the types of machine learning models adopted for network planning, capacity prediction, or optimization that is commonly used based on respondents' feedback include.

- ✓ Automatic Neighbor Relation (ANR): (Clustering Algorithms: K-Means, Hierarchical Clustering; Regression Algorithms: Linear Regression, Polynomial Regression; Neural Networks: Deep Learning models for pattern recognition)
- ✓ Network Load Distribution: (Clustering Algorithms: K-Means, Hierarchical Clustering; Regression Algorithms: Linear Regression, Polynomial Regression; Neural Networks: Deep Learning models for pattern recognition)

- ✓ Future Demand Prediction: (Time Series Analysis: Autoregressive Integrated Moving Average (ARIMA); Regression Algorithms: Linear Regression, Decision Trees; Neural Networks: Long Short-Term Memory (LSTM))

- ✓ Key Performance Metrics Evaluation: (Network Capacity Utilization and Resource Allocation Efficiency; Optimization Algorithms: Genetic Algorithms, Particle Swarm Optimization; User Experience Metrics; Classification Algorithms: Decision Trees, Random Forest; Prediction Accuracy of Future Network Demand; Time Series Analysis: ARIMA, LSTM; Call Drop Rates and Handover Success Rates; Classification Algorithms: Decision Trees, SVM; Signal-to-Noise Ratio and Mean Opinion Score; Regression Algorithms: Linear Regression; Quality Assurance Metrics; Anomaly Detection: Isolation Forest, One-Class SVM

It's important to note that the specific machine learning models adopted can vary across different telecommunications companies based on their unique requirements, datasets, and objectives. More so, while the models listed above are general categories, and within each category, there can be variations and combinations of different algorithms based on the specific use case.

5.4 Data Collection and Management

- The telecommunications companies collect various types of data for network planning and optimization purposes, such as coverage maps and drive test logs, network load distribution and handover statistics, signal strength measurements and interference data, user behavior patterns and application usage trends, and call detail records and user session data. These data sources provide valuable

insights into network performance, quality, and reliability, as well as user preferences and expectations. [Figure 4.10]

- The telecommunications companies use various tools or platforms to store and manage the collected data, such as a centralized data warehouse with SQL-based querying, custom-built data repositories with APIs, cloud-based solutions for real-time data streaming and analytics, machine learning-powered data lakes, and big data platforms like Hadoop and Spark. These tools or platforms enable telecommunications companies to store, process, and analyze large volumes of data efficiently and effectively. [Figure 4.11]

5.5 Data Analytics for Demand Forecasting

- The telecommunications companies use various methods to forecast and predict the demand for mobile communication services, such as historical trend analysis of subscriber growth and data usage, hybrid models combining statistical methods with AI algorithms, machine learning models predicting future demands based on user behavior patterns, regression models considering external factors such as population growth, and time series analysis incorporating events and holidays. These methods help the telecommunications companies to anticipate and plan for future network capacity and optimization needs. [Figure 4.12]

The research findings also show that the respondents from the focus group discussion highlighted a few challenges in implementing machine learning for network planning and optimization, such as storage, institutional capacity, skill, privacy, and accuracy of data. These challenges reflect the technical and organizational difficulties in collecting, storing, and analyzing data for machine learning purposes.

The research findings also reveal that:

- Most of the telecommunications companies (73%) use data analytics techniques to analyze historical data for demand forecasting, while the remaining 27% do not. This indicates a relatively high level of adoption of data analytics techniques for demand forecasting, but also a gap of 27% for improvement. Data analytics techniques can help telecommunications companies to identify patterns, trends, and anomalies in historical data, and use them to inform future network planning and optimization decisions. [Figure 4.13]

