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Protection of Underground Fiber to the Home Installations against Accidental Damage by Contractors – the case for Lusaka City

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Abstract: *Fiber to the home technology has become widely adopted because of its great capabilities. However, despite the great capabilities of fiber technology, it is vulnerable to accidental damage by contractors undertaking excavation works in the vicinity of the cables. Fiber cuts disrupt internet and telephone services that are a necessity in today's global economy. The research sought to identify the cause and implications of fiber cuts on stakeholders and recommendation on how fiber cuts by contractors can be prevented or minimised. The study identified four groups of stakeholders namely regulators, contractors, FTTH subscribers and FTTH service providers, then questionnaires and interviews were administered. The study appliedpragmatic and mixed methods approaches, following a concurrent triangulation design. The data was analysed using univariate, content and thematic analysis. The results showed that contractors undertaking excavation works repeatedly damaged underground fiber cables in the process of doing their works around the city of Lusaka. The fiber cuts were mainly due to negligence by either contractors or fiber owners who did not follow industry best practices when installing fiber or during excavation. The study concluded that, the lack of fiber standards and weak legislation is contributing to the fiber cut phenomena in Lusaka and all fiber to the home stakeholders suffer financial and non-financial implications as a result of fiber cuts. The study results also revealed that, in an attempt to address the fiber cut phenomena, authorities have come up with intervention measures. Lusaka City Council (permitting agent) has passed by-laws that prohibit right-of way permits of excavation works for the purpose of installing new underground fiber cables. Additionally, the Council is installing underground ducts in fiber cut prone areas of the city for use by all fiber owners. ZICTA (regulatory agent) is in the process of implementing GIS to map underground fiber routes, while Zambia Bureau of Standards is developing fiber installation standards. The researcher recommends the formation of a damage prevention council that should comprise of members from all stakeholders. The mandate of the council would be to raise public awareness and creating a sense of shared responsibility for damage prevention by all stakeholders.*

Keywords: *Accidental damage, Concurrent triangulation design, Content analysis, Contractors, Excavation, Fiber Cuts, Fiber Optic, Fiber to the Home, Mixed Methods, Pragmatic, Right-of-Way, Thematic analysis*

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I. Introduction

Fiber networks are said to be “futureproof" infrastructure because of the constant improvements in fiber optic technology and equipment can improve how much bandwidth is available without having to deploy new networks FTTH provides enormous bandwidth and long-reach offering triple play services (data, voice, and video). Advancement in the electronic equipment coupled with a fall in the price of Fiber Optic Cables and equipment make FTTH deployment an affordable choice for the telecom operators that result in long term returns.Furthermore, the connection of homes and business to fiber optic networks facilitates enormous improvements in what bandwidth devices are capable of delivering. Current fiber optic technology can provide upload and download speeds of over a gigabit per second. Fiber networks are speedily being adopted by telecoms, because fiber can carry voice, data and video at higher speeds over a longer distance compared to copper (Kunigonis, 2009; Senior &Jamro, 2009; Forzati &Mattsson, 2012; Ezeh& Diala, 2014).

Though fiber optic offers extremely high bandwidth, freedom from external interference, immunity from interception by external means, it suffers the drawbacks of accidental damage by excavators and vandalism.Accidental fiber cuts by contractors undertaking excavation works in the vicinity of underground fiber cables and disrupting vital services have been reported in many countries (Afzal, 2005; HKT, 2012 & Siau, 2015). Table 1 depicts summarised accidental fiber cuts reported in different countries.

Table 1: Summarised fiber cut incidences around the world

Author/Country	Article	Incidence Details
Afzal (2005) Pakistan	Effect of Fiber Cut in Pakistan	On June 27, 2005 all Internet and Telecom connectivity inPakistan was discontinued. All international STM-1 links via SEA-ME-WE-3 optical fiber network went down. The cable was cut 35 nautical miles (69-km) south-west of Hawksbay, Karachi in deep sea. Traffic was shifted to 3 E3 satellite links but it made no difference. The cable was recovered at 1224hrs on July 8, 2005.
Hong Kong Telecommunications HKT (2012) Hong Kong	HKT- Final Incident Report on Fiber Cable Damage On 13 April 2012	Three cross harbor fiber cable routings at Hung Hing Road in the Causeway Bay Typhoon Shelter Section were damaged by a construction contractor (China State Construction Engineering (HK Limited) (the "Contractor") employed by the Highways Department for the Central Wan Chai Bypass Tunnel project. The 3 damaged fiber cable routings were Lockart to Mongkok (LKT-MKK), Jordan to Telecom House (JDN-THT) and Hung Hom to Victoria (HHM-VTA). The services were restored approximately 10 hours after the outage occurred.
Siau (2015) Singapore	Damaged fiber optic cables down broadband, TV, phone services on June 11	Hundreds of subscribers of fiber broadband, television and phone services across the island were affected by a network outage after a Land Transport Authority (LTA) contractor damaged fiber optic cables while carrying out piling work at the Thomson-East Coast Line's Great World Station worksite. The affected subscribers were from various telecoms Singtel, StarHub, M1 and MyRepublic. Services were reportedly disrupted in areas including Orchard, Outram, and Cantonment Road, Marina Bay. Bukit Merah, Bukit Panjang, TiongBahru, TanjongPagar and Woodlands. Services were restored, more than 10 hours after the outage occurred.

A number of studies have been conducted to identify the causes and suggest ways to resolve the problem of fiber cuts by contractors, but only the studies conducted in the United States of America have documented follow-up studies on the implementation of the recommendations of previous studies (Harrison, 1996; Hoffman, 2004). Previous studies mainly concentrated on documenting the causes and possible solutions of fiber cuts with minimal concentration on the impact of fiber cuts on service providers, customers and contractors. This study aims not only to identify the causes and possible solutions but go further by identifying the implications suffered by different stakeholders as a result of fiber cuts and building a growing awareness of shared responsibility for damage prevention among all stakeholders.

Fiber to the home service was first deployed in Lusaka, Zambia in 2014/2015 and not widely deployed. The service is only provided by two telecommunication companies in selected townships of the city. With the increase in road infrastructure development, water reticulation, sanitation and drainage projects being implemented by the government, Lusaka city has turned into a construction zone. As these projects are underway, underground fiber which is buried on the road sides is repeatedly being damaged by contractors, disrupting internet and telephone services. Between week 1 and week 44 of 2017, C-Liquid Telecom reported a total of 2,097 incidences of fiber cuts on their three fiber infrastructure networks namely backbone, FTTH (GPON) and metro/last mile networks.

Table 2: C-Liquid's Reported Incidences of Fiber Cuts between week 1 and 44 of 2017

C-Liquid Reported Fiber Cut Incidences For Weeks 1 - 44 of 2017		
Type of Network	**Count of Incidences**	%
Backbone	43	2
FTTH (GPON)	545	26
Metro/Last Mile	1,509	72
Total	**2,097**	**100**

Statement of a Problem

The number of government funded and private projects in infrastructure development such as the improvement and expansion of roads network, water, sanitation and drainage networks, shopping malls and fiber roll-out by telecoms has been on the increase in the recent years. With this, there is considerably more excavation, more construction and more fiber being placed in the ground, turning Lusaka into a construction zone. This poses challenges for the existing underground fiber infrastructure, as it constantly gets damaged causing repeated outages of internet and telephone services, leaving affected businesses and individual go without internet and telephone services for several hours and at times for days. In today's global economy, businesses heavily rely on fast and stable internet and telephone services to conduct business and survive the competitive business environment. Broadband networks are considered an essential enabling infrastructure in the modern knowledge based economies. There is need therefore, to look into the effective management of right-of-way which can allow the integration of all activities that use roads and road reserves to advance side by side to develop the economy of the city of Lusaka.

Research Objectives

I. To identify the standards and regulations for fiber installations applicable to Lusaka.
II. To identify the causes and implications of accidental damages to FTTH underground infrastructure.
III. To devise strategies that could be used to prevent underground fiber cuts.

Research Questions

I. What standards and regulations for underground fiber installations exist in Lusaka?
II.a. Why do accidental damages occur on underground fiber optic cable?
II.b. What are the implications of accidental damages tounderground FTTH infrastructure on stakeholders?
III. How can underground fiber optic cables be protected from accidental damage?

