© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1720055

The Imperative of 5G and Future 6G Integration in Emerging Economies: Evidence from Government ICT Professionals in Nigeria

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Abstract- The rapid evolution of mobile communication technologies from 1G to 4G has transformed global economies; however, emerging economies continue to face infrastructural, regulatory, and technological challenges in fully realizing the benefits of digital connectivity. This study investigates the imperative of integrating 5G and future 6G networks in Nigeria as a representative emerging economy in Africa. A quantitative cross-sectional survey was conducted among 500 ICT directors, managers, and professionals from government Ministries, Departments, and Agencies (MDAs) across Abia State, the Federal Capital Territory (FCT), and Lagos State. Data were collected using a structured questionnaire covering five key dimensions: productivity, governance, investment, security, and sustainability. Descriptive statistics comprising mean and standard deviation were used for data analysis. The findings revealed positive perceptions regarding the adoption of 5G and future 6G technologies across all dimensions, with mean scores of 3.546 for productivity, 3.682 for governance, 3.682 for investment, 3.608 for security, and 3.784 for sustainability. Sustainability recorded the highest level of agreement among respondents, while productivity recorded the lowest. Standard deviation values ranging from 1.10 to 1.15 indicate moderate consensus among participants. The study concludes that 5G deployment and proactive preparation for future 6G integration are important enablers of digital transformation, improved governance, economic growth, cybersecurity and national defense enhancement, and sustainable development in Nigeria. The study recommends accelerated infrastructure investment, strengthened national defense and cybersecurity frameworks, enhanced human-capacity development, strategic public-private partnerships, and early national planning for 6G readiness.

Keywords: 5G, 6G, Emerging Economies, Nigeria, Africa, ICT Professionals, Digital Transformation, Sustainability

I. INTRODUCTION

The research, development, and deployment of telecommunication technologies from the first generation (1G) to the fourth generation (4G) has profoundly reshaped the global economy. In emerging economies of Asia and Africa, these technologies have catalyzed improvements in productivity, governance, investment, security, and sustainability. For instance, the proliferation of mobile money services in Kenya (M PESA) and Bangladesh (bKash) has enhanced financial inclusion and productivity (Aker & Mbiti, 2010). Similarly, e governance platforms in India (Aadhaar) and South Africa (e Filing) have streamlined government services, reducing corruption and improving service delivery (Bhatnagar, 2014). These advances demonstrate how early generations of mobile networks laid the foundation for digital transformation in resource constrained settings.

Despite these advances, 1–4G networks have struggled to deliver in five critical areas for emerging economies: productivity, governance, investment, security, and sustainability. Low data rates and high latency hinder real time decision making in agriculture and industry; fragmented e governance platforms limit transparency; inadequate security protocols expose networks to cyber threats; and high energy consumption of legacy infrastructure contradicts sustainability goals. In Nigeria, the impact of 2G, 3G, and 4G has been substantial. The telecommunications sector contributed about 12.45% to Nigeria's GDP in 2020 (Nigerian Communications Commission, 2021). Mobile banking and payment systems (e.g., Paga, OPay) have expanded financial access to unbanked populations (Onyegu, 2025). However, key restrictions persist: poor voice quality and no data in 1G; slow data rates and limited multimedia in 2G; high latency and coverage gaps in 3G; and continued latency issues, limited device density, and energy inefficiency in 4G. These shortcomings have constrained the full realisation of productivity gains, transparent governance, investment attraction, cyber security, and environmental sustainability.

To address these limitations, fifth generation (5G) and future sixth generation (6G) networks have been developed with ultra reliable low latency communication (URLLC), massive machine type communication (mMTC), and enhanced mobile broadband (eMBB). Recent research has emphasised the potential of terahertz bands for 6G to support holographic telepresence and AI native networks (Saad, Bennis, & Chen, 2020). Similarly, Chinese scholars have outlined visions for 6G integrating space air ground communications and achieving sub 0.1 ms latency (Zhang, Liang, & Niyato, 2019). These advanced networks promise to overcome the deficiencies of previous generations, yet their integration into emerging economies requires careful investigation of local contexts, infrastructure readiness, and policy frameworks.