- The telecommunications companies incorporate various external factors (e.g., events, holidays, population growth) into their demand forecasting models, such as historical event data using time-based correlation, statistical modelling to account for seasonal variations and special events, machine learning algorithms detecting patterns in external data impact, external data sources to enhance predictive accuracy, and hybrid models combining event-driven data with user behavior insights. These external factors can affect the demand for mobile communication services, and thus need to be considered in network planning and optimization. [Figure 4.14]
- The telecommunications companies have different levels of accuracy of their demand forecasting models, with 68% being very accurate, 24% being moderately accurate, and 7% being slightly accurate. This suggests a gap of 32% for improvement in the accuracy of forecasting using demand models. Accuracy is important for demand forecasting, as it can reduce the risk of over-provisioning or under-provisioning network resources, and thus improve network efficiency, quality, and reliability. [Figure 4.15]
- The telecommunications companies recognize the relevance of the adoption of data analytics in their network planning, such as understanding market trends, predicting peak network usage, customer centricity, attrition reduction, planning in line with customer preferences, and a cost-effective mechanism to structure the unstructured data. These benefits can help the telecommunications companies to gain a competitive edge, increase customer satisfaction, and reduce operational costs. [Figure 4.16]

The research findings also show that the respondents from the focus group discussion agree that machine learning and data analytics help reduce costs, save time, and improve customer satisfaction. They give an example of how machine learning and data analytics can help to resolve customer complaints faster and more efficiently, without sending someone to the location of the customer. This suggests that there is some positive feedback and experience from the telecommunications companies on the use of machine learning and data analytics for network planning and optimization.

Specifically, telecommunications companies in Nigeria adopt various data collection tools and methods for network planning and optimization purposes. Here are the specific data collection tools and methods highlighted by respondents:

A. Data Collection Tools and Methods

- Coverage Maps and Drive Test Logs:
  Utilizing coverage maps and logs from drive tests to assess and analyze the extent and quality of network coverage.

- Network Load Distribution and Handover Statistics:
  Collecting data on network load distribution and handover statistics to understand how traffic is distributed across the network and optimize handovers.

- Signal Strength Measurements and Interference Data:
  Gathering signal strength measurements and interference data to evaluate signal quality and identify and mitigate interference issues.

- User Behavior Patterns and Application Usage Trends:
  Analyzing user behavior patterns and trends in application usage to understand user preferences, anticipate demands, and optimize services accordingly.

- Call Detail Records and User Session Data:
  Collecting call detail records and user session data to gain insights into communication patterns, call quality, and user engagement.

B. Data Storage and Management Tools:

- Centralized Data Warehouse with SQL-based Querying:
  Using a centralized data warehouse with SQL-based querying for efficient and structured data storage.

- Custom-built Data Repositories with APIs:
  Employing custom-built data repositories with APIs to facilitate seamless integration and access to data.

- Cloud-based Solutions for Real-time Data Streaming and Analytics:
  Leveraging cloud-based solutions for real-time data streaming and analytics to enable quick and dynamic insights.

- ❖ Machine Learning-powered Data Lakes:
  Implementing machine learning-powered data lakes for advanced analytics and deriving actionable intelligence from large datasets.

- ❖ Big Data Platforms (Hadoop and Spark):
  Deploying big data platforms like Hadoop and Spark for handling and processing large volumes of data efficiently.

These tools and methods provide a comprehensive approach to data collection, storage, and management, enabling telecommunications companies to make informed decisions for effective network planning and optimization. The challenges highlighted, such as storage, institutional capacity, skill, privacy, and accuracy of data, underscore the importance of addressing both technical and organizational aspects in implementing robust data analytics for network enhancement.

5.6 Level of Network Management (NM) Challenges To Operators of Mobile Communications

The research findings also show that the telecommunications companies face various challenges in the adoption of data analytics in network planning, such as lack of funds to establish fully functioning big data analytics, high cost of purchase, lack of literacy on big data analytics among staff, and reluctance of staff to acquire more knowledge on big data analytics. These challenges reflect the financial, technical, and organizational barriers to the adoption of data analytics in network planning, and require solutions that can address funding, training, and awareness issues. [Figure 4.17]

5.7 Performance Evaluation and Optimization

The research findings also reveal that:

- The telecommunications companies use various methods for evaluating the performance of network planning and optimization efforts, such as network load distribution analysis and handover success rate evaluation, regular network audits and comparison with benchmarking standards, KPI tracking and analysis of user experience metrics, machine learning-powered anomaly detection, and continuous monitoring of network congestion points and capacity bottlenecks. These methods help the telecommunications companies to assess the

effectiveness and efficiency of their network planning and optimization strategies and identify areas for improvement. [Figure 4.18]