II. Literature Review

Introduction

Technology requires a good infrastructure on which to ride on and fiber to the home (FTTH) isthat infrastructure which provides faster and stable internet connectivity required for conducting electronic business. Fiber to the home is described by Forzati & Mattson (2012) as the installation and use of optical fiber from a Telecom’s central point directly to individual buildings such as residences, apartment buildings and businesses to provide unprecedented high-speed internet access.Fiber networks are said to be “futureproof" infrastructure (Forzati &Mattsson, 2012) because of the constant improvements in fiber optic technology and equipment can improve how much bandwidth is available without having to deploy new networks (Kunigonis, 2009). According to Ezeh & Diala (2014). FTTH provides enormous bandwidth and long-reach, offering triple play services (data, voice, and video). Advancement in the electronic equipment coupled with a fall in the price of fiber optic cables and equipment make FTTH deployment an affordable choice for the telecom operators that result in long term returns.Furthermore, the connection of homes and business to fiber optic networks facilitates enormous improvements in what broadband devices are capable of delivering. Current fiber optic technology can provide upload and download speeds of over a gigabit per second. Fiber networks are speedily being adopted by telecoms, because fiber can carry voice, data and video at higher speeds over a longer distance compared to copper (Kunigonis, 2009). Fiber optic offers extremely high bandwidth, freedom from external interference, immunity from interception by external means (Senior &Jamro, 2009).The growing demand for high speed internet is the primary driver for the new access technologies which enable experiencing true broadband. The demand is pushing telecommunication operators to seriously consider the roll-out of optical fiber based access networks (Ezeh & Diala, 2014) because they represent a future-proof infrastructure with a bandwidth potential of thousand times higher than what is possible with copper (Forzati &Mattsson, 2012). Fiber to the Home has proven to be the most suitable choice for a long-term objective, once clients are wholly served by optical fiber, it will be easier to increase the bandwidth should the need arise (Kunigonis, 2009; Senior &Jamro, 2009; Ezeh& Diala, 2014).

Benefits of FTTH:

According to Gruber, Hätönen&Koutroumpis (2013) fiber to the home or FTTx opens up new world of possibilities. In the world of business, the availability of FTTx in a community is increasingly important as a selection criterion for businesses that are choosing a new business location or choosing to stay in a location. Gruber et al. further evaluated the net benefits of the implementation of the broadband infrastructure deployment targets by 2020 as entailed by the digital agenda for Europe initiative set forth by the European Commission, found that in the base case scenario the overall benefits outweigh the costs by 32% for the entire European Union. Gruber et al further argued that it was not just about broadband anymore, it’s about having access to reliable high-speed Internet. FTTx infrastructure addresses this need and enables businesses to be competitive. This is a reality that communities must increasingly address and those that do not will be missing out on economic development opportunities (Senior &Jamro, 2009). FTTH is not just about internet access, it opens the door to a wide range of new services and applications, both for entertainment and productivity, delivered right to the home or the office and supporting the creation of concepts like smart homes and cities (Gruber, Hätönen&Koutroumpis, 2013).

1. FTTH and Smart Cities Concept

According to Chourabi, Nam, Walker, Gil-Garcia, Mellouli, Nahon, Pardo & Scholl (2012) the concept of Smart Cities or in a broader sense Smart Regions relies on the availability of analysed information that triggers certain actions, traffic or energy management, the provision of public services in health and education.Economy is the major driver of smart city initiatives, and a city with a high degree of economic competitiveness is thought to have one of properties of a smart city. The smart city framework consisting of six main components, smart economy, smart people, smart governance, smart mobility, smart environment, and smart living. Chourabi et al.'s operational definition of a smart economy includes factors all around economic competitiveness as innovation, entrepreneurship, trademarks, productivity and flexibility of the labour market as well as the integration in the national and global market.

Chourabi et al., (2012) discussed that, municipalities are using information and communication technologies to increase operational efficiency, share information with the public and improve both the quality of government services and citizen welfare. Albino, Berardi&Dangelico (2015) echoed Chourabi et al., that investment in this future proof technology will ensure that communities remain part of the global economy and that its citizens will have access to the best resources available in education, medicine and engagement. Smart object networks play a crucial role in making smart cities a reality. Albino et al., further discussed that the availability and quality of the ICT infrastructure are important for smart cities. The implementation of an ICT infrastructure is fundamental to a smart city's development and depends on some factors related to its availability and performance. Chourabi et al.'s discussion is in line with the Smart Cities Council's vision of a world where digital technology and intelligent design have been harnessed to create smart and sustainable cities with high-quality living and high-quality jobs. The Council pointed out that, for cities to tap into the transformative power of smart technologies, cities need fiber to the home broadband connections that provide faster connection speeds and carrying capacity. The Smart Cities Council further indicated that, the Council promotes cities that embody three core values of livability, workability and sustainability (Smart Cities Council, 2018).The livability value focuses on cities that provide clean, healthy living conditions without pollution and congestion, with a digital infrastructure that makes city services instantly and conveniently available anytime, anywhere. Workability focuses on cities that provide the enabling infrastructure for energy, connectivity, computing and other essential services in order to compete globally for high-quality jobs, and the sustainability core value is concerned with cities that provide services without stealing from future generations through pollution and other environmental vices.

2. The Socio-Economic Impact of FTTH

Broadband networks are an increasingly integral part of the global economy and as the technology evolves and bandwidth increases, the scope for broadband to act as an enabler of structural change in any economy expands as it affects an increasing number of sectors and activities (Forzati &Mattsson, 2012). Forzati and Mattson further discussed that broadband is linked to increased GDP and economic growth, productivity, higher employment and increased international trade. Furthermore, it was also found that the effectiveness of the broadband investment depends on IT maturity, and that countries which invest in more than just infrastructure, such as education, benefit more from broadband. Direct effects result from investments in the technology and from rolling out the infrastructure. Indirect effects come from broadband's impact on factors driving growth, such as innovation, firm efficiency, competition and globalisation. Broadband facilitates the development of new inventions, new and improved goods and services, new processes, new business models, and it increases competitiveness and flexibility in the economy. More generally, broadband enables improved performance of information and communication technologies (ICTs) that fundamentally change how and where economic activity is organised. As such, significant impacts on the economy can be expected for example by enabling organisational change and enhancing co-ordination to reap productivity gains from overall investments in ICTs, although it may be difficult to clearly disentangle the economic impact of broadband from that of ICTs more generally (Adamsk &Dariusz, 2009; Gruber, et al., 2013).

2.1 Employment Creation

According to Gruber et al., (2013) jobs are created to build the network, and the skills gained in the process provide a competitive advantage for early adopters. Broadband also leads to job creation in the rest of the economy through the "multiplier effect" as companies use better ICT processes to help grow their business. Furthermore, Gruber et al., revealed that several studies have estimated that, for every 1,000 new broadband customers, around 80 new jobs are created. Katz et al., (2010) discussed the three types of broadband network construction effects. First, network construction requires the creation of direct jobs (for example, telecommunications technicians, construction workers and manufacturers of the required telecommunications equipment). In addition, the creation of direct jobs has an impact on indirect employment (jobs in businesses buying and selling to each other in support of direct spending). Finally, the household spending based on the income generated from the direct and indirect jobs leads to the creation of induced employment. Katz et al., (2010) further pointed out that the labor intensive nature of broadband deployment ensures that the construction jobs to be created are significant and, despite the highly technological nature of the ultimate product, broadband is to be seen as being similarly economically meaningful as conventional infrastructure investments such as roads and bridges. By implementing the national broadband strategy, Katz et al. (2010) applied the input-output matrix for the German economy and estimated that 304,000 jobs will be created over a period of five years covering 2010 to 2014.

2.2 Economic Growth

Katz et al., (2010) added that broadband penetration increases economic growth. Some emerging evidence suggests that faster broadband speeds have greater impact and generates an overall annual increase in the gross domestic product of a country. A 10% increase in broadband household penetration helps boost a country's economy and brings 1% increase in GDP and 1.5% in labour productivity growth (Katz 2012; FTTH, 2017). Preliminary evidence from a US study into gigabit communities where 1Gbps broadband is widely available indicate that those communities enjoyed per capita GDP that is 1.1% higher than communities with little or no available gigabit services (Fiber Broadband Association, 2017). ICTs and broadband are facilitating the globalisation of many services, by making it feasible for producers and consumers to be in different geographical locations. Globalisation of services is having a fundamental impact on the way economies work and on the global allocation of resources, contributing to productivity growth by expanding markets, increasing business efficiency and reinforcing competitive pressure (OCDE, 2015). There is a correlation between fiber deployments and economic growth. In particular, high-speed networks strengthen and drive diversification of economies, as small and medium businesses are often the quickest to adopt and benefit from improved online business (FTTH Council Asia-Pacific, 2014).

2.3 Productivity

The Strategic Networks Group investigated businesses and organisations in the US on how better broadband leads to higher productivity. The study revealed that, 10% greater utilisation of the internet increases revenues by 24% and reduce business costs by 7%. The study also found that the positive return on investment on internet-based technology for improving productivity is 8.9% higher for FTTH users than for cable users, and 14.2% higher for FTTH users than for DSL users (Adamski, 2009).

