IMPACT ASSESSMENT OF TOPOGRAPHY ON INFRASTRUCTURE DEVELOPMENT AND MOBILE COMMUNICATION SERVICE DELIVERY: CASE STUDY OF KUNENEKUDE IN NENO

MASTER OF SCIENCE IN INFRASTRUCTURE DEVELOPMENT AND MANAGEMENT DISSERTATION

CHISOMO MOMBA

UNIVERSITY OF MALAWI
THE POLYTECHNIC

DECEMBER 2020

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By

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Submitted to the Department of Mechanical Engineering, Faculty of Engineering in Partial Fulfillment of the Requirements for the Degree of Master of Science in Infrastructure Development and Management

UNIVERSITY OF MALAWI
THE POLYTECHNIC

DECEMBER 2020

DECLARATION

I, **Chisomo Tendai Momba**, declare that I am the sole author of this thesis, that during the period of registered study I have not been registered for other academic award or qualification, nor has any of the material been submitted wholly or partly for any other award. This thesis is a result of my own research work, and where other people's research was used, they have been duly acknowledged.

Candidate: Chisomo Tendai Momba

Signature: ______________________________

Date: ______________________________

CERTIFICATE OF APPROVAL

The undersigned certify that this thesis represents the student's own work and effort and has been submitted with our approval.

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DEDICATION

To

Lloyd, Tinashe and Luthando

This research paper is wholeheartedly dedicated to you for being a source of inspiration. You gave me strength when I thought of giving up. You gave me the drive and discipline to tackle this task with enthusiasm and dedication. Thank you very much for continually providing the moral, spiritual, emotional, and financial support without such this research would not have been possible.

Thanks for everything - Keep the faith.

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My sincere acknowledgements are hereunder outlined which is by no means exhaustive, neither is the list in any order of importance. A lot of unique people, so precious yet too numerous to list played various key roles in making my study such a success.

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ABSTRACT

The Information and Communication Technology (ICT) sector is crucial for sustainable infrastructure development and plays a key role in the socio-economic development and overall poverty reduction. Among the technological advances of the last 50 years, the expansion and technological improvements of telecommunications infrastructure have been some of the most crucial interventions in the society. The introduction of mobile communications especially the global system for mobile (GSM) communication technology provided a huge landmark for personal communications. However, the deployment of infrastructure to provide such communications services is faced by several challenges among them the topography of areas where such infrastructure must be deployed which impacts efficient service delivery.

The main objective of this thesis is to assess the impact of topography on infrastructure and mobile communication service delivery with a particular focus on Kunenekude. The thesis examines the relationship between topography and mobile communication service coverage by using the telecommunications management system (TEMS) investigation analytical tool in relation to the socio-economic impact arising out of the limited service delivery. The assessment shows that topography reduces effective service coverage and impacts mobile service delivery by almost 40% thereby increasing the costs of providing the service. Additionally, the socio-economic benefits arising from mobile communication services are affected when service coverage is limited.

This study through the findings recommends a coordinated infrastructure sharing deployment plan to address the topography challenges in infrastructure development and the use of household settlement statistical data to effectively plan coverage for mobile communication services.

Keywords: Telecommunications, Infrastructure, Socio-economic, Topography, Mobile communication, Service delivery.

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ABBREVIATIONS / ACRONYMS

3G	- Third Generation
4G	- Fourth Generation
ACL	- Access Communications Limited
ARPU	- Average Revenue Per User
BSC	- Base Station Controller
GDP	- Gross Domestic Product
GSM	- Global System for Mobile (communications)
GSMA	- GSM Association
ICT	- Information and Communication Technologies
IDM	- Infrastructure Development and Management
IEEE	- Institute of Electrical and Electronics Engineers
ITU	- International Telecommunications Union
LOS	- Line of Sight
MACRA	- Malawi Communications Regulatory Authority
MDG	- Millennium Development Goals
MPC	- Malawi Posts Corporation
MPTC	- Malawi Posts and Telecommunications Corporation
MSC	- Mobile Switching Centre
MTL	- Malawi Telecommunications Limited
NSO	- National Statistics Office
RF	- Radio Frequency
SDG	- Sustainable Development Goals
TEMS	- Telecommunications Management System

TNM	- Telekom Networks Malawi
UN	- United Nations
USD	- United States Dollar
USF	- Universal Service Fund

CHAPTER 1

INTRODUCTION

1.1 Background

Infrastructure development is combination of words namely ‘infra’ meaning below, “structure” meaning form and “development” meaning to bring the change of structure. Infrastructure development is therefore related to such aspects as roads, bridges, power generation, telecommunication networks etc. Infrastructure is the baseline for overall development of any society as it forms the foundation of development before any type of economic activity commences. Shahi, (2012) states that infrastructure development is necessary for the operation of a society, human-natural interaction and socio-economic development. Infrastructure development brings change in society through the transfer of natural structures, setting of new structures and the eventual establishment of new modern facilities. Essentially, the overall development of a society is premised on an effective service delivery in which infrastructure development plays a crucial role.

Seo, (2013) chronicles the evolution and standardization of Mobile Communications Technology over the technology generations to the present fourth/fifth generations (4G/5G). As technology evolves, the complexity of supporting infrastructure also grows. Telecommunications infrastructure belongs to the broader group of physical infrastructure and mobile telecommunication infrastructure provides links for end-to-end communication without the use of physical connection between source and destination of the message.

The challenge with telecommunications infrastructure development arise from the nature of the topography of the country and its inherent geographical features. Signal propagation for point-to-point mobile communication is largely dependent on line-of-sight (LOS) communication hence the need for a conducive terrain to facilitate ease of communication service delivery and improve area coverage.

1.2 Infrastructure in Telecommunications

1.2.1 Definitions Overview

Telecommunications infrastructure, also called communications infrastructure refers to organizations, personnel, procedures, facilities and networks employed to transmit and receive information by electrical or electronic means. Before the emergence of the internet and other data networks, telecommunications had a clear meaning: the telephone (and earlier the telegraph) was an application technology that allowed people to communicate at a distance by voice. Today people think of telecommunications in terms of both products and services. The telecommunications network therefore encompasses the collection of terminal nodes, links and any intermediate nodes that are connected to enable telecommunication between the terminals. The transmission links connect the nodes together to;

(a) represent all the players that make the telecommunication possible, i.e. from transmitters and receivers to the communication mediums that make it possible for the messages to be transmitted; and

(b) the (tele)communication medium refers to the channel that carries the signal between the transmitter and the receiver, e.g., optical fibre cable, transmitter and receiver towers, etc.

1.2.2 Telecommunications Services Infrastructure

Infrastructure development mainly aims at providing the basic needs of society with the aim of facilitating better living and working conditions for socio-economic development. The UN Sustainable Development Goals (SDG's) goal number 9 highlights the need to build sustainable infrastructure, promote sustainable industrialization and foster innovation.

Salunke, & Gaikwad, (2015) stated that mobile communications networks are getting more and more complex due to (i) variety of services they offer, (ii) variety of devices connected to the network, (iii) variety of environment and channel conditions they work, (iv) variety of possible interconnections they have to make, and (v) more recently, variety of network topologies they can use. This complexity has therefore necessitated the evolution of the supporting infrastructure in order to efficiently support the growing services.

