International Journal of Information and Communication Sciences
2025, Vol. 10, No. 1, pp. 23-33
https://doi.org/10.11648/j.ijics.20251001.13

Research Article

Implementation of Telecommunication Corridor on Infrastructure Roll out (Rail, Road, Power Lines and Inland Waterways) to Fast Track Broadband Penetration and Nation-Wide Surveillance

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Abstract

Insecurity and terrorism in Nigeria have led to widespread vandalization of critical telecommunication and power infrastructure, hindering broadband penetration and compromising national surveillance systems. Road preparations for upgrade or constructions at local, state and national level causes damages to optic-fibre cables buried underground especially as these critical infrastructure mostly lack geospatial information including outright theft for ornaments. The cuts and damages to optic-fibre cables arising from case studies causes performance degradation to telecommunication's quality of service (QoS) even after repair if there is ferrule misalignment, contaminated face of the fibre core causing dispersion losses or scattering losses or micro bending losses and thus high dB loss. These challenges amplify the digital divide, particularly in underserved and rural areas, and highlight the urgent need for robust solutions. The paper examines the benefits of geospatially designed telecommunications corridor with infrastructure roll-outs, such as roads, railways, power lines, and inland waterways dredging among others in addressing insecurity and vandalization of critical telecommunication infrastructure. Quantitative Situational analysis of broadband and optic-fibre infrastructure was presented including vulnerabilities to theft and vandalism, lack of geospatial data, and regulatory gaps especially as it concerns enforcement of some telecommunications policies. Key policies in Nigeria's National Integrated Infrastructure Master Plan (NIIMP). Nigeria's National Broadband Plan (2020–2025) and the Nigerian Communications Commission (NCC) Co-location & Infrastructure Sharing (C/IS) guidelines are evaluated for mitigating these challenges. The findings shows the potential of telecommunication corridors alongside infrastructural roll-out to protect fragile optic-fibre cables, improved quality of services (QoS) and quality of experience (QoE) without incessant down-time during road constructions at local and state government levels, facilitation of cost-effective infrastructure sharing & co-location to accelerate broadband penetration and roll-out plan performance of operators with National Metropolitan Cable (optic) Network Licenses. These corridors will enhance connectivity, reduce operational costs, and improve nationwide surveillance capabilities by adopting an integrated "dig-once" approach and leveraging a technology mix comprising terrestrial, wireless, and satellite-based systems. The study concludes that coordinated efforts among stakeholders, including government ministries, regulatory bodies, and private operators, are essential to achieving long-term digital connectivity, development and transformation while strengthening Nigeria's security framework. Implementation of these recommendations will not only provide robust and resilient ICT infrastructure but promote sustainable socio-economic growth and digital transformation.

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Received: 4 January 2025; **Accepted:** 21 January 2025; **Published:** 10 February 2025

Keywords

Broadband Penetration, Digital Transformation, ICT, Integrated Infrastructure, Surveillance, Smart Cities, Sustainable Environment, Telecommunications Corridor

1. Introduction

Insecurity and terrorism have emerged as significant challenges in Nigeria, manifesting through various forms of violence, including the vandalization of telecommunications infrastructure, power lines and the destruction of oil facilities. The on-going conflict has resulted in a substantial loss of life, with reports indicating that approximately 10,366 individuals died due to terrorism-related incidents by 2021, translating to an average of about 14 deaths per day, and generally over 80,000 deaths and three (3) million Internally Displaced Persons (IDPs) have been recorded [1, 2]. The pervasive threat of groups such as bandits, terrorists, kidnappers and other militant factions has not only led to loss of lives but has also severely impacted the nation's infrastructure and economic landscape, making Nigeria the third most affected country by terrorism according to the Global Terrorism Index [3]. The vandalization of telecommunications infrastructure has been particularly detrimental, with over 50,000 installations reportedly damaged [4]. This destruction has hindered broadband penetration, which is crucial for digital transformation, economic growth and development. The lack of geospatial information regarding the location of optic-fibre cables exacerbates the problem, especially during road construction and upgrades, leading to further damage. Additionally, the destruction of oil facilities, particularly in the Niger Delta of the country, has resulted in significant damage to optic-fibre cable infrastructure, contributing to performance degradation in quality of experience (QoE) of telecommunications services including outright theft for ornaments. The cuts and damages causes performance degradation to telecommunication's quality of service delivery even after repair if there is ferrule misalignment, contaminated face of the fibre core causing dispersion losses or scattering losses or micro bending losses and thus high dB loss. Issues such as ferrule misalignment and contamination of fibre cores lead to increased signal loss, further complicating the delivery of quality of services (QoS). To address these challenges, the Nigerian government has recognized the necessity of implementing an integrated infrastructure strategy as outlined in the National Integrated Infrastructure Master Plan (NIIMP) initiated in 2014. The deployment and implantation of an integrated infrastructure as enshrined in the 30-year National Integrated Infrastructure Master Plan (NIIMP) as a policy document [5]. One of the authors; Lasisi Salami Lawal was a member of the ICT Technical Working Group (TWG) at National level on National Integrated Infrastructure Master Plan (NIIMP) for 30 years (2014-2043). The policy document plan emphasizes the importance of deploying integrated infrastructure with security systems capable of monitoring public spaces and critical infrastructure. Such systems are essential for enhancing public safety and enabling security agencies, including the Nigeria Security and Civil Defense Corps (NSCDC), to effectively carry out their mandates [6]. The integration of surveillance systems is vital for tracking criminal activities and apprehending offenders, thereby promoting a safer environment for citizens and businesses alike [7].