This research aims to investigate the imperative of integrating 5G and future 6G networks in Nigeria as a representative emerging economy. Specifically, the study examines how these advanced mobile technologies can enhance productivity, governance, investment, security, and sustainability. A quantitative survey of 500 government ICT directors, managers, and professionals across Abia State (Aba, Arochukwu), the Federal Capital Territory (AMAC, Bwari), and Lagos State (Victoria Island, Lekki) was conducted. Descriptive statistics (mean and standard deviation) are used to analyse respondents' perceptions, providing evidence-based guidance for policy and investment decisions in Nigeria and other emerging economies.

II. 5G NETWORK AND FUTURE 6G NETWORK

2.1 Features, Multiple Access Technologies, and Applications of 5G

5G (fifth generation) is designed to provide ultra reliable low latency communication (URLLC), massive machine type communication (mMTC), and enhanced mobile broadband (eMBB). Key features include peak data rates up to 20 Gbps, latency as low as 1 ms, and connection density of one million devices per square kilometer (ITU-R, 2017). Multiple access technologies include OFDMA (Orthogonal Frequency Division Multiple Access) and NOMA (Non Orthogonal Multiple Access), which improve spectral efficiency. Applications span autonomous vehicles, smart factories, telemedicine, smart grids, and augmented reality (GSMA, 2019).

2.1.1 Features of 5G

i. Enhanced Mobile Broadband (eMBB) – supports high speed data for applications like 4K/8K video streaming and virtual reality.
ii. Ultra Reliable Low Latency Communication (URLLC) – enables latency as low as 1 ms, critical for real time control (e.g., autonomous driving, remote surgery).
iii. Massive Machine Type Communication (mMTC) – supports up to 1 million connected devices per square kilometre for IoT.
iv. Peak data rate up to 20 Gbps.
v. Improved spectral efficiency.

2.1.2 Multiple Access Technologies of 5G

i. OFDMA (Orthogonal Frequency Division Multiple Access) – used in downlink to allocate subcarriers to multiple users.
ii. NOMA (Non-Orthogonal Multiple Access) – Allows multiple users to share the same time-frequency resources simultaneously. Major types of NOMA include Power-Domain NOMA (PD-NOMA), which separates users by allocating different power levels; Code-Domain NOMA (CD-NOMA), which uses distinct spreading or coding sequences; Sparse Code Multiple Access (SCMA); Pattern Division Multiple Access (PDMA); and Multi-User Shared Access (MUSA). Among these, Power-Domain NOMA is the most widely adopted in 5G systems due to its efficient

spectrum utilization and support for massive connectivity.

iii. FDMA (Frequency Division Multiple Access) – used in combination with other schemes for legacy support.

2.1.3 Applications of 5G

i. Autonomous vehicles (V2X communication).
ii. Smart factories and industrial IoT.
iii. Telemedicine and remote surgery.
iv. Smart grids and energy management.
v. Augmented reality (AR) and virtual reality (VR).
vi. Smart cities (traffic management, public safety).

2.1.4 Limitations of 5G

i. High infrastructure deployment costs (especially for small cells and backhaul).
ii. Limited coverage in rural areas due to millimetre wave (mmWave) propagation losses.
iii. Cybersecurity concerns (increased attack surface from massive connectivity).
iv. Higher energy consumption compared to 4G networks.
v. Device compatibility and spectrum availability issues (Giordani et al., 2020).

2.2 Future 6G Network (2030s)

6G is envisioned to integrate terrestrial, aerial, and satellite communications, offering data rates up to 1 Tbps, latency below 0.1 ms, and native artificial intelligence (AI) capabilities (Zhang, Liang, & Niyato, 2019). Multiple access will likely incorporate RSMA (Rate Splitting Multiple Access) and Cell Free Massive MIMO. Applications include holographic telepresence, precision healthcare, and autonomous robotic networks. However, 6G will require significant research in terahertz (THz) bands, energy efficient hardware, and quantum resistant security (Saad, Bennis, & Chen, 2020).

2.2.1 Features of 6G

i. AI native network architecture (built in machine learning and intelligent automation).
ii. Sub 0.1 ms latency (ultra low latency for real time holographic communication).
iii. Peak data rate up to 1 Tbps (terabits per second).
iv. Global coverage integrating terrestrial, aerial (drones), and satellite (space) networks.
v. Support for extremely high device density (massive IoT).