The telecommunications sector is rapidly changing due to the pace of technology change. Technology change in mobile telecommunications is influenced by infrastructure innovation which provides a platform for offering access to mobile services and internet data. Damsgaard, Ping, (2007) indicate that the infrastructure innovation involves both radical and evolutionary shifts in its underlying technologies. Service providers therefore need to be responsive to the needs of the sector and develop infrastructure to facilitate the delivery of good quality of service. The development of infrastructure is therefore key to service providers in their planning requirements for telecommunications services in order to meet the demands of service delivery as well as license obligations from sector regulators. Strategic development of telecommunications infrastructure is not only a key driver but is also an enabler for socio-economic development of any country.

The GSM communication family of technologies has since 1991 provided a platform for mobile communication with enhancements that can deliver an increasingly broad range of services to match the growing demand. Various studies over the years by the GSM association (GSMA) have shown that continued growth of core telecommunications business especially mobile telecommunications which is driven by rapid innovations around service provision has seen the emergence of non-traditional applications i.e. data services and online applications that is putting a huge strain on existing infrastructure. This rapid growth has presented both challenges as well as opportunities for mobile service providers in the sector. The demand for services has thus necessitated enhanced planning requirements to facilitate service delivery to areas that have traditionally been deprived of access to telecommunication services.

1.3 Mobile Telecommunications Services in Malawi

The International Telecommunications Union (ITU, 2013) indicates that the Malawi telecommunications market is a duopoly dominated by two mobile service providers namely Airtel and Telekom Networks Malawi (TNM) who have almost equal market share of the mobile service market. TNM which started its operations in 1995 was joined by Airtel in 2000 and since their operations were licensed under the Malawi Communications Regulatory Authority (MACRA) jurisdiction in 2000, competition between the two operators has been across not only the services but also across the network platform and the infrastructure.

The National Statistical Office (NSO) population estimates the population of Malawi to be around 18 million (NSO, 2018) with access to telecommunication services at an average of around 45%. These figures provide leverage to telecommunication service providers as there is an addressable market for growth of telecommunication services in the country. Lancaster (2015) indicates that penetration of telecommunication services remains low in comparison to the regional averages hence a lot of opportunities for further growth especially for the mobile sector. NSO (2018) indicates that “84% of the population reside in rural areas” which presents excellent opportunities for extending services to rural areas despite the challenges of topography that are inherent in accessing such areas.

Graham & Marvin (1996) state that telecommunication technologies are claimed to lead to a new urban and regional spatial organization with the particular emphasis on the belief that they promote rural development by attracting information and knowledge-based entities by allowing such entities to trade their services beyond their local areas. However, for most developing countries, the development and distribution of infrastructure for telecommunication services has inherently been concentrated in urban areas more than the rural areas mainly since service providers focus on the average revenue per user that can be obtained for services provided. With the high level of rural – urban migration in developing countries, the development of infrastructure in rural areas has been limited to selected areas mostly based on operational or licence obligations. Guldmann (2001) further highlights that advances in telecommunication services may eventually be a two-way street for rural areas, because they may also make it easier for urban firms to capture and serve rural markets, thus inhibiting local rural development.

1.4 Problem Statement

The failure to access communication services is not only attributable to the financial challenges faced by service providers to extend services to all areas but is also attributed to the topographical challenges encountered in extending services to areas that have a difficult terrain to navigate especially for mobile services. Poor access to many rural areas as well as the high cost of telecommunication services contribute to the low access and usage of mobile services.

The prevalent lack of or limited service in the rural areas is a factor that defeats the right to communication as a basic service in line with the mandate of universal ICT access. Even where we have strong supply side interventions in developing countries with over 90% mobile coverage and even 50% of the population owning smart devices, many developing countries cannot reach the 20% penetration necessary to reach the critical mass required to enjoy positive multipliers associated with socio-economic development (Gillwald, 2017).

Kunenekude area in Neno district is one area whose antagonistic topographical challenges affect the provision of telecommunication services. There has been no study that has assessed the impact of topography on infrastructure development in Kunenekude. Limited mobile service is available in areas near Kunenekude. Ligowe, which is the nearest area to Kunenekude receives partial coverage from three telecommunication transmission sites namely Neno, Neno Turn-Off and Mwanza. However due to the hilly topography of Kunenekude, a telecommunication transmission site at Ligowe cannot still provide the required mobile telecommunication signal coverage to Kunenekude hence the need to assess other alternative coverage options.

1.5 Research Objectives

1.5.1 Main Objective

The main objective of this research is to assess the impact of topography on infrastructure development and mobile communication service delivery in Kunenekude.

1.5.2 Specific Objectives

In assessing the impact of topography in the identified area, this paper addresses the following specific objectives.

(i) To address the technical capabilities of mobile network coverage in providing effective mobile service coverage to terrain challenged areas; and

(ii) To analyse the comparative significance of mobile communication services in enhancing socio-economic development of rural areas.

The findings and recommendations of this study therefore are crucial to identification of alternative coverage options to enhance mobile communication service delivery for Kunenekude.

1.6 Research Hypothesis

Rogers (1966) stated that hypotheses are single tentative guesses, good hunches – assumed for use in devising theory or planning experiments intended to be given a direct experimental test when possible. In this research, the developed hypotheses are premised on the fact that the topography has an impact on infrastructure development required for mobile telecommunications coverage and service provision in the area. The developed hypothesis will be reviewed based on the findings for the area in order to address the overall objectives of the research.

It is hypothesized that topography affects the mobile signal coverage in terms of the signal propagation from any transmission site. The terrain therefore impacts the level of mobile telecommunication services that can be provided in an area lending credence to the assumption that topography limitations influences the overall infrastructure development and affects the mobile communication service delivery. Terrain also impacts the associated infrastructure facilities thereby influencing the level of service coverage in an area.

The following hypothetical propositions were developed for the study of Kunenekude.

a) Impact of mobile service delivery challenges emanating from the topography of Kunenekude.
   - ✓ *H_0 – The topography of the area* ***has*** *an impact on mobile service delivery.*
   - ✓ *H_1 – The topography of the area* ***has no*** *impact on mobile service delivery.*

(b) Impact of mobile communication service on socio-economic development in Kunenekude.
   - ✓ *H_2 – Mobile communication service* ***has*** *impact on socio-economic development.*
   - ✓ *H_3 – Mobile communication service* ***has no*** *impact on socio-economic development.*

1.7 Justification

Hosman & Fife (2012) state that mobile phones have the potential to reach a large and growing base of users across any country and can be used for development-related purposes. However, there is still a lot that governments need to support further growth of telecommunications services. This ranges from support of infrastructure development and establishment of Universal Service Fund (USF) that should support provision of services to areas that are deemed commercially not viable by licensed operators.

In assessing the impact of topography on mobile communication service delivery, the body of knowledge was broadened by reviewing Kunenekude in Neno that has inherent topography challenges leading to lack of mobile communication service provision for the area. The review draws upon practical limitations on the ground offering technical insights on coverage assessment to facilitate the alternative options for the area under focus. The research findings are thus replicable in other areas with similar challenges.