Moreover, the establishment of telecommunications corridors during the construction of roads, railways, and power lines is crucial for improving broadband access and penetration in cities and underserved areas while simultaneously bolstering national security efforts. This approach not only facilitates better connectivity but also enhances the capacity for surveillance and monitoring, which is essential in combating the pervasive insecurity that has plagued Nigeria for years [8]. This paper is categorized into four sections; section one is the introduction and general overview of the subject, and section two is the situational analysis of the broadband Infrastructure and optic-fibre cable network in Nigeria. Section three deals with the bottlenecks limiting broadband penetration and nationwide surveillance, and the final section discuss the solution and way forward.

2. Situational Analysis

2.1. Broadband Penetration

Information and Communication Technology (ICT) is an umbrella that includes any communication device or application, encompassing: radio, television, cellular phones, computer and network hardware and software, satellite systems, and so on, as well as the various services and applications associated with them, such as videoconferencing and distance learning. Broadband Internet is high-speed Internet access that is always on. The disparity in access levels in homes in Nigeria has been a concern. The digital divide refers to the gap between people that have access to modern information and communications technology and those that do not or have restricted access [9]. Broadband penetration has been on the increase from February 2022 up to August

2022, moving up from 40.9% to 44.5%; a 3.9% increase within 5 months while between June, 2022 to May 2023, we had 3.96% broadband penetration growth rising from 44.32% to 48.28% as illustrated in figure 1; a 3.96% growth in broadband penetration within a year. This shows realistic progression to meet up with the 70% broadband penetration by the year 2025 as outlined in Nigeria's National Broadband plan 2020 to 2025 with adequate coverage of unserved and underserved communities with fast Internet Services and thus fast tracking bridge of the digital divide [10, 11]. The growth of broadband penetration in recent years slowed down as a result of vandalization, theft, devaluation of naira affecting capital expenditure (CAPEX) as a going concern especially replacement of vandalized sections as well as operations expenditure (OPEX), high cost of import and excise duties for telecommunications equipment, multiple taxations, right of way (ROW) issues among others. For instance, figure 2 shows decrease of broadband penetration from 44.04% in July, 2024 to 41.56% in September, 2024; a 2.48% decrease in broadband penetration within 2 months [12]. The growth of penetration must continue and with strict adherence to policies and technological advancements anticipated in the coming years and it is expedient that there will be a proliferation of devices in the industry. It is, therefore, essential for the Commission to ensure that the right regulatory frameworks can accommodate such eventualities [13].