- The telecommunications companies consider various key performance indicators (KPIs) for network performance evaluation, such as call drop rate and handover failure rate, network utilization and resource allocation, data throughput and latency, signal quality and coverage area, and user satisfaction and customer churn rates. These KPIs help the telecommunications companies to measure the quality and reliability of their network services, and the satisfaction and loyalty of their customers. [Figure 4.19]
- The telecommunications companies identify areas for network optimization and improvement through various sources, such as analysis of user complaints and service tickets, predictive analytics to detect future capacity bottlenecks, machine learning models to identify load distribution disparities, real-time network monitoring to trigger optimization actions, and heatmap analysis of network congestion and coverage gaps. These sources help telecommunications companies to pinpoint network issues and challenges and priorities the optimization and improvement actions. [Figure 4.20]
- The telecommunications companies measure the impact of network optimization on customer experience and satisfaction by various means, such as monitoring reductions in call drops and data stalls, conducting post-optimization user surveys, tracking improvements in user engagement metrics, measuring the decrease in customer complaints and support inquiries, and using machine learning algorithms to quantify enhanced user experience. These means help the telecommunications companies to evaluate the outcomes and benefits of their network optimization efforts, and the feedback and perception of their customers. [Figure 4.21]

5.8 Customer Satisfaction Level

The research findings also show that when users of the network were asked to vet the performance of service providers. They gave mixed opinions, depending on the location and the service provider. They noted that there is some improvement in network performance, but also some gaps in coverage, especially in rural areas. They suggested that the service providers should extend their broadband into areas that have poor network services. This suggests that there is some customer awareness and expectation

of network performance, and some room for improvement in network coverage and quality.

Notably, when customers/users of the networks were asked what they were satisfied and dissatisfied with the mobile network services and the internet service. Some of the customers affirmed that over the years, the network for mobile usage has been very poor, especially with difficulty hearing the caller at the other end of the phone. Customers also observed some form of predatory practices, and increasing low level of customer service and feedback mechanism stating that even after complains are made to the network providers through emails or websites, they do not respond to it. For a layman, how can he complain if he does not know about emails? This suggests that there is some customer dissatisfaction and frustration with the network quality and the customer service.

5.9 Future Trends and Challenges

- The telecommunications companies predict various future trends and advancements in machine learning and data analytics for mobile communication network planning, such as the integration of 5G capabilities for real-time analytics and response, a more advanced AI-driven autonomous network optimization, seamless integration of IoT data for dynamic network adjustments, predictive analytics for proactive resolution of network issues, and the evolution of hybrid cloud solutions for scalable data processing. These trends and advancements can help the telecommunications companies to cope with the increasing complexity and diversity of network services and user demands. [Figure 4.22]
- The telecommunications companies face various challenges and obstacles in adopting and implementing advanced analytics techniques in their network planning processes, such as a lack of skilled data science professionals, managing the computational complexity of machine learning models, protecting the security and privacy of sensitive network data, combining different data sources from different vendors, and adapting to changing regulatory requirements. These challenges and obstacles require solutions that can address the skill, technical, and regulatory gaps. [Figure 4.23]
- The telecommunications companies identify specific areas or aspects of network planning where machine learning and data analytics can bring significant

improvements, such as dynamic resource allocation based on fluctuating user demand, real-time network anomaly detection and immediate response, proactive capacity prediction to prevent congestion issues, predictive maintenance for infrastructure components, and personalized network service delivery based on user preferences. These improvements can help the telecommunications companies to enhance their network performance, quality, and reliability, and to increase their customer satisfaction and loyalty. [Figure 4.24]

The study also shows that the participants agree that machine learning and data analytics are important for network planning and optimization. One of the participants posited that data analytics is used to analyze future trends and make recommendations. Both can help in the sense that from data analytics one can extract more specifically from data, specifically subscriber level and application level, and these are the directions they are going in the future because they will be planning for different loads, different applications, different subscribers, and a lot of different things. This suggests that there is some positive feedback and experience from the telecommunications companies on the use of machine learning and data analytics for network planning and optimization.