1.8 Scope of the Study

The scope of this research entailed a detailed analysis of the impact of topography on the development of infrastructure and mobile communication service delivery. The focus on Kunenekude, an underserved rural area which sits within a radius of 15 – 25 km from the three neighbouring mobile transmission sites provides a practical guide for areas with challenging topography that can also be extended to any area with similar physical features. The review of Kunenekude topographical challenges in relation to neighbouring areas especially Ligowe and communication sites namely Neno, Neno Turn-Off and Mwanza provides a further platform for assessing the socio-economic challenges in the area under study. Large coverage areas translate to greater service requirements and an enhanced transmission network requiring infrastructure deployment over such large coverage requirement.

1.9 Limitations of the Study

In conducting the research, the limitations encountered in the course of undertaking this study include;

(i) Technology mix which rendered higher generation technologies (3G/4G) not desirable for the study as they are not a basic requirement. The assessment was therefore limited to only 2G technology (GSM).

(ii) Financial limitations on the scope of the study that did not allow extending the assessment to a detailed cost-benefit analysis of various options.

1.10 Thesis Structure

The organizational layout of the thesis is set out in five key chapters.

Chapter 1 forms the basis of the thesis providing the introduction, highlighting the background to telecommunications infrastructure and its role in the delivery of mobile services and economic development. It provides a glance of the mobile telecommunications sector in Malawi and further provides the problem statement and the rationale for the research before summarizing what is expected in the other chapters of the research.

Chapter 2 provides the literature review looking at the work that has already been done with respect to the subject matter. It highlights the relevant relationship to key aspects affecting the industry and the trends observed necessitating the research at hand. It further provides a summarized conclusion of the review and contextualizes the conceptual framework for the thesis.

Chapter 3 provides the research methodology and the variables that have been considered as part of the design. It further highlights the sampling and data collection methods used in getting the required data from the focus area.

Chapter 4 deals with the findings / results and analyses the data and provides the basis for assessing the findings to test the hypotheses in relation to the study objectives.

Chapter 5 deals with the discussions based on the findings of the study. The chapter interprets the findings based on established literature in relation to the thesis objectives and hypothesis.

Chapter 6 is the final chapter of the thesis and provides recommendations and key conclusions that inform the implications and practical recommendations for implementation and further research. It discusses the gaps and anomalies and provides recommendations on the way forward.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

In any research, a detailed analysis of previous studies in the same area is necessary to provide insight to closely related issues and findings. Previous studies provide the basis for follow-up studies and continuity to research by linking the present study with past research in order to get a proper way forward. Various literature regarding the provision of mobile services in antagonistic terrain areas is available and this research has considered the different degrees of complexity reviewed by the available literature.

2.2. Infrastructure Definition

Kasper, E. (2015) opines that despite the importance of infrastructure, there are still gaps in theoretical and empirical research. Consequently, infrastructure lacks a theoretical foundation. However, infrastructure can be broadly defined into economic and social infrastructure. Economic infrastructure as a physical network with properties of natural monopolies includes the sectors such as energy, including electricity, oil and gas, telecommunication, transport, water and wastewater. Buchner, Kaserer & Schmidt (2008) define economic infrastructure as the physical network, composed of physical nodes and edges on whose basis network infrastructure services are supplied.

Tang (2012) classifies infrastructure as typically a term to characterize the existence or condition of costly 'technical structures' such as roads, bridges, tunnels, or other constructed facilities such as loading docks, cold storage chambers, electrical capacity, fuel tanks, cranes, overhead clearances, or components of water supply's, sewers, electrical grids, telecommunications, and so forth. Infrastructure thus consists of improvements with significant cost to develop or install that return an important value over time. Infrastructure being a set of interconnected structural systems therefore provides a framework to support development structures, systems and facilities that serve an economy, business, industry or country facilitating its socio-economic development. Alleman et al (2002) indicated that most infrastructure investments can positively affect the economy in three ways namely (i) it can reduce the cost of production, (ii) it can increase revenues, and (iii) it can increase employment through both direct and indirect effects.

2.3. Telecommunications and Infrastructure

Telecommunications has been defined as a technology concerned with communicating from a distance and can be categorized in various ways. It includes mechanical communication and electrical communication because telecommunication has evolved from a mechanical to electrical form using increasingly more sophisticated systems (Anttalainen, 2003). Telecommunication infrastructure is also a little different from other infrastructure, as a determinant of economic growth because of the existence of network externalities, a phenomenon that increases the value of a service with increase in the number of users. Because of this, the impact of telecom infrastructure on economic development is more pronounced as compared to other traditional infrastructure. This phenomenon has been demonstrated by Kim, Jae-Ho Juhn & Won-Gyu Ha. (1997) in the analysis of online service competition.

Telecommunications infrastructure plays a pivotal role in industry growth and technology evolution. Telecommunications infrastructure also called communications infrastructure belongs to the broader group of physical infrastructures. It refers to the organizations, personnel, procedures, facilities and networks employed to transmit and receive information by electrical or electronic means. Telecommunications infrastructure is further classified into subcategories namely communications satellites, earth stations, computer networks, local loops, networking hardware, optical fiber, radio masts and towers, submarine communications cables, telecommunications buildings, telephone exchanges. It is however noted that mobile telephony infrastructure as well as fixed telephony infrastructure typically embrace most components of the categories of telecommunications infrastructure.

ITU (2014) stated that robust telecommunication/ICT infrastructure is considered to be an underpinning and enabling platform that should be universally available and accessible to all people to enhance a global economy and information society, and high-speed communication networks directly promote innovation throughout economies as much as electricity and transport networks, among others. The role of telecommunication infrastructure in enhancing economic growth is a subject that is still under intense debate. Arguments are that the development of a modern nation to its full potential in contemporary world can never be attained without adequate telecommunications infrastructure. This implies that the development of telecommunications infrastructure will significantly boost economic growth and development. In fact, information tools such as telephones, personal computers, and the internet are increasingly critical to economic success and personal advancement. All these helps to encourage economic growth.

2.4. Mobile Telecommunications Services

The telecommunications sector has undergone dramatic reforms since the 1980's. "Telecommunications is an essential infrastructural component that enhances the growth of other sectors; agriculture, education, industry, health, banking, defence, transportation and tourism. It is indispensable in everyday activity and promotes socio-economic development" (Wilson, Ugwunta, Okwo & Eneje, 2014). Mobile telecommunications sector is one of the fastest growing sectors in the ICT industry due to the inherent benefits of mobility that accrues to mobile communications. In tandem with such boom in growth, the corresponding aspect of infrastructure development is also growing in order to provide a sustainable infrastructural platform on which such services are to be provided (Kefela, 2010). This agrees with a study by Waverman, Meschi & Fuss (2005) who found that mobile telephony has a positive and significant impact on economic growth.

2.5. Infrastructure and Economic Development

Hardy, A. (1980) highlighted the impact of telecommunications on economic growth based on data obtained from 45 countries with the largest effect of telecommunications development on gross domestic product (GDP) observed in the least developed countries as opposed to the smallest effect in the most developed countries. Sridhar & Sridhar (2004) further stated that telecommunication infrastructure is also a little different from other infrastructure, as a determinant of economic growth because of the existence of network externalities, a phenomenon that increases the value of a service with increase in the number of users. Because of this, the impact of telecom infrastructure on economic development is more pronounced as compared to other traditional infrastructure.