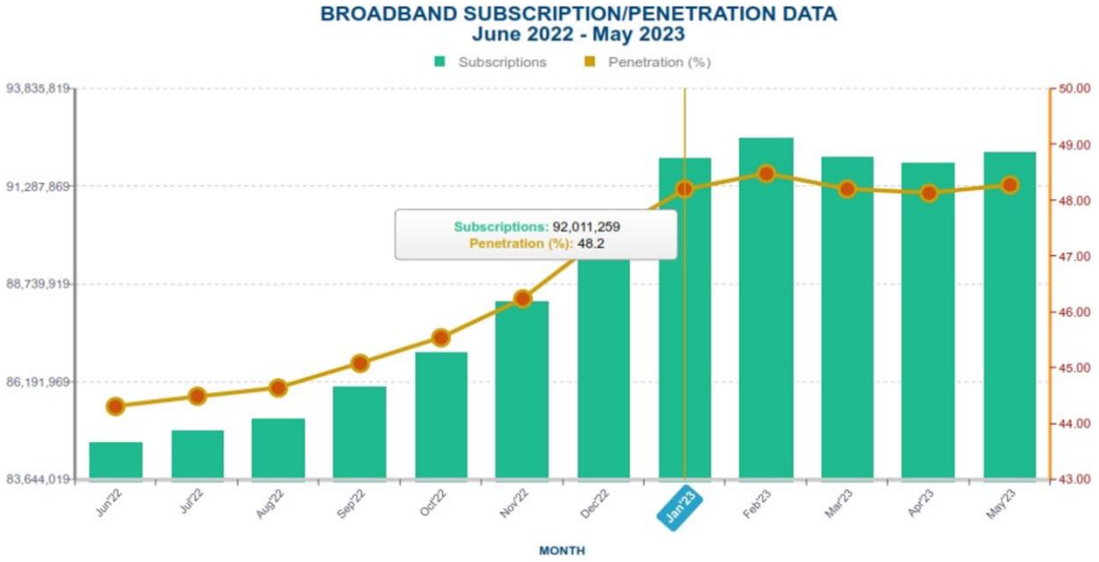

Figure 1. *Situational Analysis: Broadband Penetration from June 2022 to May, 2023 [12].*

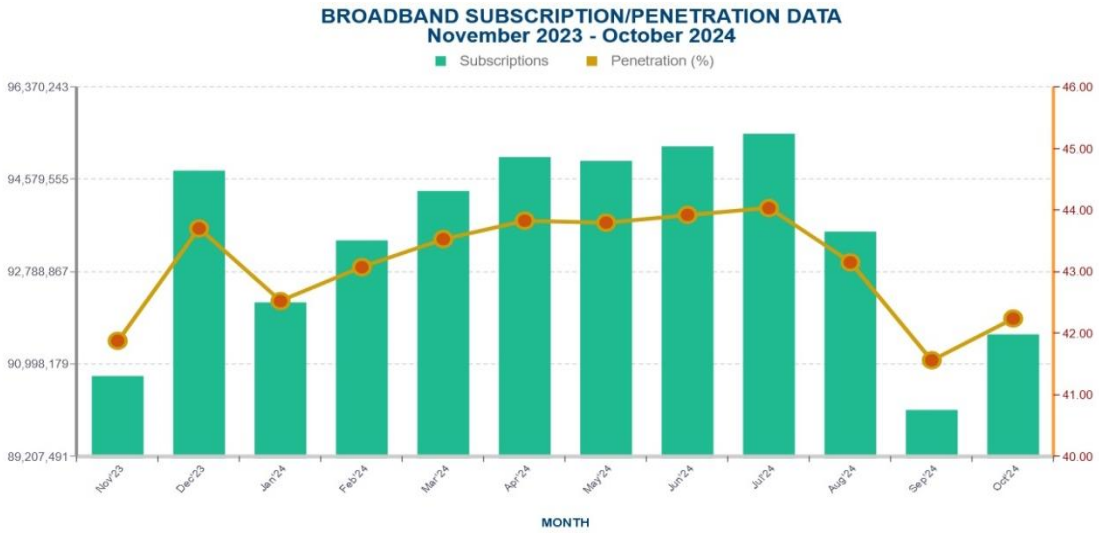

Figure 2. *Situational Analysis: Broadband Penetration from November 2023 to October, 2024 [12].*

2.2. Fiber Optics

Worldwide adoption of Internet broadband has increased as a result of widespread proliferation of undersea optic-fibre cable technologies among other technologies including metropolitan optic-fibre cable networks in urban areas, cities etc. Nigeria's optic-fibre network is extensive but entrepreneurially deployed in mostly cities to reach and meet telecommunication's needs of majority of over 200 million citizens of Nigerians living mostly in urban and semi-urban areas. African continent has sufficient submarine optic-fibre cable landing points with over 40 Tbps at Nigeria's shores by about eight subsea cables namely MainOne, SAT-3, GLO-2, Africa Coast to Europe Cable System (ACE), WACS, Equiano, 2Africa, and the Nigeria Cameroon Submarine Cable System (NCSCS) as illustrated in Figure 3. The nation currently has operational submarine optic-fibre cables providing high-speed Internet connectivity to the rest of the globe via Europe etc. With only 6% of optic-fibre broadband penetration and 10% of oceanic (submarine) Optic-fibre capacities being used, the country's Internet broadband penetration enabled substantially by optic-fibre networks in Nigeria is still low as illustrated in Figures 1 and 2 [14]. Figure 4 shows Glo optic fibre networks in Nigeria. Total Terrestrial optic fibre deloyment in Nigeria owned by telecommunications operators namely Glo, MTN, Airtel, Etisalat, Multilinks, Visafone (acquired by MTN), 21st Century and IpNX stands at 64,433 Km as at 2017 [14]. There is a need to expand the installation of optic-fibre networks and protect the current ones by providing geo-spatial information on these assets making co-location and infrastructure sharing easier. A telecommunication corridor needs to be built to house optic-fibre cables and prevent them from suffering cuts, damages and outright theft. Optic-fibres are glass in nature and media transmission is only possible via total internal reflection of light through optical fibre cladding and a cut in transmission implies break in transmission, dispersion losses, scattering losses etc causing performance degradation to quality of telecommunication services. Proliferation of optic fibre cable deployment in and around metropolitan cities, along roads, along rail lines, inland water ways, power lines etc with telecommunications corridor makes nation-wide surveillance easier to deter crime and fight insecurity [15].