5.10 Collaboration and Knowledge Sharing

The research findings also reveal that:

- Most of the telecommunications companies (75%) actively collaborate with academia, research institutions, or industry partners in the field of machine learning and network planning, while the remaining 25% do not. This indicates a relatively high level of collaboration and knowledge exchange among the stakeholders in the field of machine learning and network planning, but also a gap of 25% for improvement. Collaboration can help telecommunications companies to access the latest research and innovations, leverage the expertise and resources of other partners, and foster a culture of learning and experimentation. [Figure 4.25]
- The telecommunications companies use various methods to promote knowledge sharing and innovation within their organizations regarding machine learning and data analytics, such as allocating time for employees to pursue continuous learning and skill development, encouraging cross-functional teams to

collaborate on analytics projects, hosting internal workshops and seminars on emerging technologies, partnering with external training providers to upskill employees in analytics, and establishing an innovation hub for exploring new analytics techniques. These methods can help telecommunications companies to enhance their human capital and organizational capabilities in machine learning and data analytics, and to create a conducive environment for innovation and creativity. [Figure 4.26]

The research findings also show that the participants agree that machine learning and data analytics are important for network planning and optimization, and that they can bring significant improvements in various areas or aspects of network planning, such as dynamic resource allocation, real-time network anomaly detection, proactive capacity prediction, predictive maintenance, and personalized network service delivery. They also highlight some of the challenges and obstacles they face in adopting and implementing machine learning and data analytics, such as a lack of skilled data science professionals, managing the computational complexity of machine learning models, protecting the security and privacy of sensitive network data, combining different data sources from different vendors, and adapting to changing regulatory requirements.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The research concluded that machine learning and data analytics have significant potential and benefits for mobile communication network planning and optimization in Nigeria. However, the mobile network operators currently face some challenges and barriers in their adoption and implementation, which accounts for the low adoption rate in the sector.

Following our analysis, we have identified the following barriers and challenges to be inimical to the increasing level of adoption of machine learning and data analytics.

6.2 Barriers and Challenges:

- Lack of resources and capabilities: As most of the telecommunications companies are micro, small, or medium enterprises, they may not have sufficient financial, human, and technical resources to invest in data analysis and machine learning solutions. They may also lack the skills and expertise to implement and use these solutions effectively.
- Data quality and availability: The telecommunications companies may face issues with the quality and availability of data related to network performance, coverage, and capacity. They may have to deal with incomplete, inaccurate, or outdated data, which can affect the reliability and validity of their analysis and decision making. They may also have to overcome the challenges of data integration, security, and privacy, especially when dealing with sensitive customer data.

- Resistance to change and innovation: The telecommunications companies may encounter resistance to change and innovation from their internal and external stakeholders, such as employees, customers, regulators, and competitors. They may have to overcome the barriers of organizational culture, inertia, and risk aversion, as well as the challenges of customer satisfaction, regulatory compliance, and competitive pressure. They may also have to cope with the uncertainty and complexity of the dynamic and evolving mobile communications market.

- Organization, culture, and decision-making: The telecommunications companies may face organizational, cultural, and decision-making barriers that prevent them from fully embracing data-driven and intelligent solutions for network planning and optimization. They may have to deal with a lack of leadership support, a lack of data literacy and skills, a lack of trust and confidence in machine learning models, and a lack of alignment and collaboration among different departments and stakeholders. These barriers require solutions that can foster a data-driven culture, a learning mindset, and a shared vision and strategy.
- External constraints or regulations: The telecommunications companies may encounter external constraints or regulations that limit their ability to implement machine learning for network planning and optimization. They may have to comply with legal, ethical, and social norms and expectations, such as data protection and privacy laws, consumer rights and consent, and social responsibility and accountability. They may also have to cope with market competition and pressure, such as price wars, customer churn, and service differentiation. These constraints require solutions that can balance the trade-offs between innovation and regulation, and between efficiency and ethics.
- Data architecture and technology: The telecommunications companies may face data architecture and technology challenges that hinder their adoption and implementation of machine learning for network planning and optimization. They may have to overcome the issues of data quality, availability, and integration, such as data completeness, accuracy, timeliness, and consistency. They may also have to deal with the challenges of data storage, processing, and analysis, such as data volume, velocity, and variety. They may also have to cope with the complexity and diversity of machine learning models and algorithms, such as model selection, validation, and evaluation. These challenges require solutions that can provide a robust, scalable, and flexible data infrastructure and technology platform.