Infrastructure may be owned and managed by governments or by private companies, such as sole public utility. Generally, infrastructure such as roads, major ports and airports, are publicly owned, whereas most energy and telecommunications networks are privately owned. Publicly owned infrastructure may be paid for from taxes, tolls, or metered user fees, whereas private infrastructure is generally paid for by user fees.

Government owned and operated infrastructure may be developed and operated in the private sector or in public-private partnerships, in addition to being operated in the public sector. Sridhar, &

Sridhar (2004) studies the impact of telecommunication infrastructure and the telecommuting it enables, on spatial dispersion of population. Gupta (2000) further submitted an estimate that one percent growth in telecommunication services generates three percent growth in the economy and such results overall point to the fact that technology is a complement, not a substitute, for face-to-face interaction.

2.5.1. Mobile Phones in relation to Economics and Socio-demographic Characteristics

Qiang (2009) notes that in just over a decade, mobile technology has provided most users the first extensive system of electronic communication. Mobile communication influences all spheres of life in developing countries and has been harnessed as a cost-efficient and accessible means for poverty alleviation with applications across all key economic sectors namely health, agriculture, education, commerce and tourism. Ricketts (2002) opines among other things that telecommunications aids coordination of information flow, provide opportunities for increasing the efficiency of interaction and coordination, and in this manner influence the success of economic activities.

Patel & Rathod (2011) state that the mobile phone popularity revolves around convenience, business, recreation and safety. In various studies undertaken all over the world, a positive relationship has been evidently shown between telecommunications and economic growth, especially with respect to developing and developed countries. Bayes, Von Braun & Akhter (1999) found out that half of all telephone calls involved economic purposes such as discussing employment opportunities, prices of the commodities, land transactions, remittances and other business items. It was further indicated that the average prices of agricultural commodities were higher in villages with phones than in villages without phones.

According to the study of Qiang (2009), for every 10%-point increase in the penetration of mobile phones, there is an increase in economic growth of 0.81 percentage points in developing countries, versus 0.60 percentage points in developed countries. The study also found that all information and communications technologies promote growth more effectively in developing countries than in developed ones. This is because telecommunications services help improve the functioning of the both the public and private sectors. These issues were more acute in developing economies than in developed ones. The structure of mobile communication is premised on infrastructure linkage from source to destination, providing a seamless platform for the transfer of communication messages between the two points as shown in Figure 2.1.

The communications equipment consists of the base transceiver (BSC) station with its associated transmission/receiving tower and antennas for conveyance of the message through a common mobile switching centre (MSC). Due to the nature of having both receive and transmit capabilities, reciprocal communication can be made between two communicating points.

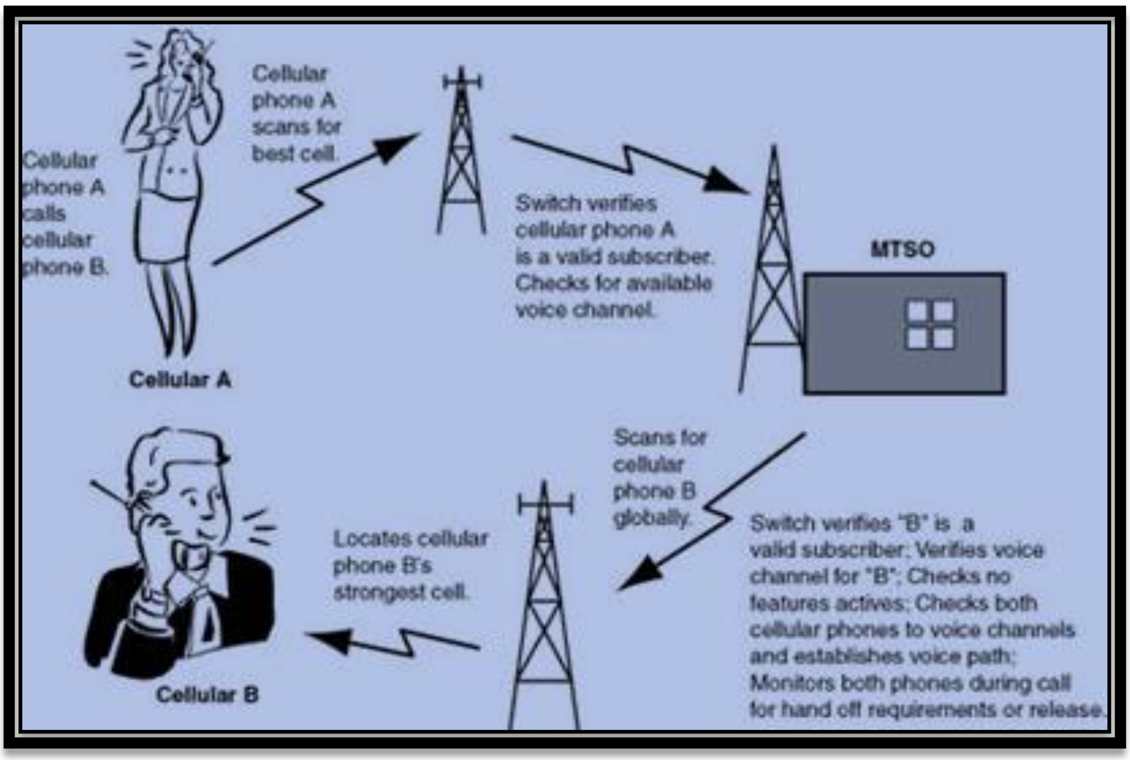


Figure 2.1 Basic mobile telecommunication set-up

GSMA indicates that in today's mobile market, commercial considerations appear to be driving the increasing trend for network operators to adopt a variety of infrastructure models. Gruber, Koutroumpis, Mayer & Nocke (2010) have shown a high degree of correlation between the real GDP and the mobile penetration. The contribution of telecommunications to economic growth is not independent of the level of telecommunications development and additionally, studies indicate that the contribution of telecommunications to economic growth is not independent of the level of telecommunications development hence deployment of services through universal infrastructure development is essential (Waverman, Meschi & Fuss, 2005). The mobile boom premised on wireless technology has made one of the biggest differences to the lives of people more quickly than any other previous technology and is thus offering new opportunities as evidenced by entrepreneurship decisions that are linked to a set of economic and socio-demographic characteristics. Therefore, developing countries stand to gain more through better access to telecommunications.

2.6. Infrastructure in the Developing World

Poot, Longhi & Nijkamp (2008) indicates that there is sufficient empirical evidence to indicate a positive and statistically significant relationship between infrastructure investment and long-run economic growth under certain circumstances. However, the direction of causality, and the extent and nature of the contribution, is still largely unsettled. Kingombe (2011) states that according to researchers at the Overseas Development Institute, the lack of infrastructure in many developing countries represents one of the most significant limitations to economic growth and achievement of the Millennium Development Goals (MDGs).

Telecommunication infrastructure is an integral part for continuous growth of industry. Infrastructure investments and maintenance can be very expensive, especially in such areas as landlocked, rural and sparsely populated countries in Africa. Infrastructure investments contributed to more than half of Africa's improved growth performance between 1990 and 2005, and increased investment is necessary to maintain growth and tackle poverty. The returns to investment in infrastructure are very significant, with on average thirty to forty percent returns for telecommunications (ICT) investments, over forty percent for electricity generation, and eighty percent for roads (Hakim, Albert & Shiftan, 2016).