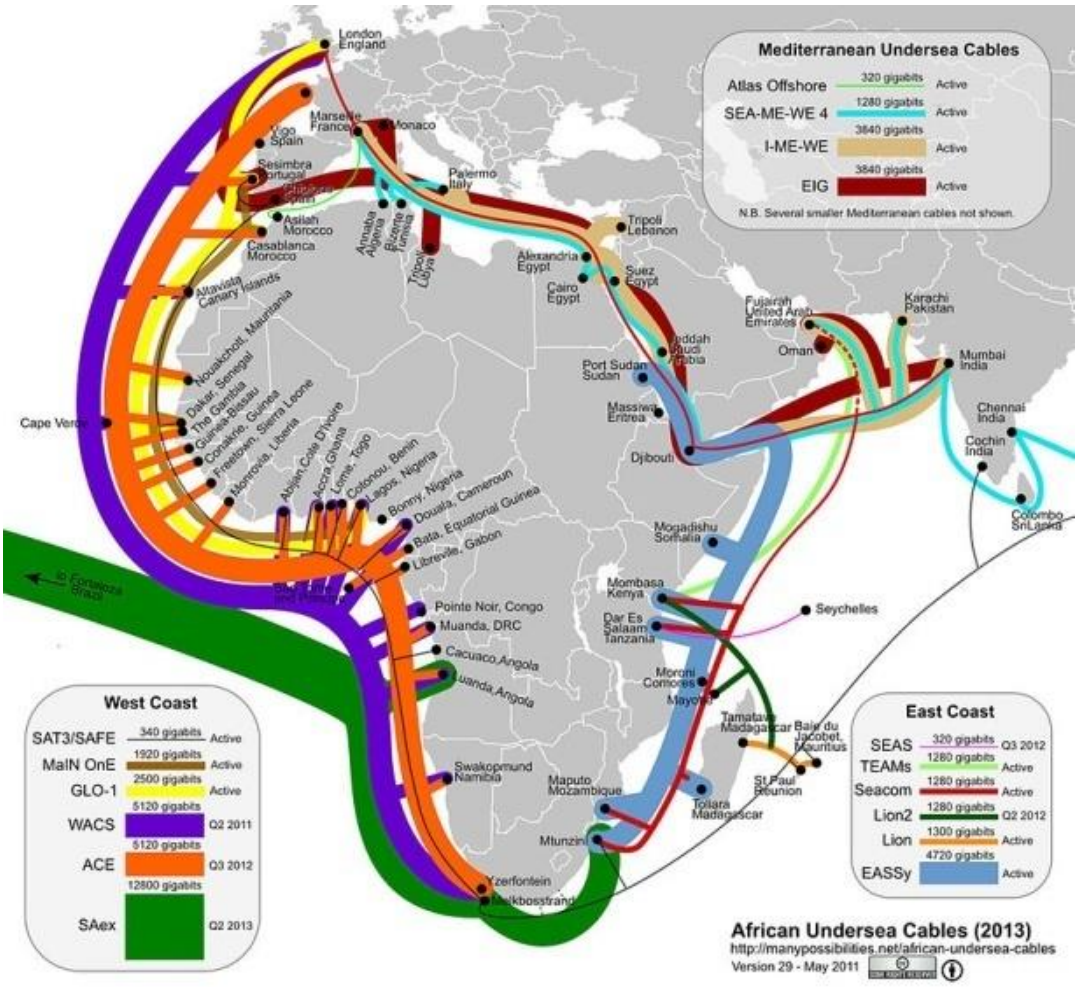

Figure 3. *Situational Analysis: Submarine Network (Undersea Cables) in Africa [14].*

Figure 4. State of Glo Optic-Fibre Networks in Nigeria [14].

3. Bottlenecks Limiting Broadband Penetration

Despite modest success in broadband penetrations, there are bottlenecks and challenges limiting access in delivering uninterrupted broadband services and fast tracked broadband penetration to unserved and underserved areas. These factors are discussed below.

Theft, vandalization, and vulnerability of power and telecommunications infrastructure are bottlenecks for terrestrial optic fibre deployment in Nigeria. These heinous acts damages the optic fibre cables already deployed causing disruption to Internet access, performance degradation in quality of service (QoS) and quality of experience (QoE) and penetration to unserved areas. Performance Issues arise with optic fibre splice because optical power loss budget is a function of attenuation over a cable run and increases by the inclusion of connectors and splices over damaged sections of optic fibre restoration. Computing acceptable attenuation (loss budget) between a transmitter and a receiver involves: dB loss due to the type and length of optic fibre cable, dB loss introduced by connectors, and dB loss introduced by splices. Connectors typically introduce 0.3 dB per connector on well-polished connectors. Splices typically introduce about 0.2 dB per splice.