2.4 Health Care

According to FTTH Europe (2017) healthcare is one of the major issues faced by the European society, and the convergence of digital technologies with healthcare has significantly expanded across Europe. Recent initiatives in the field of advanced digital healthcare applications in hospitals in rural Sweden has reduced medical scan costs by 35% by sending images to Spain for analysis. This is in addition to the €800,000 cost savings per year and the time patients had to wait to get their results was cut by half. The FTTH Europe further indicated that, a telepresence robot tried in Västerås which used the Giraff was designed to help the elderly live independently for longer. The robot was described by the European Commission as "the greatest digital story of 2014", the idea has been further developed with EU funding.

2.5 Environment

Teleworking and remote access to services can reduce carbon emissions and thus help the environment, by reducing the need to travel. If workers could work from home for two days a week, this would save the CO2 equivalent to about 800 kilos a year for each member (Consoglobe, 2014) as cited by (FTTH Europe, 2017). This is in agreement with Xiong (2013), who pointed out that one million users connected to a FTTH network can save one million tons of carbon-dioxide a year through reduced car usage by 4600 kilometres per household, and 20% less electricity usage compared to a VDSL2 (very-high-bit-rate digital subscriber line 2} access network with the same amount of subscribers.

2.6 Education

According to Arnold et al (2018) fiber has demonstrated to be a key success factor for excellent and fair education. In Sweden, most schools, universities and other tertiary education institutions have FTTH internet access. Municipalities have been the driving force behind fiber roll-out in Sweden. Arnold et al. further said, Sweden proactively promotes digital learning devices, and many schools feature "digital classrooms". Given the country's demographic situation, distance learning plays an important role. Fiber infrastructure enables fair participation of all youths in education regardless of where they live. It was found that, massive open online courses (MOOCs) are very popular in Sweden.

FTTH Deployment Architecture:

According to Gutierrez, Kim, Rotolo, An &Kazovsky (2015) in order to have an improved fiber network infrastructure, it is important to understand the challenges and trade-offs facing potential network owners and operators when designing and building FTTH networks. Some challenges may result in conflicts between functionality and economic demands. A FTTH network build must present a profitable business case, balancing capital expenses with operating costs while ensuring revenue generation.Gutierrez et al. further discussed two ways in which fiber can be deployed, underground and aerial installations. For underground installation, the fiber is buried underground, while in aerial architecture, the fiber is suspended in the air along poles. The choice of fiber deployment method and technology will determine CAPEX (capital expenditure) and OPEX (operational expenditure), as well as the reliability of the network. These costs can be optimised by choosing the most appropriate active solution combined with the most appropriate infrastructure deployment methodology.

1. Aerial Deployment

Aerial fiber deployments are one of the most cost-effective methods of installing fiber cables (Senior &Jamro, 2009). Rather than digging up roads, operators can simply use existing pole infrastructure to deploy the cables (Gutierrez et al., 2015). Though aerial deployment is cost effective, the downside of aerial fiber deployments is that, because it is so fragile, it must be heavily insulated to protect against damage from weather, extreme wind, and even birds. If poles and the cable need to be made stronger, it will impact cost and time (Hayford-Acquah & Asante, 2017).

2. Underground Deployment

In this form of installation, the optical fiber cables are buried in the earth with or without duct and it requires a warning tape to be buried above the cable (Gutierrez et al., 2015; Hayford-Acquah & Asante, 2017). Underground optical fiber cables can be deployed as either direct burial or indirect burial. In the**Direct burialdeployment method**, the cable is buried underground without any covering or sheathing. This type of optic cable is built to tolerate specific conditions such as the moisture, heat, soil acidity, and conductivity. Unlike standard fiber cables, which have only a thin layer of insulation and a waterproof outer cover, direct burial cable consists of multiple layers of heavy metallic-banded sheathing, reinforced by heavy rubber covers, shock absorbing gel, wrapped thread-fortified waterproof tape, and stiffened by a heavy metal core. Hayford-Acquah & Asante further pointed out that, direct burial was the most common method of deployment for long cross-country optical network infrastructure. In this method, armoured fiber cables are ploughed in or buried in trenches directly, without putting them in ducts. The optical fiber cable type often used are steel armoured, in order to give the cable some extra protection against cuts and rodents. Direct burial method can deploy fiber very quickly. When using this deployment method, it is vital to follow the industry best installation practices, such as burying the cable at the right depth (most accepted depth of 1.5m), placing warning taps or labels buried directly above the cable, proper backfilling must be done, deployment of market poles and observing of minimum bending radius and maximum rated cable load must be applied in accordance with installation best practice (Hayford-Acquah & Asante, 2017). **Indirect burial deployment**is the most conventional method of underground cable installation and involves creating a duct network to enable subsequent installation of cables using a pulling, blowing or floatation technique. The duct or the conduit provides protection from both physical and environmental abuse. The conduits also protect the cable from shifting rocks, aggressive rodents and damage from hand shovels (Agrawal, 2010). Underground cable that is in a conduit is easy to replace, the old cable can easily be pulled out while the new one is being installed (Hayford-Acquah & Asante, 2017). Both types of underground fiber infrastructure is vulnerable to accidental cuts by excavators and other activities. Excavation damage can cause interruptions to vital services and can involve tremendous repair costs, as damages require immediate repairs to restore services.

Fiber Cut Studies in Other Countries

Very few studies have been conducted on the subject of fiber cuts by contractors despite many countries having experienced the problem. The United States of America conducted a series of studies on the subject following the repeated fiber cut incidences that country experienced in the early 1990s. The first study was conducted in 1992/1993 by the Fiber Cable Focus Group led by Dan Crawford. The fiber cable focus group was formed by the NOREST a subcommittee of the Federal Communications Commission. The purpose of the study was to identify the causes and cures of fiber cuts. Subsequent studies were conducted by other teams that were formed to implement and follow up on the recommendations of the Fiber Cable Focus Group (Crawford, 1993). The Fiber Cable Focus Group collected and analysed industry data concerning service interruptions resulting from cable failure caused by fiber cuts. The focus group also reviewed the practices of other utility companies and outside groups such as the “one-call” associations. It was established that the most frequent cause of fiber cable cuts was dig-ups by Contractors, which was the largest cause (90%) of fiber cable failures and accounted for 60% of all the reported failures to FCC.

After analysing the industry data, mostly collected from the Federal Communications Commission (FCC), the focus group determined that several primary activities could mitigate or certainly reduce cable dig-ups. Through the statistical analysis of the industry data, the Fiber Cable Focus Group developed the preventive measures which were presented to NOREST as recommendations and incorporated a balance of legislative, technical, and procedural elements called the technical paper (Crawford, 1993). According to Crawford, the Fiber Cable Focus Group's recommendations were grouped into three categories namely strengthening of the damage prevention legislation, broad and uniform implementation of best practices and endorsement of a benchmarking study to identify innovative approaches to fiber cable damage prevention and/or assess the need to revise existing practices.

Another study was conducted by the Best Practice Team in 1996 which was led by Harrison. The team was formed by the Network Reliability Performance Committee, a subcommittee of the Federal Communications Commission. The study was a follow up to the Fiber Cable Focus Group, its mandate was to consider the applicability of the best practices recommendations contained in the technical paper for implementation. The Best Practice Team encouraged the industry to study and assess the applicability and implementation of the recommendations in their respective companies (Harrison, 1996).According to Harrison (1996) the Best Practice Team was tasked to address five issues assigned to it by the NRC. The first issue was to recommend and implement relevant measures of the industry's implementation of the best practices. Secondly, to determine if and to what extent industry is implementing applicable industry best practices. Thirdly, to evaluate the effectiveness of applicable best practice for avoiding or mitigating service outages. The forth issue was to determine the cost/value of applicable best practices. Lastly, to determine if there were additional or new best practices that could be added to the existing set that was utilized in industry.

Harrison pointed out that, the Best Practice Team, which had addressed these issues for nearly a year, had analysed data from individual companies and from FCC outage reports on an ongoing basis. The BPT recognized the overall effectiveness of industry best practices in maintaining network reliability and believes that industry must continue building on the team's findings (Harrison, 1996). The Best Practice Team made seven major conclusions and the first conclusion was that there was a high level of awareness and implementation of thebest practices. Secondly, the symposium and purple book were effective communication channels to the telecommunications industry. Thirdly, competing companies can share their experiences, processes and procedures to the benefit of customers and new entrants to the industry. The Best Practice Team also concluded that companies took seriously NRC's recommendations, and because of limitations in the data, some obvious conclusions may not be supported. For example, improved outage trends may or may not be directly related to the implementation or effectiveness of Best Practices because the data did not indicate a timeline of when they may have been implemented. Analyses of best practice sections of FCC outage reports indicated that the implementation of best practices was valuable in preventing and mitigating outages but does not guarantee that an outage will not occur. Lastly, the Best Practice Team concluded that ninety percent of identified service provider best practices were determined to still be universally applicable, based on data and evaluation of obsolete and alternate solution responses.