Kinyanjui (2018) states that technology change in telecommunications has increased the costs associated with sophisticated telecommunication infrastructure Governments all over the world are a key institution in the telecommunications industry as they facilitate establishment of institutions that regulate the industry to nurture competition and develop governing policies by positioning telecommunication infrastructure on an autonomous path to sustained growth through policy formulation, implementation and financing.

2.7. The Malawi Telecommunications Sector Development

2.7.1. Background

The Malawi ICT / Communications sector was liberalized through the enactment of the Communications Act in 1998. The Act delinked the postal services from the telecommunications services through the establishment of the Malawi Posts Corporation (MPC) and the Malawi Telecommunications Limited (MTL). Additionally, the Act provided for the establishment of the sector regulator, MACRA. Prior to the liberalization, telecommunication services were purely fixed and were provided by the then Malawi Posts and Telecommunications Corporation (MPTC) that was a government agency charged with the provision of posts and telecommunications since attainment of independence in 1964.

Technology change in mobile telecommunications has generated a lot of interest in the last two decades. The change evolves due to increased innovation by firms as a competitive strategy applied by new entrants. Mobile technological changes are built upon networked technologies and infrastructure. The emergence of mobile technology especially GSM in the early 1990's necessitated a shift of focus to mobile communications in many countries across the globe. In Malawi, TNM was the first GSM operator to provide mobile services in 1995. Thereafter Celtel Malawi (now Airtel Malawi) was launched in 1999 and both operators were duly licensed by MACRA in 2000 after the Communications Act had established MACRA as the sole regulator for the communications sector (Clark, Gebreah Frew & Mgombela, 2003).

Over the years, the enhancement of the legal and regulatory framework has seen the growth of the ICT through many licensed players as well as advanced and value-added services being provided on the market. Southwood (2011) highlights that MACRA embarked on a converged licensing framework to align with global telecommunication trends. By removing the regulatory barriers to entry into the market, MACRA allowed operators to provide fixed and/or mobile services without restriction on the technology used.

2.7.2. Current Telecommunications Sector Status

Clark, Gebreah Frew & Mgombela (2003) indicates that like most African countries, Malawi's ICT indicators have significantly improved in recent years owing to the liberalization of the sector in 1988 which has enabled more players and facilitated competition across the sector. In terms of the telecommunication sector growth, the pace of technology has always overtaken the legal and regulatory framework. Eggers (2018) agree that the assumption that regulations can be crafted slowly and deliberately, and then remain in place, unchanged, for long periods of time, has been upended in today's environment due to sweeping technology advancements.

ITU (2013) indicated that the co-dominance in the mobile telecommunications market between TNM and Airtel is largely due to the limited competition in the sector as well as the lack of a common infrastructure / facilities owners resulting in competition across all levels from infrastructure to services. This eventually has led to the concentration of mobile services in the urban areas with provision of services in the rural areas being negatively affected due to limited telecommunications infrastructure. Although mobile connectivity has extended beyond the reach of the electricity grid as evidenced by GSMA (2012) analysis, the growth of the services in the rural areas is still very slow. Moldkar (2013) analysis of infrastructure deployment as part of the spectrum audit and re-farming project indicates that the spread between urban and rural area telecommunications infrastructure is around 60/40 for the mobile sector (TNM and Airtel deployments).

Such disparity has thus presented a platform for the provision of various services in line with technology growth. However, for areas with limited network access, the benefits which technology brings cannot be enjoyed hence the need to facilitate coverage in all areas to fulfill universal access mandate across the country. The literature on this subject therefore investigates the feasibility of telecommunication infrastructure development as one of the determinants for economic development and attempts to entangle the reverse causality between economic development and the demand for telecommunication services and the impact that lack of such services can have on socio-economic development.

2.7.3. Mobile Communications Service Coverage

Kunenekude area in Neno district is one area whose antagonistic topographical challenges affect the provision of communication services. Limited mobile service coverage is available for areas near Kunenekude that is the focus area for this study. Ligowe area, which is the nearest area to Kunenekude receives partial coverage from three telecommunication transmission sites namely Neno, Neno Turn-Off and Mwanza. However due to the topography of Kunenekude, a telecommunication transmission site at Ligowe cannot still provide the required mobile telecommunication signal coverage to Kunenekude. Figure 2.2 indicates the terrain profile for the area under study.

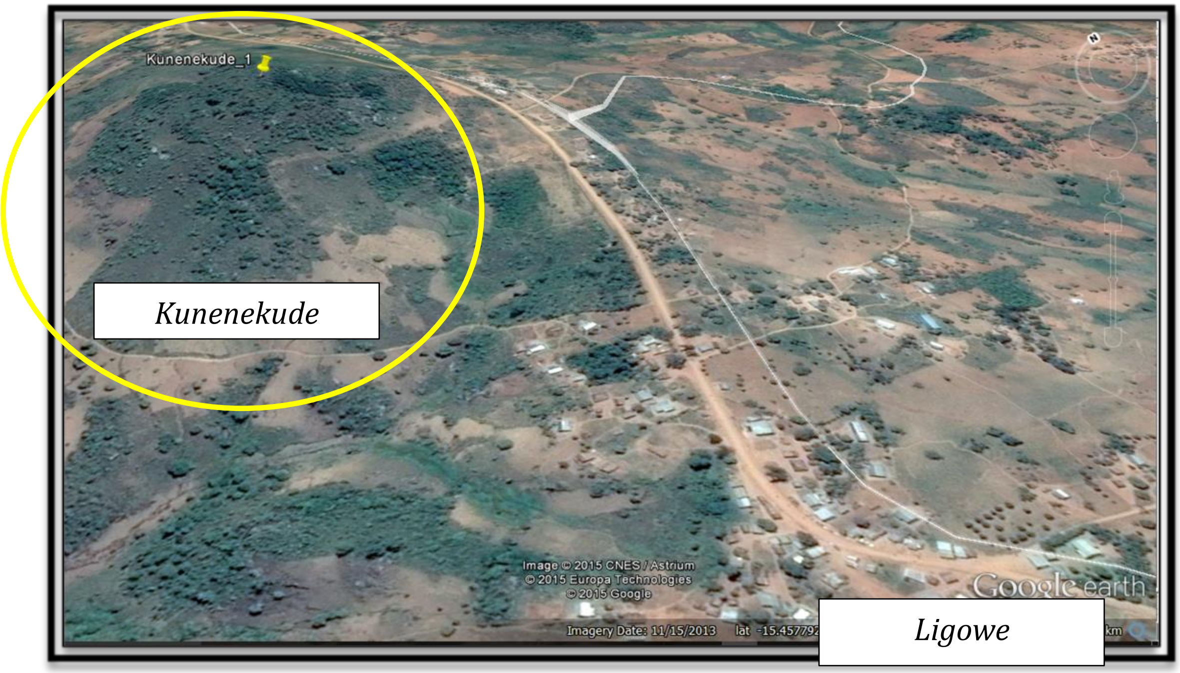


Figure 2.2 Aerial view of Kunenekude topography

The public benefits of mobile communications vary and rely on having infrastructure that offers extensive network coverage not only to urban but also to rural areas. Continued roll-out of infrastructure is therefore essential to support digital networks. When objects stand in the path of the radio waves, there is a resultant signal shadow that consequently affects the quality of the received signal. Terrain geography is identified in several sources as the number one cause of coverage blackspots / not spots and service providers around the globe are always trying to address by optimizing their networks to meet coverage and service quality requirements. In many topography challenged areas, the phenomenon of "mobile not spot / black spot" is experienced resulting in limited or no service coverage. Figure 2.3 shows the effect of not spots on service coverage.