Thus, total loss is sum total function of dB loss per connector and number of connectors, dB loss per splice and number of splices, dB loss per kilometer and optic-fibre cable lay in kilometers where the dB loss per kilometer is a function of the type of fiber and can be found in the manufacturer's specifications. For example, a typical 1550 nm single-mode fibre has a loss of 0.3 dB per kilometer. Calculated loss budget can be used when testing to confirm that the measured loss is within the normal operating parameters. Figures 5, 6 and 7 shows vulnerable optic fibre cables during road construction and vandalization of high voltage power line respectively.

Figure 5. Vulnerable optic fibre cables during road construction.

Figure 6. *Vandalization of high voltage power line.*

Figure 7. *Vandalization of high voltage power line.*

Poor urban and town planning with little or no geo-spatial information or geographic information system (GIS) of existing optic fibre cables deployed. As a result, these critical ICT infrastructures suffer cuts and damages during road constructions or repairs. Sometimes, the damages are caused by other telecommunications that do not have prior knowledge of existing fibre infrastructure in such route or location. Figure 8 illustrates optic fibre cable deployment along road corridor without geospatial information.

Figure 8. *Vulnerable optic fibre cable deployment along road corridor.*

Unavailability and inadequacy of 24 hours power supply affects continuous delivery, installation and management of telecommunication infrastructures. The cost used in sourcing alternative source of power through provision of generating plants, solar-battery energy solution etc in powering telecommunication equipment (Base stations, radios etc.) increases operating expenditures (opex) and capital expenditure (Capex) and thus, rise in cost of services offered affecting telecommunications service affordability and availability of capital to expand services to unserved areas [9].

Right of way (ROW) permits, multiple taxation and open access shared infrastructure remains an impediment for unbundling metro access by licensed infrastructure companies (INFRACO) etc to deepen optic-fibre cable infrastructure as well as expand the reach of huge capacity of submarine cables at the shores to hinterlands and to neighboring sub-national capitals and metropolitan cities among others.

The journey so far in infrastructural roll-out as it concerns railways, federal, state and local government roads, inland waterways is encouraging in recent times but hugely disappointing with the absence of ICT/telecommunication corridor for sustainable digital connectivity across board. There would have been deterrence by terrorist gang men who mined the track along Abuja Kaduna rail as illustrated in figure 9 in the evening of 29th March, 2022 if there was surveillance system along the rail facilitated by telecommunication corridor along the railway infrastructure roll-out including highways and alternative routes. The train, carrying 970 passengers was forced to a stop on Monday evening, surrounded the carriages, opened fire, abducted and kidnapped several passengers for ransom [16].

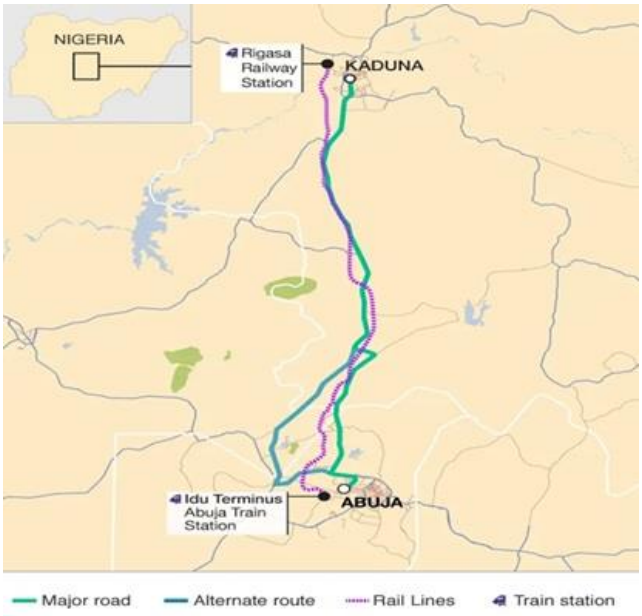

Figure 9. *Abuja-Kaduna Rail Tracks [16].*

Optic-fibre cable cuts and damage by rodents with strong canine teeth: Some rodents with strong canine teeth as illustrated in figures 10 and 11 enjoy eating optic fibre cable particularly the optical fibre protection tubing (OFPT) as food. Figure 12 shows optic-fibre cable buffer eaten by rodents along Abuja Airport Road owned by one of the cable operators causing service outage for several hours before restoration. The said optic-fibre cable network is a critical infrastructure serving several Government agencies, schools and private

enterprise along Abuja International Airport route. The continuity cable to the client has no slack provision for re-preparation as shown in figure 13 and thus restoration engineers had to check intermediate Pilot Holes for slack to be pulled back to Plastic Optical Fibre (POF) before repair was carried out causing prolonged delay in service restoration.