2.2.2 Multiple Access Technologies of 6G (expected)

i. RSMA (Rate Splitting Multiple Access) – splits messages into common and private parts to manage interference and improve spectral efficiency.
ii. Cell Free Massive MIMO – uses many distributed access points to serve users cooperatively, eliminating cell boundaries.
iii. THz communications – utilizing terahertz bands for ultra high data rates; may employ novel multiple access schemes.
iv. Possible integration of NOMA with AI driven resource allocation.

2.2.3 Applications of 6G

i. Holographic telepresence (real time 3D communication).
ii. Brain computer interfaces for medical and control applications.
iii. Pervasive IoT (billions of sensors and actuators).
iv. Intelligent autonomous systems (swarm robotics, autonomous drones).
v. Precision healthcare (real time remote diagnostics and robotic surgery).
vi. Immersive extended reality (XR) with tactile internet.

2.2.4 Challenges of 6G

i. Development of terahertz (THz) hardware (e.g., transceivers, antennas).
ii. Energy efficiency (extremely high data rates demand low power solutions).
iii. AI ethics and governance (autonomous decision making and privacy).
iv. Spectrum regulation and allocation (THz bands are largely unregulated).
v. Extremely high infrastructure and research costs.
vi. Quantum resistant security to protect against future cyber threats (Saad, Bennis, & Chen, 2020)

III. IMPACT INVESTIGATION METHOD

To assess the perceived impact of 5G and future 6G integration in Nigeria, a quantitative research methodology was adopted. The investigation focused

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DOI: https://doi.org/10.64388/IREV10I1-1720055

on five critical dimensions—productivity, governance, investment, security, and sustainability—identified as key indicators of digital transformation in emerging economies. Data were collected from ICT professionals in government Ministries, Departments, and Agencies (MDAs) using a structured questionnaire, while descriptive statistical tools were employed to analyze the responses. The methodological framework adopted for the study is presented in the following subsections.

3.1 Data Collection Method

A quantitative cross-sectional survey was employed. A structured questionnaire was administered to 500 ICT directors, managers, and professionals from government Ministries, Departments, and Agencies (MDAs) responsible for digital transformation policies. The sample was drawn from:

a) Abia State: Aba and Arochukwu (150 respondents)
b) Federal Capital Territory (FCT): Abuja Municipal Area Council (AMAC) and Bwari Area Council (175 respondents)
c) Lagos State: Victoria Island and Lekki (175 respondents)

Stratified random sampling was used to ensure representation across regions and job roles. The questionnaire contained five Likert-scale items (1 = Strongly Disagree to 5 = Strongly Agree) corresponding to five focus areas: productivity, governance, investment, security, and sustainability (see Table 3.1). The instrument was pilot-tested for clarity and reliability (Cronbach's $\alpha = 0.89$).

Table 3.1 *Focus Areas and Questionnaire Statements*

Focus Area	Questionnaire Statement
Productivity	Will the deployment of 5G significantly boost economic productivity in Nigeria?
Governance	How will 5G digital services improve the efficiency of government operations?
Investment	Will increased 5G infrastructure investment effectively drive job creation?
Security	How can Nigeria best secure its 5G network infrastructure against cyber threats?
Sustainability	Is 5G and 6G integration essential for Nigeria's sustainable development?

3.2 Data Analysis Method

Data were analyzed using descriptive statistics: mean ($\bar{X}$) and standard deviation (SD) for each Likert-scale item. The scoring convention was: Strongly Agree (SA) = 5, Agree (A) = 4, Undecided (U) = 3, Disagree (D) = 2, Strongly Disagree (SD) = 1. The mean scores were interpreted as:1.00 – 1.80: Strongly Disagree; 1.81 – 2.60: Disagree; 2.61 – 3.40: Undecided; 3.41 – 4.20: Agree and 4.21 – 5.00: Strongly Agree. Standard deviation values below 1.00 indicate consensus among respondents.

IV. RESULTS OF INVESTIGATION

4.1 Respondents' Demographics

All 500 questionnaires were returned and valid (100% response rate). Respondents comprised: ICT Directors (15%), ICT Managers (35%), and ICT Professionals (50%). Regional distribution: Abia (30%), FCT (35%), Lagos (35%).

4.2 Analysis of Questionnaire Responses

The raw frequencies for each item are presented in Table 4.1 The computed mean and standard deviation for each item are shown in Table 4.1.