The Best Practice Team (BPT) recommended the industry, including new entrants, should implement and continue to implement, evaluate, internally track, and monitor implementation of NRC best practices as modified and categorized by the Best Practices Team (BPT). Secondly, companies should use the tools developed by the BPT for best practice implementation decision making, monitoring implementation, and outage reporting and analysis. And lastly, industry should continue to use industry forums such as the Network Operations Forum (NOF), NRSC, and Standards organizations such as Committee T1 to introduce new best practices and propose changes to or obsolescence of existing best practices.The Best Practice Team also followed up on the implementation of the Fiber Cable Focus Group's recommendations and it was observed that the Fiber Cable Focus Group's best practices termed as "FBxx" had the highest average cost to implement and the lowest effectiveness average of all the focus groups. The key recommendation of the fiber cable focus group was about the "One Call" legislation. This was not considered to be a best practice by the Best Practice Team because it was not something implementable by service providers or suppliers. Although all service providers supported the need for enforceable, uniform "One Call" legislation, it had not become a reality. The Benchmarking study recommended by the fiber cable focus group was completed prior to the formation of the Best Practice Team and also was part of the questionnaire and analysis by the Best Practice Team. Harrison (1996) further revealed that, the review of FCC outage reports and trends indicated that fiber dig-ups was still a major problem. This was consistent with the lower effectiveness ratings of the Fiber Cable Focus Group's best practices and the lack of national "One Call" legislation recommended by the Fiber Cable Focus Group.

The last study from the United States of America that this study reviewed on the subject of fiber cuts was that of Hoffman in 2004. The study explored the frequency, location, causes and impact of cable cuts on information systems. The study revealed that between the years 1993 to 2001, fiber cuts were responsible for only 25% (compared to the 70% reported in the fiber cable focus group study) of all network outages reported to the Federal Communications Commission (Hoffman, 2004). Hoffman (2004) in his analysis said KMI Corporation, a fiber consulting group, estimated that over 283 million miles of fiber optic cables have been installed below ground since the 1980s, and an additional 335,000 miles was projected to be added by 2006. The United States alone contained over 200,000 miles of above and below high voltage transmission lines and over 3.6 million miles of copper phone lines. This goes to show that the sub surface contains massive infrastructure of vital cables like fiber, copper and electric transmission lines. According to Hoffman, in order to better understand the dynamics of cable cuts, the study explored the frequency, location, causes and impact of cable cuts on information systems. The study revealed that cable cuts were the single largest root cause of network outages in the United States. Between the years 1993 and 2001, fiber optic cable cuts were responsible for 386 (or 25%) of all network outages reported to the Federal Communications Commission. Hoffman further indicated that in order for an incidence to be reported to the FCC, a network outage had to affect over 30,000 customers for a period of 30 minutes or more.

Hoffman mentioned that cables are essential components of nearly all modern computer and communications systems. But, they are often poorly protected, unintentional or malicious damage to these cables can readily occur, potentially causing significant network disruption. Hoffman further mentioned that in general, the annual number of fiber optic cable cuts in the United States of America had risen with the increased growth of the internet. This relationship between the increase in fiber cuts and the growth of the internet can be seen as a result of the ever-increasing demand for fiber speed continues to grow, and more consumers move toward over-the-top streaming and skinny TV offerings, internet service providers (ISPs) are deploying more fiber to add new cities as part of their original service, as well as expanding within their current footprints.

Approximately 67% of communication cables in the United States are buried underground while the remaining 33% are suspended in the air. Because buried cables are hidden from plain view, they are involved in almost 80% of fiber optic cable cuts. Communication cables were more likely to be cut in rural areas than in urban areas, even though urban areas have a higher number of cables for a given area. This discrepancy appears to be due to shallower cable burying depths in rural areas (Hoffman, 2004).Hoffman revealed that cable cuts can impact information infrastructure in a variety of ways. First, cable cuts can cause a widespread denial of service of communications to customers. It was noted that, depending on which services are affected, cable cuts can have disastrous consequences. Hoffman pointed out that, it was difficult to accurately and impartially assess the financial impact that cable cuts have on businesses that depend on the communication network. The city of Portland, OR, estimated the cost of each fiber optic cable cut at approximately $2,500, though the number did not take into account the cost of network disruption. In 1986, AT&T estimated that cable cuts cost about $4000 to physically repair and about $3,600 per minute in lost revenues.

Hoffman recommended that, the problem of cable cut attacks can potentially be addressed by further research into the effectiveness of different notification procedures for construction crews working near communications cables. Enabling construction crews to locate existing cables more accurately may reduce the number of cable cuts due to digging errors. In addition, further research is needed in the design of redundant fiber optic networks. Networks that can efficiently re-route data to several other undamaged cables are more likely to survive a cable cut attack. Addressing these issues may help make cable cuts a less common and less disruptive attack method (Hoffman, 2004).

Another study that the researcher reviewed was conducted in Nigeria by Ezeh, Ogbuehi, Eleke & Diala (2013) in their study of severity analysis of the problems of optical fiber communication in South-Eastern Nigeria.The study focused mainly on the problems that affect fiber optic usage in Nigeria, the objectives of the study was to identify the problems of optical fiber communication in South-eastern Nigeria, the extent to which these problems have affected communication in the region and to recommend solutions to the identified problems. Ezeh etal., identified seventeen problems and grouped them into four categories namely government, man-made, planning and design-related and lastly the natural problems. Under the government problems category, Ezeh et al listed four problems namely road construction/expansion damage, irregular power supply, difficulty in acquisition of Right of Way and finally inadequate underground cabling infrastructure. The roads construction and expansion damage should have been analysed further and identify the real problems associated with the excavation of roads construction and expansion. Any economy requires both the good road infrastructure and technology infrastructure to have economic growth.

To address the government problems Ezeh et al., recommended that construction companies should be made to study the road plans to see where ducts are placed. In situations where ducts cannot be placed 5meters away from drainages, they should be placed at the center of roads where disturbances is minimal. Operators should send staff to monitor road construction/expansion in areas where optical fiber cables are laid and better implementation of the duct master plan should be made by government. There should be a unified ducting system for fiber optical cables so that companies can lay new fiber cables without having to excavate the ground and damage existing fiber cables and there should be a technical site survey, so that each new route is registered with the relevant ministries and agencies. During road construction, aerial routing can be used as a temporary measure to protect optical fiber installations. Finally, the government should improve power supply in order to aid effective telecommunication in south-eastern Nigeria.

The final study that was reviewed in this study was on fiber cuts was conducted in 2017 by Hayford-Acquah and Ansate both of Ghana Technology University College. The study revealed that the fiber infrastructure in Ghana has experienced a lot of fiber cuts, which has affected network quality delivery, increased operational expenditure and declined revenue margins of telecommunication companies. Government sponsored, and private project activities were largely responsible for the menace due to negligence, ignorance and lack of coordination (Hayford-Acquah & Ansate, 2017).The study identified government sponsored projects and private property developers' activities as the highest contributing groups, accounting for the greater percentages of the fiber cut incidence contribution of 47.59% and 46.64% respectively for the two years and eight months period under review. This was followed by "Other Activity" group with 4.36% whiles the Fire category was responsible for 0.76% of the total fiber cut incidence in the study area. Natural problems also contributed 0.35% to the total fault count attributed to fiber cut.Hayford-Acquah & Asante (2017) pointed out that failure by the excavators to follow obligatory requirements before and during excavation was the highest root cause of fiber cuts in Ghana. Though the survey conducted did not establish whether or not the perpetrators of fiber cuts did have permits or ROW to engage the road reservation, it was however certain that activities of fuel and gas filling station developer's as well as private property developers and others were the worst culprits.Hayford-Acquah & Asante recommended that key actors of the telecommunication industry in Ghana to actively collaborate with other stakeholders to collectively work together to drive awareness and sensitization on the importance of this national asset and its implication when there are damages. Telecommunication companies and stakeholders should embark on educational campaigns to sensitize the public on optical fiber cables whiles the government of Ghana put in measures to build mandatory right-of-way with support from the private sector.

III. Material And Methods

The study collected both survey and interview data from four target population groups consisting of fiber specialist engineers from Lusaka City Council and Zambia Information & Communication Technology Authority, project managers and safety managers from the construction companies implementing the Lusaka water, supply, sanitation and drainage project, Network Engineers from C-Liquid Telecom and Zamia Telecommunication company, and finally both business and individual fiber to the home customers from C-Liquid who had a ticket opened for service outage resulting from fiber cuts. A total of 64 respondents from all the stakeholder groups participated in the study.