Figure 10. *Rodent eating cable.*

Figure 11. *African Rodent with strong canine teeth capable of cutting and chewing glass, wires and some optical fiber protection tubing (OFPT).*

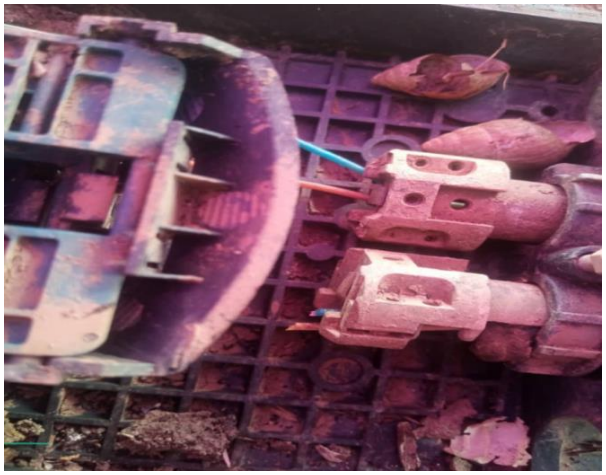

Figure 12. *Optic fibre cable buffer eaten by rodents along Abuja Airport Highway Road.*

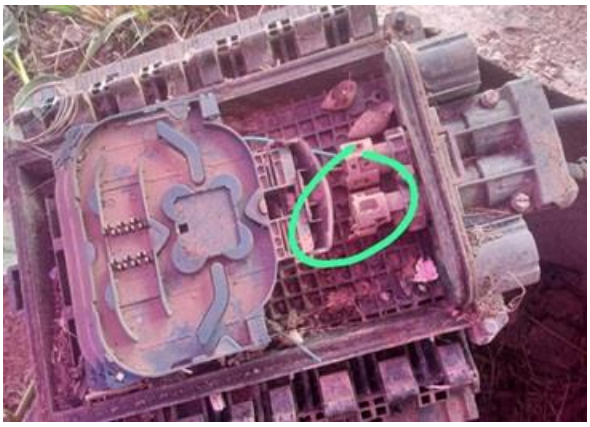

Figure 13. *Absence of optic fibre cable slack within the Plastic Optical Fibre (POF).*

4. Solutions

Integrated Infrastructure rollout with ICT/Telecommunications corridor will facilitate Dig-once policy of Nigerian Communications Commission and aid broadband penetration as well as nationwide surveillance system. One way to reduce capital expenditure on ICT infrastructural roll-out, co-location and infrastructure sharing (C/IS) etc is to provide telecommunication corridor with installation of channels and man-holes with or without optic-fibre cable. The local government, city or town can install optic-fibre conduits with minimal financial investment while upgrading or repairing water or sewer pipes or repairing and building roads and sidewalks without hindrance or destruction to telecommunications facilities particularly optic-fibre cables. The conduit or corridor with defined standards should relatively be inexpensive. Provision of such infrastructure and installation will save telecommunication service providers tens of billions of dollars in service disruption, degradation of quality of services (QoS), repair costs, replacement of damaged or stolen optic fibre with overall improvement in quality of experience (QoE) to telecommunications subscribers [17]. Figure 14 shows a built-up modern road with integrated infrastructure for water, sewer and telecommunications.

The integrated Infrastructure rollout of ICT infrastructure will facilitate Nation-wide deployment of surveillance systems including monitoring of critical national assets and Infrastructure and in particular to equip the Nigeria Security and Civil Defence Corps (NSCDC) in their ever expanding mandate in maintenance of peace and order, 24 hours surveillances over infrastructure and projects for Federal, State and Local Governments, apprehension of person or group of persons reasonably suspected to have committed an offense, criminal activity, vandalization of critical national assets and infrastructure [6].