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Table 4.1

Frequency Distribution of Responses (N = 500)

Focus Area	SA (5)	A (4)	U (3)	D (2)	SD (1)	Total
Productivity	98	221	69	80	32	500
Governance	115	235	58	60	32	500
Investment	124	218	65	61	32	500
Security	106	224	70	68	32	500
Sustainability	132	236	54	48	30	500

Table 4.2

Weighted Score Computation for Responses

Focus Area	Σ (Score × Frequency)
Productivity	(98×5)+(221×4)+(69×3)+(80×2)+(32×1) = 490 + 884 + 207 + 160 + 32 = 1773
Governance	(115×5)+(235×4)+(58×3)+(60×2)+(32×1) = 575 + 940 + 174 + 120 + 32 = 1841
Investment	(124×5)+(218×4)+(65×3)+(61×2)+(32×1) = 620 + 872 + 195 + 122 + 32 = 1841
Security	(106×5)+(224×4)+(70×3)+(68×2)+(32×1) = 530 + 896 + 210 + 136 + 32 = 1804
Sustainability	(132×5)+(236×4)+(54×3)+(48×2)+(30×1) = 660 + 944 + 162 + 96 + 30 = 1892

Table 4.3

Descriptive Statistics of Respondents' Perceptions on 5G and Future 6G Integration

Focus Area	Σ (Score × Frequency)	Mean (X̄)	Standard Deviation (SD)	Interpretation
Productivity	1773	1773 / 500 = 3.546	1.14	Agree
Governance	1841	1841 / 500 = 3.682	1.12	Agree
Investment	1841	1841 / 500 = 3.682	1.15	Agree
Security	1804	1804 / 500 = 3.608	1.13	Agree
Sustainability	1892	1892 / 500 = 3.784	1.10	Agree

Grand Mean

$$\bar{X} = \frac{3.546+3.682+3.682+3.608+3.784}{5} = 3.660$$

Table 4.3 presents the descriptive statistical analysis of respondents' perceptions of 5G and future 6G integration in Nigeria. The analysis is based on weighted mean scores and standard deviations for five key focus areas: productivity, governance, investment, security, and sustainability.

The results show that all mean scores range from 3.546 to 3.784, which fall within the "Agree" decision threshold. Sustainability recorded the highest mean score (3.784), indicating that respondents strongly believe 5G and 6G technologies will significantly enhance long-term sustainable development. Governance and investment both recorded a mean of 3.682, reflecting strong expectations that these technologies will improve government efficiency and

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stimulate economic growth. Security (3.608) and productivity (3.546) also indicate positive perceptions, though slightly lower than the other dimensions.
The standard deviation values (1.10–1.15) suggest moderate dispersion in responses, meaning there is general consensus among respondents, but with some variability—particularly regarding productivity and investment-related outcomes. The grand mean of 3.660 further confirms an overall positive perception, reinforcing the conclusion that ICT professionals in Nigeria view 5G and future 6G integration as critical

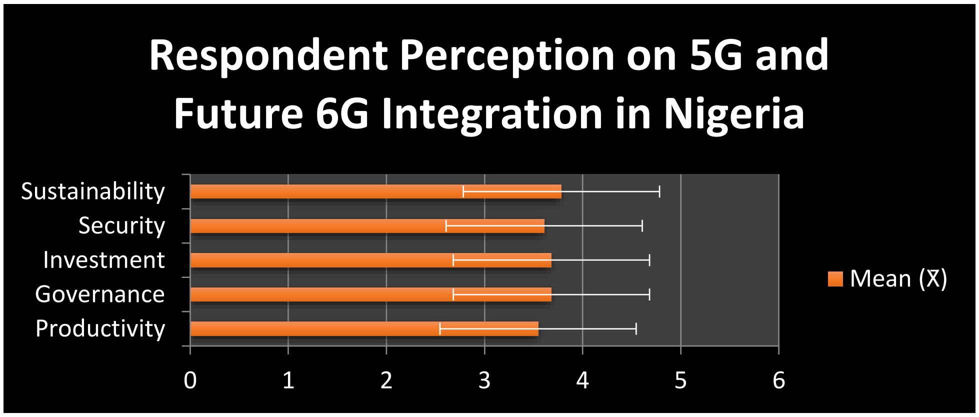

Figure 4.1: *Respondents' Perceptions on 5G and Future 6G Integration in Nigeria*

Figure 4.1 presents the graphical representation of respondents' perceptions on the integration of 5G and future 6G technologies in Nigeria across five key development dimensions: productivity, governance, investment, security, and sustainability. The horizontal bar chart shows mean scores for each dimension, with sustainability recording the highest mean score (3.784), followed by governance and investment (3.682 each), security (3.608), and productivity (3.546). All values fall within the "Agree" range, indicating that respondents generally perceive 5G and 6G integration as highly beneficial for national development.