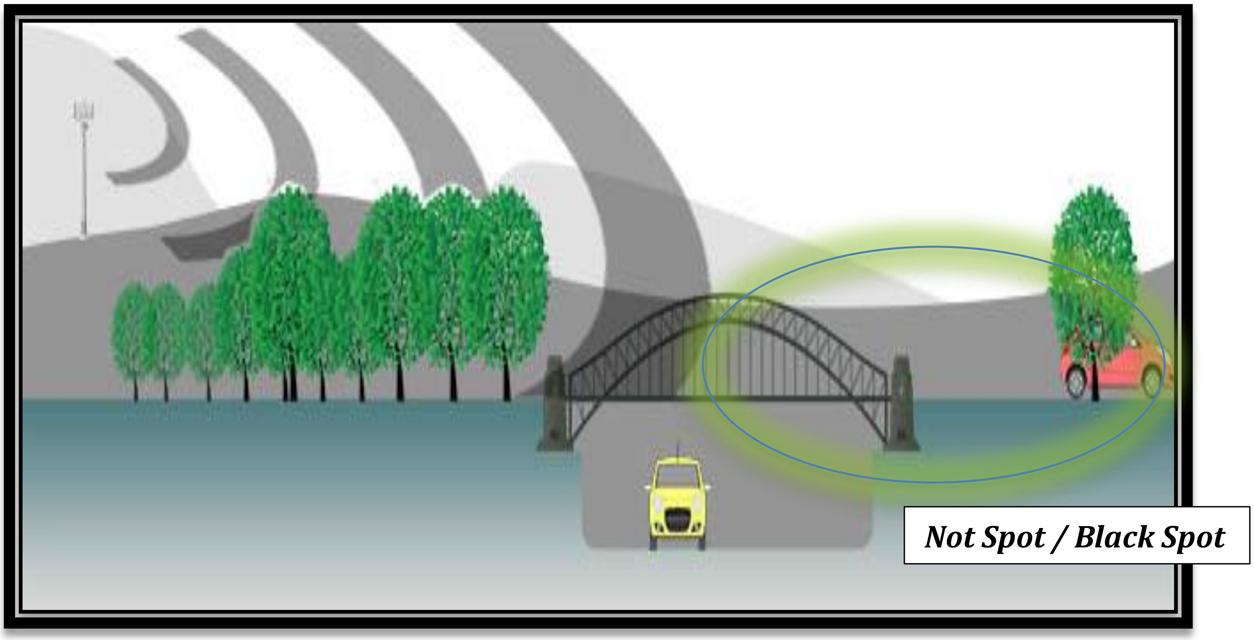


Figure 2.3 Mobile phone not spot / black spot

Kunenekude can be defined as "Not Spot" area since although surrounded by three transmission sites, coverage in the area is limited and non-existent in most parts. The availability of a clear line-of-sight from the nearby sites is of essential value to the development of a new site hence all three neighbouring sites are used as reference points to assess the terrain of Kunenekude in terms of its network coverage challenges. The conceptual framework focuses on the identified variables and explores the relationship between the variables.

Lu, Rohr, Burge & Grant (2015) looked at the impact of no network coverage on different rural population segments and highlighted a number of key findings namely (i) lack of mobile phone signal impacts rural businesses with almost half of those asked saying it had a negative impact on profit, turnover and productivity, (ii) local residents and visitors are willing to pay for better mobile coverage, (iii) people need mobile phones to deal with emergencies and (iv) the availability of mobile services may affect the long term sustainability of rural communities thus mobile coverage could be an important factor in ensuring the diversity of rural economies.

2.8. The Conceptual Framework

Oftentimes, the major complaint from mobile service subscribers is the presence of poor or no mobile signal making it difficult for subscribers to make calls or access data services. The mobile network guide states that a mobile (cellular) phone network is a combination of many cells that join or overlap to form a large coverage area classified as femto, pico, micro and macro cells depending on the cell size. Schwartz, Bennet, Stein (2004) highlight that modern telecommunications systems are designed to separate different transmitted signals on the basis of orthogonality of signals instead of frequency and/or time. The coverage radius of a cell is dependent on several factors i.e. base station transmit power and topography (environment) that are a function of several parameters. In developed areas such as cities, where the level of building obstruction is high and the concentration of subscribers is high, cells are deployed to counter such challenges as well as provide high-capacity service within concentrated points as opposed to rural areas with open spaces and scattered settlement where cell deployment targets more coverage than capacity requirements.

Based on components (parameters) in telecommunications infrastructure and service delivery, and the relationships among components (as associated with telecommunications infrastructure and service delivery), the conceptual framework in Figure 2.4 was generated.

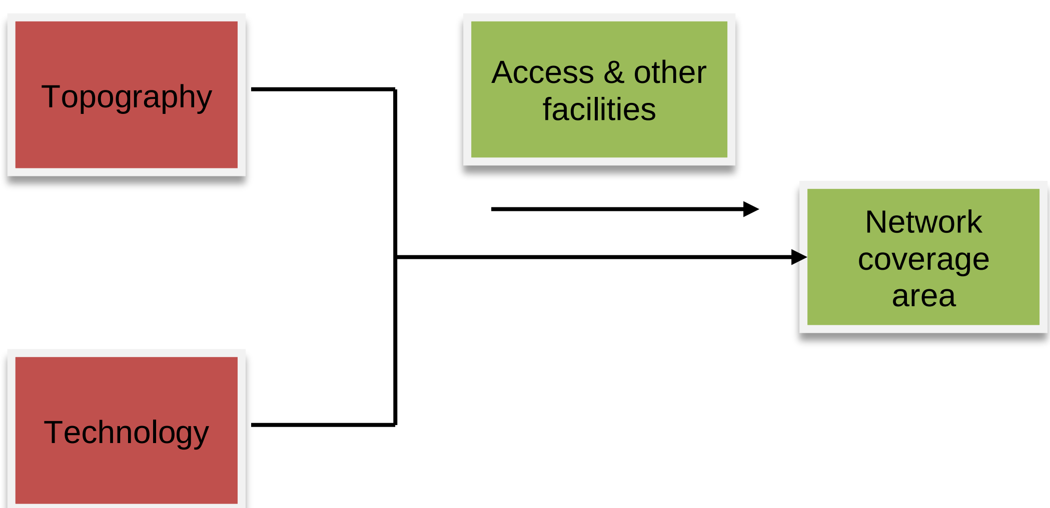


Figure 2.4 Conceptual framework

The interconnection among the components on the relationships of the components presents dependencies of existence. It can be discerned which component or parameter present dependent and independent tendencies. In this study, using several independent variables, the network of relationships among the variables and the dependent variables is established taking cognizance of the key elements for the research. Technology is defined as an independent variable based on the applications that are identified with the technology generations for mobile services while topography is the key determinant independent variable based on the area that is under study and its associated terrain. The intervening variable looks at access and other facilities that impact the planning requirements for service coverage in the identified area that is an aspect of the coverage area that the network eventually provides.