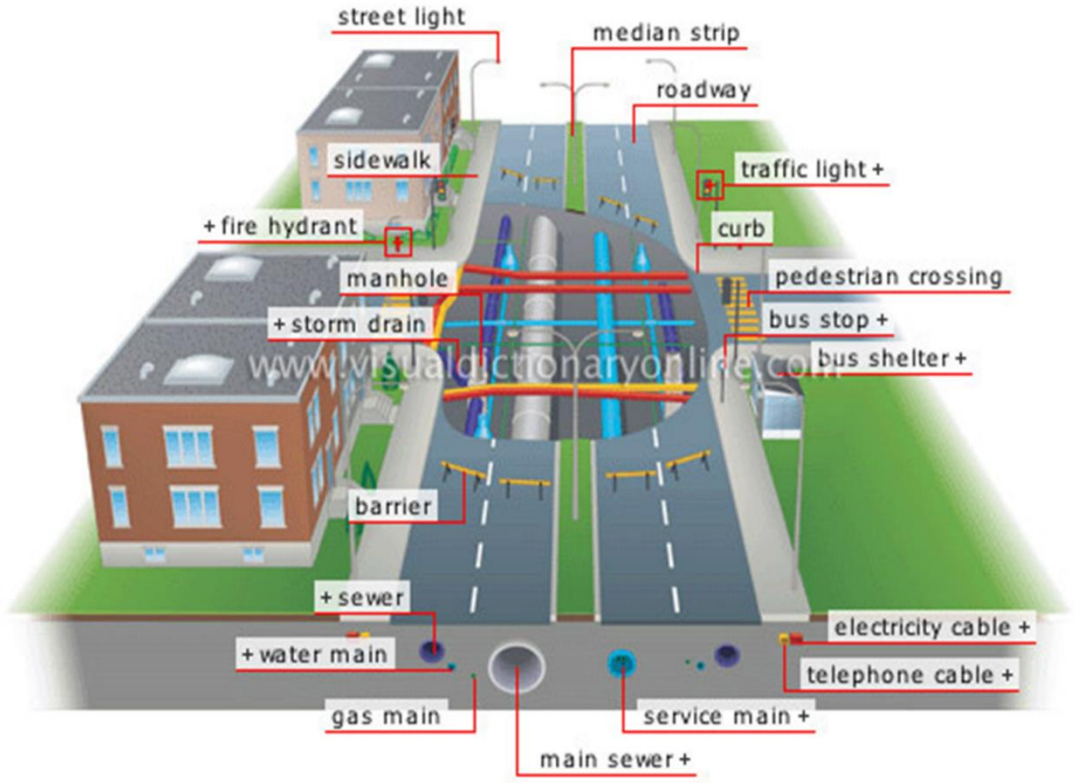

Figure 14. *A built-up modern road with integrated infrastructure for water, sewer, electricity and telecommunications. facilities.*

Geo-spatial information of optic fibre lay becomes easier with telecommunications corridor. The Geo-spatial information will map out where optic-fibre cables are installed and will provide valuable information to both existing and new entrant Telecommunication companies regarding routes of optic-fibre cable systems, facilitation of co-location and infrastructure sharing, cable restoration potentials etc [18].

Integrated rollout plan of infrastructure with ICT/Telecommunication corridor will fast-track Nigeria's National Broadband Plan 2020 to 2025 designed to deliver data download speed of about 25 Mbps in Urban areas and 10 Mbps in rural areas targeting broadband penetration of 70% and at least 90% population coverage [11]. Figures 15 and 16 illustrates telecommunication corridor along rail tracks and high power tower mast respectively.

Figure 16. *Telecommunication Corridor over High Power Tower Mast.*

Figure 15. *Telecommunication Corridor along Rail Tracks.*

Figure 17. *Utility Corridor along Highway.*

Figure 18. *Utility Corridor along Subway Tunnels.*

Utility Corridor on roads/highways and subway tunnels as shown in Figures 17 and 18 respectively are perfect example of sustainable environment for planned urbanization with pre-built utility corridors that supply public utilities like water, electricity, telecoSm and optic-fibre networks, drainage, gas supplies etc.

The integrated infrastructure rollout will fast-track NCC's 31-page Guidelines on Co-Location and Infrastructure Sharing (C/IS) released in June, 2021 in line with Nigerian Communications Act 2003 to encourage C/IS between Access Providers and Access Seekers within a predetermined framework [13].

Integrated Infrastructure rollout will facilitate licensed infrastructure companies in six geo-political regions of Nigeria to deepen Intra and Inter-Metropolitan optic-fibre network rollout and implementation.

A technology mix model of terrestrial ICT infrastructure comprising of Mobile Wireless, Microwave and Space-based ICT infrastructure (Communications Satellite comprising of Global LEO constellations and Geostationary Communications Satellite) becomes easier for sustainable, resilient, inclusive digital connectivity and enhanced digital transformation [19].