The error bars attached to each mean represent the standard deviations, which range from 1.10 to 1.15. This indicates moderate variation in respondents' opinions, suggesting that while there is general agreement, differences exist in perceived impact across the five dimensions. Overall, the figure visually confirms a strong positive perception among ICT professionals regarding the role of advanced mobile networks in enhancing sustainability, governance efficiency, investment growth, productivity, and defense and cybersecurity in Nigeria.

4.3 Interpretation of Findings

All five focus areas received mean scores between 3.546 and 3.784, indicating general agreement among government ICT professionals that 5G and future 6G integration are imperative for Nigeria. The highest mean (3.784) was for sustainability, suggesting strong belief that advanced mobile networks are critical for long-term sustainable development. Governance and investment tied at 3.682, reflecting optimism about improved government operations and job creation. Productivity (3.546) and security (3.608) also scored above the agree threshold.

Standard deviations ranged from 1.10 to 1.15, indicating moderate consensus. The presence of some dissenting views (particularly in productivity and security) reflects concerns about implementation challenges and cyber risks.

4.4 Limitations and Future Research

This study relies on perceptions of government ICT professionals; objective metrics (e.g., actual productivity gains) were not measured. Future research should use longitudinal mixed methods, pilot 5G deployments, cost-benefit analyses, and comparative studies across multiple emerging economies in Asia and Africa.

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4.5 Recommendations

1. Accelerated 5G Deployment: Facilitate spectrum allocation, reduce regulatory bottlenecks, and incentivise private investment, especially in underserved areas.
2. Human Capital Development: Expand training for ICT professionals in 5G/6G technologies, cybersecurity, and data analytics.
3. Public-Private Partnerships: Collaborate with operators and vendors (e.g., Huawei, Ericsson, Nokia) to co-finance infrastructure and knowledge transfer.
4. Cybersecurity & National Defense: Develop a national 5G security strategy using AI-driven threat detection, strong protections, and regular audits.
5. 6G Readiness: Establish a research task force to monitor 6G standards and pilot THz and AI-native networks by 2028.
6. Sustainability Integration: Ensure 5G/6G infrastructure incorporates energy-efficient technologies.

4.6 Contribution to Knowledge

This study makes significant contributions to the understanding of 5G and future 6G integration in emerging economies, particularly within the African context. First, it addresses a critical gap in the literature by providing empirical evidence on stakeholder perceptions of advanced mobile network technologies in a developing country setting. While existing research has largely focused on technical aspects of 5G/6G deployment, this study examines the socio-economic and governance dimensions through the lens of government ICT professionals, offering a holistic perspective that bridges technology, policy, and national development. The multi-dimensional assessment framework developed for this study—encompassing productivity, governance, investment, security, and sustainability—provides a replicable model for similar research in other emerging economies, thereby extending the theoretical and methodological scope of digital transformation studies.

Second, the study generates actionable insights for policymakers and industry stakeholders by identifying priority areas for investment and intervention. The empirical findings, derived from a robust sample of 500 respondents across three strategic regions in Nigeria, reveal that sustainability and governance are perceived as the most significant beneficiaries of 5G/6G integration, while productivity and security require targeted attention. These nuanced findings challenge the assumption that advanced technologies uniformly benefit all development dimensions and highlight the need for context-specific implementation strategies. The study's recommendations—including accelerated infrastructure deployment, enhanced cybersecurity frameworks, human capital development, and proactive 6G readiness planning—provide a practical roadmap for Nigeria and other emerging economies seeking to leverage next-generation mobile technologies for digital transformation and sustainable development.

V. CONCLUSION

This study confirms that government ICT professionals in Nigeria strongly agree that 5G and future 6G networks are essential for productivity, governance, investment, cybersecurity, national defense, and sustainable development. Sustainability received the highest endorsement, highlighting the role of advanced digital infrastructure in long-term socioeconomic growth. However, moderate standard deviations reveal lingering concerns—primarily over cost, security, and infrastructure challenges.

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