Study Design: The study followed the concurrent triangulation design, where both survey and interview data was collected at the time.

Study Location: This was a fiber cut study on undergroundfiber to the home infrastructure in nine townships of Lusaka that are serviced with fiber to the home.

Study Duration: January 2017 to December 2018.

Sample size: 64 participants from four target populations. Two participants were from the regulators population group, another two participants were from FTTH service providers, six from the contractors target population and fifty-four from FTTH subscribers from C-Liquid Telecom

Sample size calculation: For the regulators, FTTH Service Providers and Contractors a census was carried out on the target population. As for the FTTH subscribers/customers, the researcher randomly started at a point and selected every 10^{th} subject in the sampling frame.

Subjects & selection method: The subjects in the target population of regulators, FTTH Service Providers and Contractors were selected using expert sampling because of the expert knowledge the subjects possessed in the field of study in their respective organisations. This was the best way of obtaining the views of persons with the expertise, the samples were generally much smaller because of the diminishing return in qualitative data. For the FTTH customers, a systematic random sampling was used to provide all the subjects in this target population an equal opportunity of being selected.

Inclusion criteria:

1. Telecommunication companies that provide fiber to the home service in Lusaka
2. Construction companies implementing the Lusaka water supply, sanitation and drainage project
3. Fiber to home customers in Lusaka who called their service provider's call center to report a service outage which was later established to be caused by a fiber cut due to excavation activities in the area.
4. Engineers that are responsible for fiber infrastructure from Lusaka City Council and Zambia Information Communication & Technology Authority.

IV. Research Methodology

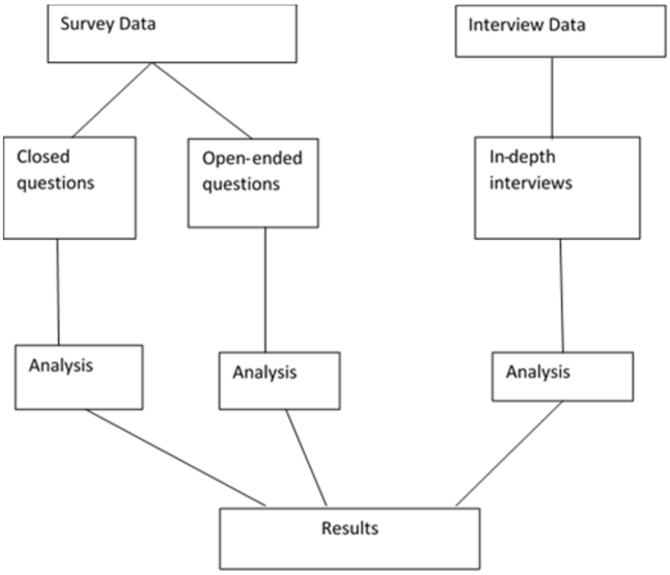
The research followed a pragmatic approach by using techniques which appeared to be best suited to the research question, the researcher had the freedom to use any of the methods, techniques and procedures associated with both quantitative and qualitative research.This philosophy concerns the thinking that choosing between one position (epistemology, ontology, or axiology) and the other is somewhat unrealistic in practice, it is argued that the most important determinant of which position to adopt is the research questions (Saunders et al., 2009; Creswell & Clark, 2011). Furthermore, the researcher adopted the mode 2 concept of knowledge creation. According to Saunders, Lewis & Thornhill (2009) the past decade has been characterised by ongoing debate within the British Academy of Management and has explored the status of management research. The debate is about the nature of management research, focusing on how it can meet the double hurdle of being both theoretically and methodologically rigorous, while at the same time embracing the world of practice and being of practical relevance by using knowledge from a range of disciplines enables management research to gain new insights that cannot be obtained through all of these disciplines separately. Saunders et al., further argued that, another feature of management research highlighted in the debate is a belief that it should be able to develop ideas and to relate them to practice. In particular, that research should complete a virtuous circle of theory and practice. Thus, business and management research need to engage with both the world of theory and the world of practice. Consequently, the problems addressed should grow out of the interaction between these two worlds rather than either one on their own.Much of this debate has centred on the production of knowledge in particular, the concepts of Mode 1 and 2 knowledge creation. Mode 1 knowledge creation emphasises research in which the questions are set and solved by academic interests, emphasising a fundamental rather than applied nature, where there is little if any focus on utilisation of the research by practitioners. In contrast, Mode 2 emphasises a context for research governed by the world of practice, highlighting the importance of collaboration both with and between practitioners and the need for the production of practical relevant knowledge. Based upon this, a research within the Mode 2 approach offers a way of bringing the supply side of knowledge represented by universities together with the demand side represented by businesses and overcoming the double hurdle. Drawing from the mode 2 concept, the researcher reviewed both the practical studies which were conducted by expert groups instituted by the Federal Communications Commission to address network outagesthat affected network reliability in the United States of America and also the scholarly studies conducted at Ghana Technology University and Federal University of Technology, Oweri Nigeria. Fiber cuts by contractors is a real business issue and a practical problem that affects business operations of internet service providers, contractors, small and big businesses and individuals as well. By combining the work of scholars and practical work of non-scholars in the field of damage prevention, the researcher offers a way of bringing the supply side of knowledge represented by universities (scholars) together with the demand side represented by businesses and overcoming the double hurdle, as indicated by Saunders et al., (2009).

The researcher also adopted the concurrent mixed methods approach which follows Creswell's concurrent triangulation design because of its simplicity and emphasises a context of research governed by the world of practice and addresses business issues and practical problems. The practical work of non-scholars that the researcher included in the study involves the studies that were instituted by Federal Communication Commission in the United States of America. The work is practical because the US went through the same problem of fiber cuts by contractors in the early 1990s and studies to resolve the issue begun in 1993, and follow up studies were conducted thereafter, where damage prevention initiatives were made to be on-going.

Research Design

The mixed methods approach was adopted by the researcher because of the flexibility it offers and that each question can be addressed by an appropriate method. Some of the research questions were best answered by interview data, while others required survey data with both closed and open-ended questions. The study involved different population groups (regulators, service providers, contractors and subscribers/customers) and since none of the population groups can experience the fiber cut phenomena in its entirety on their own, the only way to fully grasp the whole problem would be to share and accept each population group's perceptions and realities then add them all together in order to have the entire picture of the implications and mitigations of fiber cuts be realized. The concurrent triangulation design provided the simplicity and to achieve triangulation and complementarity of the findings. Triangulation was seeking convergent results on the implications of fiber cuts on different stakeholders (population groups) and complementarity was to explore interconnection and/or distinct aspects of fiber cuts.Having followed the concurrent triangulation design, this study collected both survey data and interview data at the same time. The diagram below summarises the research design that the study followed.

Figure 1: *Concurrent Triangulation Research Design Plan*



Data analysis instruments and procedures

The researcher used Microsoft Excel to analyse quantitative data which was collected using closed-ended questionnaires. The responses were inputted into Excel and the data was then presented in form of tables and graphs. The data on the tables and graphs were then interpreted to give it meaning. Qualitative data was collected through open-ended questions and in-depth interviews. Open-ended responses were analysed using content analysis and in-depth interview responses were analysed using thematic analysis. Content analysis was used to determine the presence of certain words or concepts within texts or sets of texts. The researcher counted and analysed the presence, meanings and relationships of such words and concepts, then made inferences about the messages within the texts. The counting of words or concepts serves two purposes, to remove much of the subjectivity from summaries and to simplify the detection of trends(Saunders et al., 2009). The researcher used content analysis to analyse open-ended questions in order to quantify the results and present the findings in percentages and figures.

Thematic analysis was used to analyse interview data and the data was transcripted and then grouped into themes that helped to answer the research questions under the objective, “To identify the standards and regulations for fiber installations in Lusaka”. A thematic analysis strives to identify patterns of themes in the interview data. One of the advantages of thematic analysis is that it’s a flexible method which can be used for both explorative studies, where you don’t have a clear idea of what patterns you are searching for, as well as for more deductive studies, where you know exactly what you are interested in (Saunders et al., 2009). Some themes directly evolved from the research questions, while others naturally emerged from the data as the study was conducted. In conducting the thematic analysis, the researcher followed the Braun and Clarke six-phase framework

Research Limitations

In undertaking this study, the researcher encountered some challenges in having certain relevant target groups to participate in the study. Since the participation was voluntary some relevant target population groups could not participate, these are the fiber to the home customers from Zamtel and the excavators (who actually do the digging) from the participating construction companies.Lastly, the researcher’s financial limitations and time constraints only limited the study to fiber to the home underground fiber infrastructure excluding backbone and metro infrastructure within Lusaka. But it is hoped that the mode of investigations employed by the researcher will infer the findings to other underground fiber network infrastructure considering that the challenges are basically the same.

