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GUIDELINES

Policy Compliance Standards for Underground Fiber Cable Deployment and Post-Deployment Protection

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Abstract

The general utilization of telecommunication services and the value users place on communication networks has grown exponentially in the past few decades. The dependence on telecommunication networks has become an essential factor in how people survive during a national or global crisis. Telecommunication network infrastructures such as cables, satellites, and cellular towers play an indispensable role in maintaining society's stability worldwide when there is a major crisis. Therefore, the protection of these telecommunication assets is critical. However, there have not been any measures to protect these vital infrastructures. This colossal gap prompted the authors to write this paper. The paper is a policy framework designed as a regulatory compliance document to guide the stakeholders in ensuring the underground fiber cable is fully protected. Additionally, the paper gave a direction on how the monitoring agencies can enact laws to make the active fiber cable a critical national infrastructure. There have been a series of underground fiber cable cuts in Ghana and other low-income countries. However, the available policies are not stringent enough to prevent individuals and contractors from activities that may lead to the destruction of underground cables. Based on the lapses identified in the regulatory standards, we proposed a comprehensive policy and regulatory measures to be implemented by the mobile network operators (MNOs) and the state regulatory institutions. This paper touched on regulatory measures to protect the underground fiber cables before, during and deployment. The post-deployment management of the underground fiber cable is critical in ensuring high network performance, reliability and availablibity. The policy plan proposed in this paper has been divided into various sections to make it more convenient for reading and referencing. The paper's novelty is the scope of work done by designing and formulating policies as guiding measures to control and mitigate the frequent fiber cable cuts.

Keywords: Policy Document; Critical National Infrastructure; Underground Fiber Cable cut; Policy Compliance; Policy Framework

1 Introduction

In Ghana, socio-economic activities are vital to the nation's day-to-day functioning and security; for example, transportation of goods and people, communications, banking and finance, the generation and distribution of electricity, gas pipeline, bulk petroleum storage and water supply. Domestic security and the ability to monitor, deter, and respond to hostile acts depend mainly on some of these activities and other more specialized activities like intelligence gathering and command and control of police and military forces. Severe disruption in these activities and capabilities could significantly impact the nation's safety and security [(1)]. These activities and capabilities are supported by an array of physical assets, functions, information, people, and systems [(2)], forming what is known as the nation's critical infrastructures. These infrastructures have grown complex and interconnected, meaning that a disruption in one may lead to disruptions in others. One such infrastructure is the telecommunications system which has its physical infrastructure scattered across the country. Ghana is one of the nations that have adopted fiber optics to form a transmission medium for its telecommunications infrastructure. The country has a layout of underground fiber cables transmitting communications signal from cities to cities and towns to town through the various villages. Protection of this facility is paramount in ensuring quality service delivery and 100% network availability. Over the years, operators of these telecommunications infrastructures have guarded against and quickly responded to many threats that sought to disrupt service. In order to improve the reliability and safety [(3)] of the underground fiber cable, a deliberate effort must be made to prevent the destruction of the cable. The underground fiber cable networks have been classified as critical national infrastructure. This situation has lead to the rampant destruction of the fiber cables because there has not been any form of policies that strictly protect the facility from assailants.

The value chain process of fiber installation and post-installation management has been reviewed to reflect current international standards, such as enforcing underground fiber cable deployment laws. The entire process has been evaluated technically to align with the best international practices. The mobile network operators (MNOs) and the regulators were consulted in formulating clear regulatory policies and deployment guidelines [(4)] that are friendly and fair as a well-structured technical framework for underground fiber optics deployment and management. The policy and compliance framework on underground optical network infrastructure protection has been outlined in this document. Government agencies and local authorities must design a streamlined permitting process and then impose a clear procedural framework with tight deadlines for approving or denying a request for the Right of Way [(1)] or any form of the permit request.

2 Literature Review

According to [(5)], Critical national infrastructure has not been explicitly defined in ITU's Basic Text or ITU bodies' decisions. However, many references to the protection of critical national infrastructure exist, especially in the security of telecommunications/ICT networks and services, including Critical Resources, Critical (national) infrastructure and Critical Information Infrastructure. Primarily, Critical Infrastructure is defined in the context of the adequacy of a nation's public works, e.g. bridges, roads, airports, dams, etc. This includes telecommunications, particularly major national and international switches and connections [(2)]. The Electronic Communications Act 2008 (Act 775) in Ghana forbids the cut of underground fiber cable in section 57 and 58. However, Ghana is one of the countries with the highest number of fiber cuts. Other countries include Nigeria, Kenya, etc. and other countries in Asia, suffer the same fate.