- Storage and institutional capacity: The telecommunications companies may face storage and institutional capacity challenges that limit their ability to collect, store, and analyze large volumes of data for machine learning and data analytics purposes. They may have to deal with the issues of data storage space, cost, and scalability, as well as the challenges of data governance, management, and security. They may also have to cope with the lack of institutional support, commitment, and resources for data-driven initiatives. These challenges require

solutions that can provide adequate and affordable data storage and management solutions, as well as institutional capacity building and empowerment.

- Skill and privacy: The telecommunications companies may encounter skill and privacy challenges that hinder their adoption and implementation of machine learning and data analytics techniques for network planning and optimization. They may have to overcome the skill gap and shortage of data scientists, analysts, and engineers, as well as the challenges of data literacy and education among their employees and customers. They may also have to comply with the data protection and privacy laws and regulations, as well as the ethical and social norms and expectations of their customers and stakeholders. These challenges require solutions that can provide skill development and training programs, as well as data privacy and security measures.
- Accuracy of data and models: The telecommunications companies may face accuracy challenges that affect the reliability and validity of their data and models for machine learning and data analytics purposes. They may have to deal with the issues of data quality, completeness, timeliness, and consistency, as well as the challenges of model selection, validation, and evaluation. They may also have to cope with the uncertainty and variability of the mobile communications market and user behavior, as well as the complexity and diversity of the machine learning and data analytics techniques and algorithms. These challenges require solutions that can provide data quality assurance and improvement, as well as model testing and optimization.

- Lack of funds and high cost: The telecommunications companies may face financial barriers that prevent them from investing in data analytics platforms and solutions for network planning and optimization. They may have to deal with the high cost of purchase, installation, and maintenance of data analytics tools and systems, as well as the challenges of return on investment and cost-benefit analysis. They may also have to cope with the limited availability and accessibility of funds and financing options for data analytics initiatives. These barriers require solutions that can provide affordable and cost-effective data analytics solutions, as well as funding and financing opportunities and incentives.
- Lack of literacy and reluctance of staff: The telecommunications companies may encounter human and organizational barriers that hinder their adoption and implementation of data analytics techniques for network planning and optimization. They may have to overcome the lack of literacy and skills on data

analytics among their staff, as well as the challenges of training and education programs and resources. They may also have to deal with the reluctance and resistance of their staff to acquire more knowledge and skills on data analytics, as well as the challenges of motivation and engagement. These barriers require solutions that can provide literacy and skill development and training programs, as well as motivation and engagement strategies and incentives.

The research recommended that the telecommunications companies should invest more in data infrastructure and technology, train and upskill their staff in data science, collaborate and partner with other stakeholders in the field, and leverage the latest innovations and best practices in machine learning and data analytics for network planning and optimization. The research also suggested some areas for further research, such as the impact of machine learning and data analytics on network security and resilience, the ethical and social implications of machine learning and data analytics for network planning and optimization, and the comparative analysis of machine learning and data analytics for network planning and optimization across different countries and regions.

6.3 Specific Recommendations Based on the Research Findings:

- The telecommunications companies should adopt more data-driven and intelligent solutions to enhance network performance, coverage, and capacity, such as machine learning algorithms that can analyze user data to predict future demand patterns, or real-time monitoring and data streaming to quickly identify performance bottlenecks.
- The telecommunications companies should address the organizational, technical, and regulatory challenges and limitations in implementing machine learning for network planning and optimization, such as changing the organization culture and decision-making to be more data-oriented, investing in data architecture and technology to support machine learning models, and complying with the external constraints or regulations that may affect the use of network data.
- The telecommunications companies should improve the accuracy of their demand forecasting models and incorporate more external factors that may affect the demand for mobile communication services, such as events, holidays, population growth, and user behavior. This can help them to plan and optimize

their network capacity and resources more effectively and efficiently, and to avoid network congestion and degradation.