V. ResultPresentation

Profiles of the respondents

Of the 64 respondents who participated in this study, 2 were engineers responsible for fiber installations from ZICTA (regulating agent) and Lusaka City Council (permitting agent). The two organisations were grouped together into a population group called regulators. Another group of respondents were 2 network operations engineers from C-Liquid Telecom and Zamtel. These two organisations were grouped together into a population group called FTTH service providers, because they are the only two telecommunication companies that provide fiber to the home service in Lusaka. The Project Managers and Safety Managers from the Construction companies that were implementing the Lusaka water supply, sanitation and drainage project had 6 respondents out of the 64 respondents who participated in this study. The six construction companies under the LWSSD project were grouped together into a population group called contractors. The last population group was that of fiber to the home subscribers or customers which was called FTTH Customers. This group had Business FTTH customers and Home/ individual customers. This group had ICT managers and Business owners from 30 organisations. The home/individual FTTH customers group had 24 respondents out of the total 64 respondents who participated in this study. The composition of the respondents is regarded by the researcher as a balanced sample, because it includes a collection of respondents from the fiber to the home stakeholders in Lusaka, who have a stake in the fiber to the home infrastructure. This composition brings credibility to the research results as these make up the key players.The research results were presented following the research questions.

The first research question was about the standards and regulations of underground fiber installations applicable in Lusaka, it used in-depth interviews to collect data. The interview data was transcribed and thematic analysis was performed following Braun and Clarke's six steps. The data was organised in a meaningful and systematic way, and codes were identified. The researcher was concerned with addressing the research question number one and analysed the data with this in mind. Given this, the researcher coded each segment of data that was relevant to or captured something interesting about standards and regulations pertaining to underground fiber installations in Lusaka. The data was organised into four codes namely "standards", "regulations", "legislation" and "procedures". These codes were then collated into a theme called "underground fiber installation guidelines". Table 4.1 on the next page, shows the theme together with the associated codes and the captions from the responses where the codes were derived from.

The respondents from both institutions provided similar answers to all the interview questions. The analysis revealed that there is collaboration and coordination between the permitting agents which is Lusaka City Council and the regulating agents Zambia information & Communication technology Authority. The analysis further indicates that currently there are no specific standards and laws pertaining to fiber installations. The Type Approval Manager (Engineer) from ZICTA indicated that fiber standards are still being developed by the Zambia Bureau of Standards. In the meantime, each institution uses alternative guidelines, industry best practices and legislation to grant permits and regulate fiber installations. The general guide, control & management of the wayleave and road reserve provided for in the Local Government Act and the Public Road Act are being used by Lusaka City Council when granting permits. On the other hand, ZICTA uses industry best practices to conduct fiber networks inspections and meting penalties where anomalies are detected. Any entity wishing to install underground fiber or undertake any excavation works in Lusaka are required to apply for an installation or excavation permit from Lusaka City Council and hold stakeholder engagements with ZESCO, ZEMA, Lusaka Water & Sewerage company and all telecoms in Lusaka prior to commencement of works. Table .2 below indicate that there is collaboration and coordination between the permitting agents which is Lusaka City Council and the regulating agents which is ZICTA.

Table 3: Standards and Regulations for underground fiber installation in Lusaka

Theme: Underground fiber installation guidelines.	**Captions**
Code 1: "Standards" **Code Description**: Lack of underground fiber installation standards	1. "There are no fiber specific standards currently in use". 2. "Currently the Authority (ZICTA) uses industry best practices to approve and inspect all installations". "Industry best practices include encouraging the use of armored optic fiber cable for use in buried installations or trunking of fibers and the sharing of fiber ducts as opposed to each entity doing excavations". 3. "Optic fiber installation standards are currently being developed by the Zambia Bureau of Standards (ZABS)".
Code 2: "Regulations" **Code description:** Applicable regulations for underground fiber installations	1. "Telecommunication companies and contractors are required to apply for an installation permit, prior to commencing works". 2. "The approval process among other things will check if a survey has been done and if sharing of infrastructure is possible". 3. "Any entity that wishes to carry out any excavation works is required to get clearance from other service providers and ZEMA before their application can be approved by LCC".
Code 3: "Legislation" **Code description:** Lack of fiber specific legislation	1. "No law for fiber, but the general guide, control management of the wayleave and road reserve is provided for in the Local Government act and public road act are used in the management of underground fiber installations." 2. "It is worth noting that some local authorities (Councils) have since passed bylaws making it illegal to install underground fiber." 3. "LCC has passed bylaws that prohibits approval of excavation works for the purpose of installing new underground fiber. Please note that the bylaws do not apply to the existing underground fiber."
Code 4: "Procedures" **Code description:** Permit approval procedures for underground fiber installation	1. "A written application for the intention to undertake excavation works must be submitted to the Council and conditions for the approval are stipulated to the applicant." 2. "Hold meetings with underground service owners prior to commencement of excavation works." 3. "Installation permit must be obtained prior to commencing works."

Incidences of underground fiber cuts in Lusaka

All the respondents from the contractors target population group indicated that their organisations had accidentally damaged or cut underground fiber more than ten times in the last six months while undertaking excavation works for the LWSSD project in Lusaka. The respondents further indicated that it is mandatory in Lusaka to obtain excavation permit from Lusaka City Council prior to commencement of excavation works. One of the requirements for obtaining an excavation permit is to engage stakeholders who have underground installation infrastructure. The purpose of the stakeholder engagement is to allow infrastructure owners to locate their underground utilities in the area where contractors have applied to undertake excavation works. Secondly, it's for contractors to proceed with caution as they undertake excavation works in the vicinity of utilities. The stakeholders whom contractors have to engage prior to being granted a permit Lusaka Water & Sewerage Company, the electricity utility company (ZESCO), Zambia Environmental Management Agency (ZEMA) and all the Telecommunication companies (Airtel, MTN Zambia, Zamtel, C-Liquid and internet service providers).The study revealed that despite contractors meeting the permit requirements including stakeholder engagement prior to commencement of excavation works, fiber cuts still occur on the underground fiber installations.

Causes of underground fiber cuts (accidental damages) in Lusaka

The results identified three major causes and four minor causes of fiber cut/accidental damage to underground fiber in Lusaka. The major causes included the lack of surface warning along the fiber routes as the highest ranking cause, followed by negligence or digging error, which consisted of ignorance as some workers involved in excavation works have no knowledge of fiber, so if they find fiber during excavation they just go ahead and cut the cables. The other causes grouped under negligence are use of wrong tools, miscommunication between machine operators and spotters, pressure to meet project deadlines and failure to follow internal controls and procedures. The third cause under major causes of fiber cuts is shallow cables. Lusaka is generally a rocky as a result excavators tend to bury fiber barely on the surface.

Under the minor causes, the four causes included lack of documented information on underground fiber cables, inaccurate locate by fiber owners, meandering cables and insistent cable depth. The table 3 below shows the causes of fiber cuts identified by the study.

Table 4: Causes of fiber cuts

Rank	Major Causes
1	Lack of surface warning
2	Negligence (digging error) • Ignorance (some workers don't know fiber) • Use of wrong tools • Miscommunication between machine operators and spotters • Pressure to meet project deadlines • Failure to follow internal controls and procedures
3	Shallow cables
Rank	**Minor Causes**
1	Lack of documented information on underground fiber infrastructure
2	Inaccurate locate by fiber owners
3	Meandering cables
4	Inconsistent cable depth

Implications of accidental damages to underground FTTP infrastructure

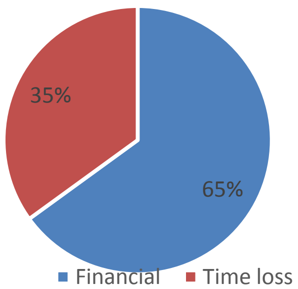
The question on the implications of fiber cuts was asked to three different target population groupsnamely contractors, FTTH service providers and FTTH subscribers/customers. Responses from all target population groups indicated that they suffered financial and non-financial implications. The implications suffered by each target population are presented below, starting with the contractors followed by service provider and finally the subscribers of FTTH.

1. Contractors

All the respondents indicated that the current legislation classified damaging of fiber optic cables as vandalism as such repair costs associated with fiber cuts are borne by the offender, this makes the contractors responsible for the repair costs of fiber cuts because they are the offenders. However, the respondents indicated that, when there is an incident of fiber cut, serious negotiations take place between the offending construction company, the telecom company that owns the damaged fiber and ZICTA as the regulator. The negotiations are for the purpose of proving that the damage was due to negligence by the offender. Repair costs and other costs associated with fiber cuts was identified as the highest implication suffered by contractors, it constituted 65% of the responses. All the six respondents indicated that it is not in all incidences of fiber cuts that their companies paid for the repair of the damages. In such cases, fiber owners were found to be negligent and were responsible for the repair costs. Whatever the case, the costs of fiber cut repairs is negatively affecting construction contractors. The Health and Safety Manager for UWP Consulting, mentioned that fiber is not cheap, hence it comes at a high cost on the organization.