The submarine fiber cable has not been spared either, even though the United Nations Convention on the Law of the Sea (UNCLOS) is a legal document enacted some years ago as a protective measure to the submarine fiber cable [(6)].

As affirmed by [(7)], many countries in defining critical infrastructure include in the definition a reference to that nation. Other countries have specifically included the national component in the term itself (e.g. the UK). In general, critical infrastructures are defined as the systems and assets, whether physical or virtual having a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters [(8)].

Table 1. Definition of Critical Infrastructure by countries and other regions

Australia	Those physical facilities, supply chains, information technologies, and communication networks that, if destroyed, degraded or rendered unavailable for an extended period, would significantly impact the nation's social or economic well-being or affect Australia's ability to conduct national defence and ensure national security.
Canada	Critical infrastructure refers to processes, systems, facilities, technologies, networks, assets and services essential to the health, safety, security or economic well-being of Canadians and the effective functioning of government. Critical infrastructure can be stand-alone or interconnected and interdependent within and across provinces, territories and national borders. Disruptions of critical infrastructure could result in catastrophic loss of life, adverse economic effects and significant harm to public confidence.
European Union	'critical infrastructure' means an asset, system or part thereof located in the Member States which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions

Continued on next page

Table 1 continued

United Kingdom	The [Critical National Infrastructure] comprises those assets, services and systems that support the economic, political and social life of the UK whose importance is such that loss could: 1) cause large-scale loss of life; 2) have a severe impact on the national economy; 3) have other grave social consequences for the community; or 3) be of immediate concern to the national government.
United States	Whether physical or virtual, systems and assets so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters.
Nigeria	Facilitate an Executive Order's issuance, declaring telecoms facilities as Critical National Infrastructure (CNI). Protecting telecoms equipment from vandalization and prevention of disconnection by government officials. Will improve service and stimulate confidence for further investment
China, Korea, Turkey and Thailand	critical information infrastructure' as 'information infrastructure that affects national security, the national economy and people's livelihoods, such that, if data is leaked, damaged or loses its functionality, national security and public interests may be seriously harmed.
India	The Information Technology Act, 2018 defines Critical Information Infrastructure (CII) as those computer resource, the incapacitation or destruction of which, shall have a debilitating impact on national security, economy, public health or safety. The Critical Sectors include Power & Energy, Banking, Financial Services & Insurance, Telecom, Transport, Government and Strategic & Public Enterprises
Senegal, Kenya, Ghana, South Africa	Transport systems, air and seaports, electricity, water and communications systems, hospitals and health clinics, and centres for fire, police and public administration services.

[**Sources:** [5,9–12]

The developed nations such as Australia, Canada, U.S., UK, and many other European countries have a well-defined critical infrastructure [13]. These countries have all the necessary legislation that protects the infrastructure, especially the underground transmission systems such as power cables, fiber cables, gas pipelines, water lines, among many others.

Even though countries in Africa and other low-income countries have defined their critical national infrastructure [14], they do not have legislation to protect those infrastructures [15]. In Ghana, unlike Nigeria, which has added telecommunications systems and, more specifically, fiber optics infrastructure, the country has not criminalized the destruction of underground fiber infrastructure. Most African nations and low-income countries do not have well-structured policy compliance measures that could be adopted to safeguard the critical national installations.

According to [10], in 2013, Nigeria developed its first National Broadband plan to cover the 5-year period through 2018. At the inception of the plan, internet penetration and broadband services enjoyed a period of fast growth, coming off the issuance of 3G licenses in 2007 and the landing of several submarine cables in Nigeria between 2010 and 2013. These cables include MainOne, Glo1 and WACS.

Legislative Instrument (LI) and Executive Order

Every nation's health, wealth, and security rely on producing and distributing certain goods and services. These goods and services can be produced when a strong infrastructure has been put in place to ensure the production processes are executed appropriately. In this document, we will focus on the nation's infrastructure required to deliver certain services. For instance, the collection of physical assets, functions, and systems across which the services revolve are called critical infrastructures (e.g., electricity, hospitals, transportations, telecommunication, mining, refinery, etc.). In most countries, national security makes a deliberate effort to address any form of vulnerabilities identified in the critical infrastructure in line with attacks. In addition, the government often develop and implement plans that would protect the public and privately owned infrastructures. These initiatives call for dialogue between the public and the private sector to establish a NIAP to protect all of the nation's critical infrastructures. In contrast, there is a need to protect both human-made and natural events that directly affect the nation's critical infrastructure.