The conceptual framework looks at two independent variables and one moderating variable affecting the overall dependent variable of the concept. The dependent variable (network coverage area) is also a factor of the cell size with respect to the independent variables. The cell size although defined as one perfect cell ideally, is a function of a number of sectors that are planned for coverage. The planned design will thus target a three-sector approach with a theoretical coverage of 120° for each sector to make up a total of 360° for a cell coverage. The planning parameters for the cell are thus ideally identical but coverage might be affected by other factors i.e. terrain where the topography varies within the targeted radius.

However, despite the best efforts to ensure maximum coverage, any mobile network deployment will encounter black spots that are areas that lack mobile signal coverage. Black spots are often the result of the base station not being able to transmit into a particular area due to either technical or environmental effects. Kunenekude which is only about 15 – 25 km away from nearest transmission sites i.e. Mwanza Boma and Neno Turn-Off is predominantly un-served by the nearby sites hence suffering the black spot syndrome necessitating the research into the impact of the terrain on infrastructure development and effective service delivery.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Introduction

This chapter provides a detailed review of the methodology used in the research with respect to study design, sampling methods, data collection and tools used, data profiling and analysis. The chapter further highlights the ethical considerations and limitations considered as part of the study.

3.2. Research Design

The research method was designed based on the research objectives of this study and the developed conceptual framework that is a useful tool in assessing the impact of topography on infrastructure and mobile service delivery. The design provides the structure of the research and is mostly concerned with the cause-and-effect relationship based on the observations or interpretations. Quantitative research examines the cause-and-effect of relationships and is mainly analyzed through the use of statistics and presented in numerical form. The exploratory nature of the research focuses on the relationship between the variables in a cause-and-effect manner with a specific focus on addressing the research objectives and providing solutions to the research questions through by identifying the problem and its impact on the people within the study area.

Utilizing both qualitative and quantitative approaches (mixed method approach), the research considered a number of factors within the framework of the methodology to realize the best possible output in line with the objectives of the research. Creswell (2003) indicates that the mixed method approach tends to allow the researcher to base claims on pragmatic grounds by involving strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand the research problems. The data collected is both numeric (on instruments) as well as text (from interviews) so that the final database represents both quantitative and qualitative information.

Cooper & Schindler (2006) states that quantitative research is mainly deployed where the researcher wants to test a theory, in which the researcher maintains a distance from the research so as not to bias the results. In this research, the quantitative approach was used to determine the magnitude of inaccessibility of the mobile telecommunication signal due to the topography limitations of the study area. The qualitative approach on the other hand was used to verify the quantitative data based on the population feedback in terms of their knowledge of the problem and its impact on the socio-economic development of the area.

3.2.1. Ethical Considerations

Ethical considerations are an important factor in every research process. In undertaking this research, several ethical considerations were made in line with the data collected and respondents interviewed. Ethical considerations are critical as they establish the conduct of the research and determine the difference between acceptable and unacceptable norms. This study was in partial fulfillment for the award of academic certification but because of its practical impact, it has the potential to be expanded for telecommunications policy considerations. However, approval was sought from TNM (mobile operator company) with respect to secondary data and use of TEMS for data collection, Kunenekude community school, Kunenekude hospital as well as the local leaders for the area with respect to some of the respondents to which the questionnaire was administered but also in terms of getting access to the area in collecting terrain data. Key ethical considerations undertaken as part of the study included (i) informed consent and voluntary participation from the respondents to the survey, (ii) anonymity and confidentiality in terms of the respondents and data, and (iii) privacy in terms of the data collection and processing.

3.3. Study Site

Kunenekude is located in Neno district which lies in the southwestern portion of Malawi. The district with a population of approximately 138,291 shares an international border with Mozambique to the west and Ntcheu district to the north; Balaka and Zomba districts to the north-east; Blantyre district to the east; Chikwawa to the south; and Mwanza district to the south-west as shown in Figure 3.1.

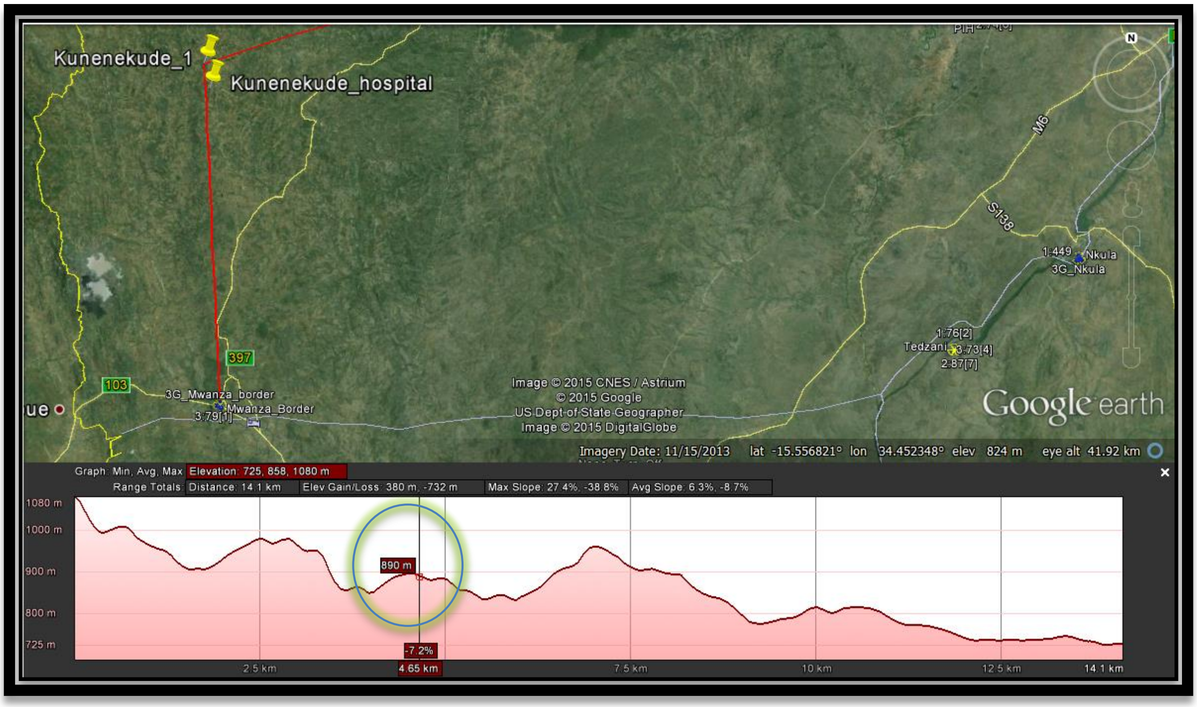
Figure 3.1 Map of Neno in relation to neighbouring Mwanza district

Kunenekude takes its name from the major hill within the area shown in Figure 3.2 and is located 15 Km from Mwanza district and about 25 Km from Neno Turn-Off. The area has got substantial economic activity centred around the key focus areas namely (i) health centre, (ii) market and (iii) school that cover a catchment area of approximately 15,800 people from within the surrounding villages.