Furthermore, the responses indicated time loss as the second ranking implication of fiber cuts on contractors and it constituted 35% of the responses. In the event of a fiber cut or damage, excavation works are stopped to allow for notifications and initial reports to be taken, in some cases where the fiber owners have been identified immediately, they are notified and allowed to arrive at the scene before excavation works can resume. Also the performance level of workers drop tremendously after the fiber cut, leading to more time loss. Time loss significantly affect project timelines. Figure 4.3 below shows the implications of fiber cuts on contractors.

***Figure 2:** Fiber cut implications on contractors*



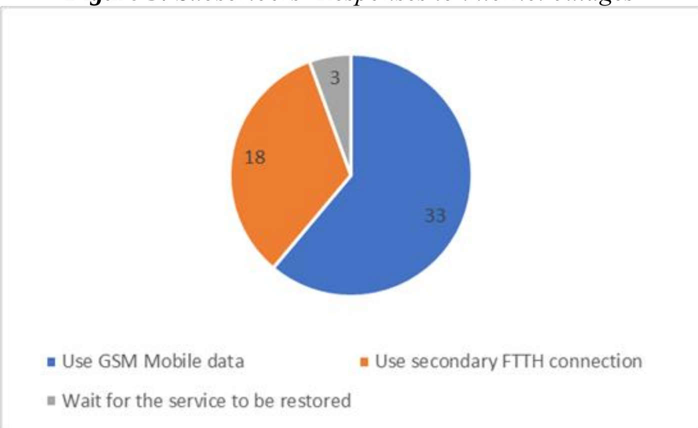
2. Service Providers

The respondents from FTTH service providers indicated that their organisations suffered both financial and fiber network performance related implications. The responses indicated high costs associated with fiber damage repairs increased their operational expenses and reduced the revenue for service providers. Both respondents from C-Liquid and Zamtel indicated that, when there is an incident of fiber cut, service providers have to attend to the fiber repairs immediately, in order to restore services that have been disrupted by the incident of fiber cut regardless of who is at fault. Negotiations follow later after services have been restored. The other implications are those associated with the network performance indicators which comprise of network reliability, network quality and quality of service. The responses show that the quality of the fiber network infrastructure degrades as damages increase and consistent fiber cuts or damages affect the reliability of the FTTH network. As for the quality of service, it is affected during the time of the fiber damage before it is instated to its original state. The respondents indicated that the cost of internet is affected by other factors and not fiber cuts.

4.5.3 FTTH Subscribers (Customers)

Fiber to the home subscribers also indicated that they have been affected by the fiber cuts by contractors. The responses indicated that they suffered various implications as a result of internet outages caused by fiber cuts. Of the total 54 respondents who participated in the study, only 3 respondentssaid they did not use analternative internet connection during the service outages, 33 respondents indicated that they used GSM mobile data as their alternate internet connection while 18 respondents indicated that they purchased a secondary FTTH connection from their service provider. Secondary fiber links run in the different direction and connected to a different Point of Presence from that of the primary fiber link. Figure 4. Below shows subscribers responses to service outages.

Figure 3: *Subscribers' Responses to internet outages*



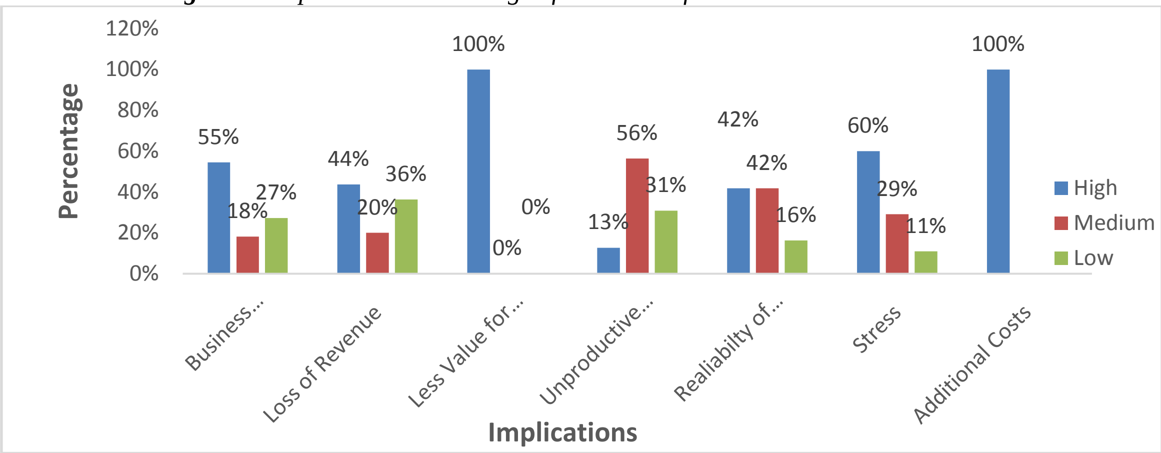
The responses from FTTH customers revealed that customers do suffer financial and other implications due to fiber cuts. Fifty-five percent of the respondents said their business processes and activities were highly disrupted by the outages caused by fiber cuts. While eighteen percent and twenty-seven percent ranked business disruptions as medium and low respectively.

Forty-four percent of the respondents said the loss of revenue was high, twenty percent said it was medium while thirty-six percent said loss of revenue was low. Hundred percent of the respondents said they got less value for their money and they ranked it as high. Unproductive hours is another implication that FTTH subscribers suffered, and thirteen percent gave a ranking of high, while fifty-six percent said it was medium and lastly thirty-one percent said unproductive hours was low.

Another implication that was identified is reliability of service, forty-two percent said the service was not reliable was high, while another forty-two percent said it was medium and sixteen percent ranked reliability as low. Sixty percent of the respondents said the stress resulting from accidental cuts was high, while twenty-nine percent of the respondents said the stress was medium and lastly, sixteen percent said the stress was low.

Hundred percent of the FTTH subscribers who participated in the study said they incurred high additional internet expenditure or operational costs and they all ranked it as high. Figure 4. 6 below shows the implications and rankings of accidental fiber cuts on FTTH subscribers.

***Figure 4:** Implications & rankings of accidental fiber cuts on FTTH customers*



VI. Discussion

The research results showed that there are currently no standards and legislation that are specific to fiber installations. In the absence of standards, quality of underground fiber installations may be compromised. The respondents from the contractors target group indicated that fiber is barely buried on the surface, as shallow as 20cm beneath the surface in some cases and lack of surface warning markers on fiber routes are as a result of lack of standards. Ezeh&Diala (2014) indicated that in order to effectively deliver fiber to the home service, service providers and the various regulatory agencies need to define comprehensive standards and models that can effectively manage the complex hand-offs and interactions in the deployment process. This is the more reason the fiber cable focus group study led by Crawford (1993) spent time reviewing different national standards, procedures and activities of other national associations striving to reduce the frequency and severity of cable damage and its impact on network reliability. The fiber cable focus group noted that complying with the best practices and standards was essential in improving fiber cable security. The move by ZICTA to engage the Zambia Bureau of Standards to develop standards for fiber installation is the step in the right direction. The development and enforcement of the fiber standards should bring some significant improvement in the manner that fiber is installed in Lusaka and address most of the identified causes of fiber cuts.

The current vandalism legislation and bylaws that prohibit the installation of new underground fiber, are not adequate or the best legislation. The vandalism legislation is not enough to stop the fiber cut menace, it has some loopholes as it is only applicable to those who damage the fiber infrastructure and does not address those who install fiber wrongly. This has brought in a situation where negotiations come in when there is an incident of fiber cut in order to establish who is at fault. The end of the negotiations can end up favoring the best negotiators even when they could be at faulty. Both the Crawford (1993) and Harrison (1996) studies emphasised on the strengthening of legislation in order to remove the grey areas in the event of an incidence of fiber cut and also to deter offenders. The bylaws that prohibit the installation of new underground fiber are not the best, as indicated by Crawford (1993) and echoed by Hoffman (2004) and Hayford-Acquah & Asante (2017), both underground and aerial fiber installations are susceptible to accidental damage. What is needed is strong fiber specific legislation, proper management of the right-of-way combined with public awareness initiatives on damage prevention. These will address the fiber cut causes that are grouped under negligence or digging error. Moving to aerial installations is just transferring the problem.