Under the 1992 Constitution of Ghana, Legislative instruments are laws on matters of detail made by a person or body authorized to do so by the relevant enabling legislation. As issued by the government of Ghana, the Executive Order may define this policy framework as a set of standards, methodologies, procedures, and processes that critical infrastructure owners and operators could implement to reduce the frequent occurrence of failures and damages in their underground fiber cable infrastructure.

1. Through its regulatory bodies, Ghana's government must pass executive orders or enact LIs to make telecommunications systems and fiber optics installations one of the national critical infrastructures. It is in the domain of the ministry of communication, the National Communications Authority and the Ghana Chamber of telecommunication to spearhead the passing of these LIs.
2. The LI must prohibit individuals, group of people or contractors from damaging such critical infrastructure.
3. The LI must also criminalize any activity or events deliberately or unintentionally targeted at destroying underground fiber cables. Such damages caused by an individual or group of persons or contractors must duly be punished by law or the perpetrator made to

pay for the damages' cost.

MNOs, Regulators and Contractors

The protection of these critical infrastructures and their supporting structures is of paramount interest to public and private organizations. Recent catastrophic events such as the 9/11 terrorist attacks in America, Indian Ocean Tsunami, Hurricane Katrina, the Wenchuan earthquake in 2008, the Haiti earthquake in 2010 and the Japan earthquake and tsunami in 2011 have strongly emphasized the significance of protecting critical infrastructure systems against natural occurrences such as anthropogenic or natural disasters. The failure of a telecommunication network will delay the relief effort due to the inability to send the information to responders. Reliance on telecommunications services (e.g. internet, data, voice, etc.) worldwide, during the COVID-19 pandemic in 2019/2020/2021, brought comfort at homes, working remotely, and several other activities were done online when there was general lockdown in many nations. Over the years, policies, programs and legislation related to the physical security of critical infrastructure have helped some developed countries to a large extent.

The key stakeholders to ensure that the Executive Orders or legislative instruments are fully implemented is the mobile network operators, the mobile network regulators, thus, National Communications Authority (NCA) and Ghana Chamber of Telecommunications (GCT)) and the contractors who execute installation projects, private developers, civil contractors, etc.

Research Design and Methodology

This study sought to examine the policy and regulatory framework available to the MNOs as a guide for their underground cable deployment. There has been a series of underground fiber cable cuts in Ghana and other low-income countries [16]. Several international and local policy documents were examined, but we concluded there were not enough biting policies and regulatory standards available that prevent individuals and contractors from destroying underground cables.

There several MNOs in Ghana, including the five submarine fiber landing stations. Our study design followed the concurrent triangulation design, where both survey and interview data were collected at the time. We interacted with twelve senior managers of the MNOs. A simple analysis to measure the need for a stiffer policy document was done in MS Excel, and the result indicated a mean opinion score of 4.2. A 5-point Likert scale was used to obtain data. One (1) was the least, and five (5) was the maximum on the 5-point Likert scale. According to the outcome of the analysis, we concluded that the available laws in Ghana against underground fiber cuts are too lenient.

Based on the lapses in the regulatory standards, we proposed a comprehensive policy and regulatory standards to be implemented by the MNOs and the state regulatory institutions. This paper touched on regulatory measures to protect the installation of underground fiber cables and post-deployment management. The MNOs in Ghana have designed their respective policies for this underground fiber cable infrastructure. The policy plan has been sub-divided into various sections to make it more convenient for reading and referencing.

The outcome of our analysis propelled us to formulate a regulatory policy framework based on the current state of affairs regarding the frequent fiber cable cuts in Ghana.

Proposed Policy Regulatory Standards

The policy document formulated to help protect and prevent private developers and contractors from destroying the underground fiber cables has been clearly defined and presented in the sections as indicated below**.**

Best Practice in Underground fiber cable deployment

Before starting any underground cable installation operations, all personnel must thoroughly be familiar with local company safety practices. Practices covering the following procedures should be given particular emphasis:

- Innerduct
- Cable Lubricant
- Cable Placing Methods
- Pulling Fiber Optic Cable
- Blown Optical Cable Installation
- Optical Cable Coiling
- Racking Fiber Optic Cable and Innerduct

Land acquisition and Challenges

In most cases, land acquisition and landlord rental payment are not made per the standard set out in a clearly defined policy, which often generates unnecessary tension between contractors and landlords. These processes must duly be followed in land acquisition and payments.