- The telecommunications companies should evaluate the impact of network optimization on customer experience and satisfaction and use various data analytics techniques to measure and improve customer satisfaction and loyalty, such as sentiment analysis, natural language processing, or user surveys. This can help them to identify and address customer complaints and feedback, and to increase customer retention and loyalty.
- The telecommunications companies should actively collaborate with academia, research institutions, or industry partners in the field of machine learning and network planning, and use various methods to promote knowledge sharing and innovation within their organizations regarding machine learning and data analytics, such as allocating time for employees to pursue continuous learning and skill development, hosting internal workshops and seminars on emerging technologies, or establishing an innovation hub for exploring new analytics techniques. This can help them to access the latest research and innovations, leverage the expertise and resources of other partners, and foster a culture of learning and experimentation.
- The telecommunications companies should prepare for the future trends and advancements in machine learning and data analytics for mobile communication network planning, such as the integration of 5G capabilities for real-time analytics and response, a more advanced AI-driven autonomous network optimization, or seamless integration of IoT data for dynamic network adjustments. They should also address the challenges and obstacles in adopting and implementing advanced analytics techniques in their network planning processes, such as acquiring skilled data science professionals, managing the computational complexity of machine learning models, protecting the security and privacy of sensitive network data, or combining different data sources from different vendors.

CHAPTER SEVEN
FRAMEWORK FOR POLICY INTERVENTION AND IMPROVED ADOPTION

Based on the research findings, the level of network management challenges to operators of mobile communications in Nigeria is high, as they face various issues such as network congestion, capacity limitations, spectrum scarcity, urbanization, user behavior, and infrastructure scaling.

These challenges affect the quality and reliability of network services, as well as the satisfaction and loyalty of customers. Therefore, there is a need for policy intervention to address these challenges and to facilitate the adoption of machine learning and data analytics models for network optimization and improved customer service.

7.1 Proposed Framework for Policy Intervention

- Identify the key stakeholders involved in network management, such as operators, regulators, service providers, customers, and researchers, and assess their roles, responsibilities, and interests.
- Define the objectives and criteria for network management, such as performance, quality, efficiency, security, resilience, and customer experience, and align them with the national and international standards and regulations.
- Analyze the current state of network management, such as the methods, tools, data, and metrics used by the operators, and identify the gaps, challenges, and opportunities for improvement.
- Design and evaluate alternative solutions for network management, such as machine learning and data analytics models, and compare their costs, benefits, risks, and impacts on the stakeholders and the environment.
- Select and implement the best solution for network management and monitor and measure its outcomes and effects on the network performance, quality, and customer satisfaction.
- Review and revise the solution for network management and incorporate feedback and learning from the stakeholders and the data and adapt to the changing needs and conditions of the network and the customers.

7.2 Recommended Machine Learning And Data Analytics Models To Enhance Operators Level of Adoption:

- Machine learning models for predicting future network demand based on user behavior patterns, such as neural networks, support vector machines, or random forests. These models can help the operators to anticipate and plan for network capacity and optimization needs and to avoid network congestion and degradation.
- Machine learning models for identifying and mitigating network anomalies and faults, such as deep learning, reinforcement learning, or anomaly detection algorithms. These models can help the operators to monitor and diagnose network performance and quality issues, and to take immediate corrective actions, such as reconfiguring network parameters, rerouting traffic, or triggering alarms.
- Data analytics platforms for analyzing and visualizing network data, such as big data platforms like Hadoop and Spark, or cloud-based solutions for real-time data streaming and analytics. These platforms can help the operators to store, process and analyze large volumes of data efficiently and effectively, and to gain valuable insights into network performance, quality, and reliability, as well as user preference and expectations.
- Data analytics techniques for evaluating the impact of network optimization on customer experience and satisfaction, such as sentiment analysis, natural language processing, or user surveys. These techniques can help the operators to measure and improve customer satisfaction and loyalty, and to identify and address customer complaints and feedback.

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