Fiber cuts lead to service outages that presents various implications on different stakeholders, but financial implications is common to all stakeholders. The service providers incur high operational costs as they had to spend time and financial resources to attend to the damage repairs because damage repairs require immediate attention by service providers regardless of who was at fault. The literature review is silent on the financial implications suffered by service providers, this is the gap that this study is trying to fill. Apart from financial implications, network quality and network reliability are performance indicators that are also affected adversely by fiber cuts.

The Network Engineer at Zamtel further pointed out that fiber cuts affect network reliability negatively, the times that the there is a fiber cut, the customers on the affected fiber cable are unable to use the various services that the network provides. C-Liquid is developing its network with some redundancy with alternative fiber routes coming from more one point of presence to a customer's premises, so that in event of a damage on one fiber, traffic is rerouted to the other fiber from a different point of presence to customer's premises. This is to improve network reliability but there are times when both fibers can be damaged at the same due to heavy excavations going on in Lusaka. The performance indicators responses are in agreement with

Crawford (1993), Harrison (1996) and Hoffman (2004) studies conducted in the United States of America. Fiber cuts negatively affected network reliability and the Federal Communications Commission had to establish a network reliability steering committee which in return established a number of focus groups like the fiber cable focus groups and the Best Practice Team in order to address the issue of network reliability which was adversely affected by repeated fiber cuts which the country experienced in the early 1990s. The focus groups were tasked to identify and recommend damage prevention measures. The recommendations were implemented and service outages caused by fiber cuts that were reported to FCC reduced from 60% in 1992 to 25% in 2001. In the similar way, ZICTA and LCC are also putting in measures to deal with the issue of fiber cuts. The move to develop standards for fiber installation, the implementation of GIS to map fiber routes. The infrastructure sharing among fiber owners being encouraged and the adoption of aerial fiber installations are measures towards damage prevention.

Contractors suffer financial implications as well as delayed project timelines. Contractors have to settle huge damage repair bills, which are said to be in thousands of United States dollars. This is in agreement with what was reported on the google fiber project in Charlotte city. According to Landes (2017), the contractors in Charlotte received 41 damage claims totalling US$688,000. This proves that the contractors who damage underground fiber installations are also affected negatively by this phenomenon, not only in Lusaka but world over.

FTTH subscribers do not get the value for their money, because of the way service subscription packages are made. Subscribers are billed based on monthly packages regardless of the service availability in a particular month, subscribers still have to pay the full monthly charge which is mostly paid in advance except for few big organisations who pay after the service has been consumed.

The responses from FTTH subscribers indicated that they incurred additional internet costs (which raises their operational costs), for implementing backup internet solutions in order to avoid business disruptions which many organisations in today's business world cannot afford to have. Furthermore, This implication got the highest ranking of 100%. The literature reviewed does not mention anything about financial implication on customers this is another gap that this study is trying to fill. Though, the silence could be explained by the network survivability as a way of ensuring network reliability as pointed by Crawford (1993). The Federal Communications Commission requires all telecommunication companies to build their networks in such a way that when there is a damage on one fiber, traffic can be routed to other fiber cables at no extra cost to the government or customers. In Lusaka, C-Liquid has built its fiber network in this manner, except this comes at an extra cost to the customer, in that customers have to purchase extra equipment and another internet subscription to enjoy this service.

Business disruption is a huge implication suffered by fiber to the home customers. In today's global business world stable and faster internet connectivity is the bloodline of the business. Business transactions, processes and decisions are concluded online. When there is an outage, businesses are cut out of the rest of the global business community and lose out on opportunities, unproductive hours are also costly for any business, many businesses are dependent on web-based applications and services and revenue is also lost as they are not able process transactions during service outages. This agrees with Grover (2014) analysis of the Gartner research which attributed up to $500 million in business losses due to network failures at the end of that year in the US. Direct voice-calling revenue loss from failure of major trunk groups was quoted at $100,000/minute or more. But other revenue losses arise from service level agreements (SLAs) for private line or virtual network services, or even bankruptcy of businesses that are critically dependent on 1-800 or web-based services. Many businesses are completely dependent on web-based transaction systems or 1-800 service for their order intakes and there are reports of bankruptcies from an hour or more of outage.

All these implications being suffered by stakeholders including the contractors who damage the fiber is not good for the economic growth of Lusaka and indeed the country as a whole. The theoretical evidence in the Literature review has shown how fiber to the home is not just about internet access, it opens the door to a wide range of services and applications. According to OECD (2007) the scope for broadband to act as an enabler of structural change in the economy expands as it affects an increasing number of sectors and activities. According to FTTH Europe (2017), the high-speed broadband plan in France, where €20 billion was invested in broadband and infrastructure, is expected to create 20,000 jobs in the country by 2022. With the prevailing high unemployment levels, Lusaka has the potential to create jobs through the deployment of fiber to the home. The World Bank (2012) revealed that faster broadband speeds have greater impact and generates an overall annual increase in the gross domestic product of a country. A 10% increase in broadband household penetration helps boost a country's economy and brings 1% increase in GDP and 1.5% in labour productivity growth. In the US, the Fiber Broadband Association (2017) reported that preliminary evidence from a study into gigabit communities, revealed that communities where 1Gbps broadband is widely available indicate that those communities enjoyed per capita GDP that is 1.1% higher than communities with little or no available gigabit services. Unless the regulatory authorities emulate what communication authorities in other countries have implemented and are now benefiting from the socio-economic impact of fiber to the home, Lusaka will not get to enjoy the benefits of fiber to the home technology. The government of Zambia has already provided the platform and the conducive environment for ICT evidenced in the provisions of the sixth national development plan and the seventh national development plan. ICT sector was moved from being a supportive sector to that of an economic sector that contributes to the economic growth of the country. This movement of the ICT sector to be an economic sector has moved the government into developing a national broadband strategy that is intended to bring down broadband costs in Zambia and fast-track social and economic development in the country by increasing access and promoting widespread deployment of ICT services through the expansion of the nation's telecommunications backbone and ICT infrastructure development.

VII. Conclusion

Based on the analysis of literature review and responses from the study participants, the researcher was able to make some conclusions as outlined below;

I. Lack of fiber standards detailing the underground installation specifications is contributing to the fiber cut phenomena in Lusaka.
II. Fiber cuts have financial implications on all stakeholders.
III. Underground fiber cables can be protected from accidental damage by contractors undertaking excavation works.

VIII. Recommendations

The intervention measures being implemented and enforced by Lusaka City Council and ZICTA are a good start in the right direction towards damage prevention, but these strategies are not enough, more needs to be done to ensure the protection of underground fiber installations in Lusaka and indeed the rest of the country. The researcher recommends the following strategies in addition the ones already being implemented in Lusaka.

I. Establishment of a damage prevention committee to champion the damage prevention awareness campaigns and actively engage all the stakeholders in the sub-surface of our soil to encourage damage prevention in all installations and exercise safe digging.
II. Establishment of a periodic stakeholder symposium to foster a synergy between telecommunication and construction companies.
III. Establishment of a central repository for the storage of service outage reports recorded by all operators.
IV. Fiber awareness training for excavators prior and during excavation works.
V. Review of the current legislation on fiber.
VI. The designing of redundant fiber optic networks that can efficiently re-route data to several other undamaged cables without making the cost of internet access too high.

The damage prevention committee should consist of team members from institutions with underground utilities, construction companies or the National Construction Council, Lusaka City Council and ZICTA .The committee will be dedicated to the protection of buried infrastructure by raising public awareness, championing the call of shared responsibility of damage prevention by all stakeholders and actively engage all the stakeholders in the sub-surface of our soil to encourage damage prevention in all installations and exercise safe digging. One of the root causes for fiber cuts was ignorance, people don't know what fiber is, or what it is used for and what happens when it is damaged. Unless the public appreciates fiber, they won't be able to protect it.

The symposium will endeavour to bring together two economic sectors who are better off working together than in isolation. They have a stake in the sub-surface of our soils and their work can be destructive to the other. The symposiums will provide a platform where best practices and standards can be shared and encourage broad implementation by all stakeholders.

The regulatory agent ZICTA to consider establishing a central repository for service outages due to fiber cuts by contractors recorded by all operators. The information will help the authority to ascertain if the interventions being made to curb to problem are making a significant change or frequency in the number of incidences being reported.

The current provisions in the vandalism of public infrastructure, Local Government Act and Public Road Act are not adequate to deter offenders, they have been overtaken by time and technology advancement in the city. The legislation was established before the deployment of fiber in Lusaka and countrywide. The gaps in the provisions has resulted in vigorous negotiations going on when there is an incidence of fiber cut. Sometimes in negotiations the person or persons with great negotiation skills may win even when they are the offenders. Strong legislation should have no room for negotiations. The permitting agent (Lusaka City Council) and the regulatory agent (ZICTA) should engage the government and push for the review and/or establishment of new fiber infrastructure legislation which will promote damage prevention and deter would-be offenders.

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