1. It is recommended that the fiber optics land acquisition team conduct a route survey and inspection prior to cable installation.
2. Information about other underground services layout (e.g. electricity supply cable, gas pipeline, water supply lines, etc.) must be obtained from the local government agencies to guide in the survey and land acquisition.

3. Information on pits and ducts for other underground services should be inspected to determine the optimum location for chambers (wells) and duct assignments.
4. There should be a comprehensive plan to compensate landlords and other persons whose properties may be damaged or impacted during the fiber optic network infrastructure implementation. This comprehensive plan must take into account the geographical location of properties, standard valuing procedure, and the extent of damage to land and properties etc.

Cable depth and relocation

Trenching comprises digging pits and trenches and then placing the conduit or duct with the cable inserted in it and then backfilling it. The fiber cable is then pulled through the hole in the conduit. Underground conduit or ductwork allows the fiber cable to be pulled through new or existing underground cableways.

1. The trenching depth for underground fiber cables should be below the area's frost level (the MNO's RoW permit can determine the trench's depth).
2. The trenching for a long-haul fiber transmission should be between 1m and 1.5m deep (this depth of trenching may depend on the MNO's RoW permit.
3. The trenching for a metro fiber transmission (FTTx) should be between 1.5m and 2m deep (this depth of trenching may depend on the MNO's RoW permit.
4. Excess cable for splicing and future relocation must be kept in the chambers (well) to facilitate splicing and relocation.
5. The cable should be able to reach the ground, enter a splicing trailer/ truck and be placed in an enclosure.
6. Enclosure box must not be exposed to the public; neither must the bear fiber cable be left without sheaths along the roadside. Ensure that all enclosure box and any open cable ends fully capped to prevent contamination from dirt or moisture.
7. Coil the cable in the wells, carefully ensuring that the cable does not exceed the minimum bend radius.

Pipes, Conduits and Ducts deployment

The conduit used in outside plant applications is designed to provide extra protection for the cables and offer certain installation advantages. A duct or conduit for underground burial must have been manufactured using rigid, very rugged, abrasion-resistant material. These protective systems are supposed to be installed in every fiber cable route.

1. Cables must always be laid in pipes, conduits or duct as described above.
2. The fiber cables installed in a series of ducts placed under the streets must be made accessible by utility vaults or maintenance holes.
3. An installed conduit is advantageous because it offers a route for new cable installation or old removal without damage to streets, pavements, edifices, etc.
4. When laying underground fiber cables in an urban area, the cables must first be inserted by burying a duct such as a steel pipe or a vinyl pipe or constructing a tunnel.
5. There must not be any form of multiple digging in areas where fiber cable has already been laid.
6. The appropriate state agencies must ensure that provision for ducts is incorporated in road designs.
7. State or local government agencies are encouraged to build/provide ducts along community roads to avoid road destructions.

Marker Poles

Marker poles are warning signs used to show that there are installed underground utilities such as fiber optic cable, gas pipelines, petroleum pipelines, electricity lines, water lines, sewer lines and all other buried utility lines.

1. Both long-haul and metro underground fiber cable infrastructure must have marker poles placed on the buried cable.
2. The maker poles must be placed at an equal distance of not more than 100m
3. The marker poles must be at least 2m or more with WARNING or CAUTION signs boldly fitted on the pole.
4. All contractors working on underground systems close to these marker poles must inform the MNOs, the Regulators, the Municipal Assembly in writing at least fourteen days before the actual work is carried out.
5. The marker pole and its surrounding must be kept clean and clear for visibility.

The Road Reservation Corridors

Telecommunication construction is typically done within right-of-way dedicated to routing underground systems such as utility pipes, power lines, fiber cables, conduits etc. Damage to any one of these utilities could disrupt services. At worst, it may cause catastrophic harm to personnel and surrounding property.

1. Long-distance and metro transmissions of fiber cables are deployed along the corridors of the road.

2. Road contractors must make provision or reservation for underground fiber network expansion.
3. The reserved fiber route must not be less than 10m from the roads' edges in highways and must not be less than 3-4m in the metro areas.
4. Contractors are required to contact all operators of these critical infrastructures prior to the start of any excavation, including those that are out of the right-of-way (ROW).
5. The excavating party should also make necessary locate marks on their existing plant. Underground installations typically terminate in a pit or trench that is accessible to the public. Therefore, barricades, warning devices and covers MUST guard pits and trenches.