5. Conclusion

Implementation of telecommunication corridors alongside infrastructure roll-outs such as highways, metropolitan & rural roads, railways, power lines will tremendously impact positively on broadband penetration, CAPEX and OPEX reduction in restoration of ICT infrastructure damage, improved quality of experience (QoE) and quality of service (QoS) for telecommunications subscribers and reduction in the long run, on cost of telecommunications services. Telecommunications Corridors will save telecommunication service providers tens of billions of dollars in service disruption, degradation of quality of services (QoS), repair costs, replacement of damaged or stolen optic fibre with overall improvement in QoE to telecommunications subscribers. There is need for Federal Ministry of Communications, Innovation and Digital Economy to liaise with relevant agencies and ministries involved in infrastructure rollouts including Nigerian Governors' Forum (NGF) and Association of Local Governments in Nigeria (ALGON) to evolve policies, standards and regulations to ensure deployment of telecommunication corridors in infrastructure such as roads, rails, power lines at Federal, State and Local Government Level as enshrined in National Integrated Infrastructure Master Plan (NIIMP); a policy document of National Planning Commission.

Technocrats and Entrepreneurs should leverage Nigeria's National Broadband plan 2020-2025, NCC's Metropolitan Cable (optic) Network License and NCC Co-location & Infrastructure Sharing (C/IS) guidelines as well as ubiquity of Space-based Infrastructure (Communications Satellite) to bridge the digital divide in unserved, underserved and rural areas and accelerate deployment of ICT infrastructure across nooks and crannies of the Nation and as well facilitate nation-wide surveillance systems for sustainable environment, safe & secured socio-economic activities and digital transformation. Nigerian Communications Satellite is poised to continue to leverage on the ubiquity of Space-based Infrastructure; NIGCOMSAT-1R and future satellite fleet to bridge the digital divide in unserved, underserved, and rural communities including tracking and monitoring critical national assets and Infrastructure utilizing Navigation Overlay Service (NOS) of navigation transponder (L-band) on-board NIGCOMSAT-1R satellite [20]. Integrated Infrastructure for sustainable environment aligns strongly with United Nations Sustainable Development Goals 9 and 11. Building resilient and sustainable infrastructure and promoting inclusive and sustainable industrialization which recognizes the importance of innovation for finding solutions to social, economic and environmental challenges as well as need to make cities inclusive, safe, resilient, and sustainable.

6. Recommendation

Integrated infrastructure rollout with ICT /Telecommunication Corridor requires consultations with the following relevant Agencies, Ministries for a roundtable forum to fashion out standards on telecommunication corridors, optic-fibre cable system types and standard over land, water and overhead with consideration to our weather and climate change.

The agencies are:

1) Transmission Company of Nigeria (TCN) under Federal Ministry of Power.
2) Various Electricity Distribution Companies in Nigeria (Discos) across six (6) geo-political regions of the country.
3) Federal Ministry of Works and Housing for roads at Federal Level.
4) Nigeria Governors' Forum (NGF) for roads at State level.
5) Association of Local Governments of Nigeria for roads at Local Government Level.
6) Nigerian Railway Corporation (NRC) under Ministry of Transportation.

7) Nigerian Inland Water Ways (NIWA) under Ministry of Transportation.
8) Office of Surveyor General of Federation on Geospatial Data and Information for Telecommunication Corridor on all infrastructures roll out etc.

Optical Fibre Cable manufacturers need to improve and strengthen Optical Fiber Protection Tubing (OFPT) against rodents with strong canine teeth destroying and damaging optic-fibre networks in West Africa.

Abbreviations

ACE	Africa Coast to Europe Cable System
ALGON	Association of Local Governments of Nigeria
CAPEX	Capital Expenditure
C/IS	Co-location & Infrastructure Sharing
DISCO	Distribution Companies
GIS	Geographic Information System
ICT	Information and Communication Technology
INFRACO	Infrastructure Company
LEO	Low Earth Orbit
NCC	Nigerian Communications Commission
NCSCS	Nigeria Cameroon Submarine Cable System
NGF	Nigeria Governors' Forum
NIGCOMSAT	Nigerian Communications Satellite
NIGCOMSAT-1R	Insurance Replacement of First Nigerian Communications Satellite (NIGCOMSAT-1)
NIWA	Nigerian Inland Water Ways
NOS	Navigation Overlay Service
NRC	Nigerian Railway Corporation
NIIMP	Nigeria's National Integrated Infrastructure Master Plan
NSCDC	Nigeria Security and Civil Defence Corps
OFPT	Optical Fibre Protection Tubing
OPEX	Operational Expenditures
OSGoF	Office of Surveyor General of Federation
OPF	Optical Plastic Fibre
QoE	Quality of Experience
QoS	Quality of Service
ROW	Right of Way
SAT-3	South Atlantic 3
TCN	Transmission Company of Nigeria
TWG	Technical Working Group
UN SDG	United Nations Sustainable Development Goals
WACS	West Africa Cable System

Author Contributions

Lasisi Salami Lawal: Conceptualization, Formal Analysis, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Tasiu Sa'Ad Gidari-Wudil: Formal Analysis, Project administration, Validation, Writing – review & editing

Francis Ayomide Adedeji: Project administration, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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