Digging across Roads and Intersections

The digging pits and trenches across roads and intersections for new cable installations, expansion or fault resolution MUST not be encouraged. Provisions must be made for extra cables (coils), ducts, pipes and conduit when constructing roads.

1. When there are extra cables, ducts, pipes and conduit provisioned across the road at certain defined intervals, new cable installations, expansion or fault resolution can be done much easier without digging across the road.
2. The concept of digging one time must be adhered to by agencies responsible for road constructions.
3. Digging open trenches and pits across roads for underground installations may be accessible to the public.
4. In critical and exceptional cases where Pits and trenches MUST be dug, especially across roads and intersection in the communities, it has to be guarded by barricades, warning devices and covers.

Fiber cable route

Fiber cable, like most other critical underground infrastructures, must have a well-coordinated and structured layout. The layout or cable interconnectivity mapping must be documented and updated regularly as and when new installations and network expansion occurs. All current network topology and routing changes must be updated appropriately in the documentation and then communicated to all stakeholders.

Permit acquisition, Training Compliance with Laws and Norms and Sanctions

Fiber optics deployment in Ghana lacks established processes and guidelines culminating in fiber deployment challenges which have been the root causes of major underground failures. Cumbersome permit processes have been a factor that impedes smooth fiber optics deployment. Local government authorities and the regulators do not have clear procedures and timelines for application and permit application response. Local authorities have therefore taken advantages of the situation to unduly delay permit acquisition processes. ROW acquisition is costly, and undue delayed processes usually frustrate MNOs and contractors. There are delays in deploying optical networks due to its overly burdensome requests for information, bureaucratic procedures for obtaining permits and the unreasonable charges for using the ROW. ROW issues are complex, involving multiple stakeholders with divergent opinions and parochial interest.

1. All permits must be issued within the stated period, as stated by the applicants during their applications.
2. No contractor shall execute any installation along the road's reserved corridors, dig pit or trench, and perform maintenance work without having the requisite permit.
3. All contractors must be given specialized training on interpreting fiber cable route mappings before any permits are issued.

Policy Implementation and Compliance Standards

All stakeholders are to ensure full compliance with this policy framework. Any entity found to have contravened the stance of the framework shall be considered an offender, and the punishment for such an offender has been prescribed in this document. As affirmed by[17–19] a well-structured policy for telecommunications infrastructure contributes to network reliability and availability.

Punitive measures for offenders

1. All contractor found to exhibit any behaviour and acting contrary to the regulations in this framework shall have their permit/license suspended for a period not less than six months.
2. Any contractor whose activity may cause the destruction of an underground fiber cable shall;

    (a) Bear the full cost of maintenance of the damaged cable
    (b) Pay of the revenue loss incurred by the MNO, as determined by the same.
    (c) Sign a bond to adhere to all regulations governing fiber cable deployment and post-deployment management.
    (d) Have his/her permit/license confiscated for a period not less than six months.

3. An individual who intentionally or unintentionally destroys fiber cables laid underground shall be made to bear the cable repair's full cost.

4. The regulators shall sanction MNOs who leave their fiber cables and enclosure box in open space.
5. All underground fiber route without the appropriate and approved marker poles shall have their operator sanctioned by the regulators.
6. The regulator and Ghana's government shall heavily sanction any MNO who allows its contractor to dig pit and trenches across roads or intersections.

3 Conclusion

This policy document has been designed as a supplementary plan to augment the existing laws and by-laws of the MNOs and government agencies in countries that frequently suffer severe cuts in underground fiber cables. Establishing the proposed NIAP to oversee all critical national infrastructure to ensure the adoption and implementation of policy compliance documents will positively impact those infrastructures. These policies document was tested and approved by major stakeholders throughout all the formulation process stages. It is expected that when the policy document is fully implemented, 95% of all underground fiber cable cuts will be curbed. The challenge and limitation of the document implementation is the encounter between the MNOs and the offenders who might be high-ranked political figures. The situation where the stakeholder negligence may lead to the unimaginable damages of cables must not be taken lightly, but the necessary sanctions must be applied according to the policy statement. In the future, MNOs are expected to have more robust underground fiber cable deployments standards to ensure a drastic reduction in cable cut occurrences.

References

1) Anderson KM. Public good, private providers?: Alternative internet networks in Alberta. 2021. Available from: https://prism.ucalgary.ca/handle/1880/113050.
2) Rosario-Albert L, Takahashi B. Emergency communications policies in Puerto Rico: Interaction between regulatory institutions and telecommunications companies during Hurricane Maria. *Telecommunications Policy*. 2021;45(3). Available from: https://dx.doi.org/10.1016/j.telpol.2020.102094.
3) Prado TS, Bauer JM. Improving broadband policy design using market data: A general framework and an application to Brazil. *Telecommunications Policy*. 2021;45(4). Available from: https://dx.doi.org/10.1016/j.telpol.2021.102111.
4) Sahebali MWW, Sadowski BM, Nomaler O, Brennenraedts R. Rolling out of fibre optic networks in intermediate versus urban areas: An exploratory spatial analysis in the Netherlands. *Telecommunications Policy*. 2021;45(5). Available from: https://dx.doi.org/10.1016/j.telpol.2020.102080.
5) Maloor P, APT-ITU workshop on the International Telecommunications Regulations Bangkok. Protection of Critical National Infrastructure. 2020. Available from: https://www.itu.int/dms_pub/itu-t/oth/06/5B/T065B0000100043PPTE.ppt.
6) Huston G. At the bottom of the sea: a short history of submarine cables. 2020. Available from: https://blog.apnic.net/2020/02/12/at-the-bottom-of-the-sea-a-short-history-of-submarine-cables/.
7) Winterstetter A, Heuss-Assbichler S, Stegemann J, Kral U, Wäger P, Osmani M, et al. The role of anthropogenic resource classification in supporting the transition to a circular economy. *Journal of Cleaner Production*. 2021;297(126753). Available from: https://dx.doi.org/10.1016/j.jclepro.2021.126753.
8) Golicic SL, Mccarthy TM, Mentzer JT. Conducting a Market Opportunity Analysis for Air Cargo Operations. *Transportation Journal*. 2003;42:5–15.
9) Cipedia. Critical Infrastructure Sector. 2020. Available from: https://websites.fraunhofer.de/CIPedia/index.php/Critical_Infrastructure_Sector.
10) Nigeria. Nigerian National Broadband Plan 2020 – 2025 . 2020. Available from: https://www.ncc.gov.ng/documents/880-nigerian-national-broadband-plan-2020-2025/file.
11) Torres C, Briceño-Garmendia CM, Dominguez C. Senegal's Infrastructure: A Continental Perspective. 2011. Available from: https://ppiaf.org/documents/3155/download.
12) Saksena A. Co-deployment of Fibre Optic Cables (FOC) Infrastructure. Special consultative status with the UN. 2020. Available from: https://www.unescap.org/sites/default/files/a_Mr%20Arun%20Saksena-1.pdf.
13) Parsons SG, Duffy-Deno KT. Are telecommunications regulators correct in their beliefs that network size affects origination/termination? *Telecommunications Policy*. 2021;45(2). Available from: https://dx.doi.org/10.1016/j.telpol.2020.102078.
14) Boateng K, Hanson I, Nyarko-Boateng O. Evaluation and analysis of the major security systems deployed on telecommunications cell sites. *International Journal of Scientific and Engineering Research*. 2019;10:770–777.
15) Golicic SL, Mccarthy TM, Mentzer JT. Conducting a Market Opportunity Analysis for Air Cargo Operations. *Transportation Journal*. 2003;42:5–15.
16) Nyarko-Boateng O, Xedagbui FEB, Adekoya AF, Weyori BA. Fiber optic deployment challenges and their management in a developing country: A tutorial and case study in Ghana. *Engineering Reports*. 2020;2(2). Available from: https://dx.doi.org/10.1002/eng2.12121.
17) Krämer J, Schnurr D. A unified framework for open access regulation of telecommunications infrastructure: Review of the economic literature and policy guidelines. *Telecommunications Policy*. 2014;38(11):1160–1179. Available from: https://dx.doi.org/10.1016/j.telpol.2014.06.006.
18) Wang H, Alidaee B, Wang W. Critical Infrastructure Management for Telecommunication Networks. *Lecture Notes in Computer Science*. 2012;p. 493–501. Available from: 10.1007/978-3-642-35236-2_49.
19) Gómez-Barroso JL, Feijóo C, Quiles-Casas M, Bohlin E. The evolution of the telecommunications policy agenda: Forty years of articles in Telecommunications Policy. *Telecommunications Policy*. 2017;41(10):853–877. Available from: https://dx.doi.org/10.1016/j.telpol.2016.11.005.