Figure 3.2 View of Kunenekude 8 km from earth access road

Figure 3.3: Limited access across the terrain of Kunenekude

Ligowe, which is the nearest area to Kunenekude receives partial coverage from three telecommunication transmission sites namely Neno Boma, Neno Turn-Off and Mwanza Border. However due to the hilly topography of Kunenekude as shown in Figure 3.4, a telecommunication transmission site at Ligowe can still not provide the required mobile signal coverage to Kunenekude hence the need to assess other alternative coverage options. Large coverage areas translate to greater service requirements and an enhanced transmission network requiring infrastructure deployment over such large coverage requirements.



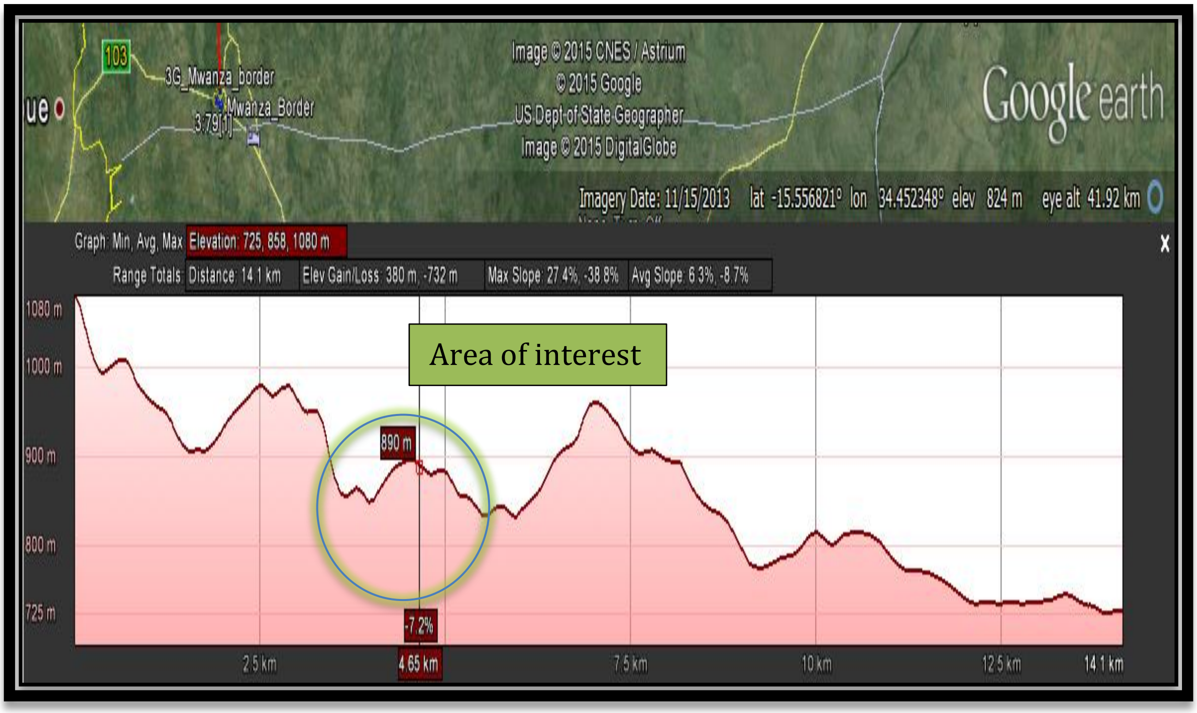


Figure 3.4 Location of Kunenekude in terrain relief

3.4. Study Population

Cooper, & Schindler (2006) define a study population as the total collection of elements about which we wish to make some inferences. MACRA (2015) indicates that although mobile signal coverage in Malawi is in excess of 85%, the actual penetration for mobile services stands at almost 45%. Out of this 45%, most of the users live in the urban areas where there is ready access to mobile telecommunication services as opposed to only 30% that live in rural areas some of which are hard to reach and barely receive the mobile signal such as Kunenekude.

The study drew participants within the age range 16 – 50 from various sectors of the society within the catchment area purposefully drawn based on Kunenekude key activity points that include a health centre, produce market and primary school that provide focus areas in the economic life of the area. Economic activity for the area is mainly dependent on agriculture within the catchment area. For this study, the sampling frame considers both the people that live within the area as well those that live outside the focus area but are only available during the day due to the activities at the three key points i.e. hospital, school and market. The study took cognizance of the linkage between the growth of mobile services and economic benefits to establish the impact that antagonistic topography poses to telecommunications infrastructure development. The target population consists of potential subscribers with the ability to utilize the service once coverage and access is available within the area.

3.5. Sampling Methodology

Sampling is a process of selecting a predetermined number of elements from the population on which the study will be conducted. Although sampling is a complicated process, it plays a very vital role in facilitating any study. In an ideal set-up, a target population is the same as the sample frame. However, for this study, the sample frame points to specific individuals within the target population from where the sample can be drawn. The size of the sample is thus dependent on a number of factors i.e. confidence level, standard deviation, margin of error and population size. These factors need to be considered before the sample size can be determined. Roscoe (1975) proposes a rule of thumb for a sample size range although it is widely accepted that a sample size should not be less than 30% of the target population.

With a mobile penetration of 30% in the rural areas (MACRA, 2015), a sample frame of 30% of the target population (within the catchment area) will translate to 4740 people i.e. (30*15800/100). This allows the frame to encompass people that have used a mobile phone before to address the impact of terrain on infrastructure development and the challenges encountered in the area due to the non-availability of mobile signal coverage.

3.5.1. Sampling Method

The study used the purposive sampling utilizing the theory / concept approach where the identified site and the respondents will help to generate specific concepts within the theory to help test the hypothesis. The use of purposive sampling provides a framework for the research to the targeted sample easily since the unique characteristics that are required for this research are defined within the sample thus facilitating a wide range of designs that the research can draw upon. Although researcher bias is always a possibility, purposive sampling allows the inclusion of typical areas of focus in a study thereby providing the most productive sample facilitating results that can be more representative of the population. Israel (1992) states that a sample size for a study can be calculated using the population statistical formula for determining a representative sample using the formula below.

$$n = \frac{pqZ^2}{e^2}$$

Where:

- n = minimum desired sample size.
- Z = the standard normal deviation set at 1.96 corresponding to 95% confidence level.
- p = the proportion of targeted population estimated to have particular characteristics = 30% mobile subs in rural areas.
- q = the proportion of the remaining population calculated by subtracting p i.e. (1-p) = (100% - 30%) = 1 - 0.3 = 0.7
- e = minimum error = 0.005 + 0.70 = 0.075

In this regard, the sample size was calculated based on the details below.

$$n = (1.96^2 \times 0.3 \times 0.7) / 0.075^2$$

$$= 0.806736 / 0.005625$$

$$= 143.419733 = \mathbf{143}$$

In calculating the sample size for the study, simple random sampling was used for the respondents within the sampling frame. Using descriptive statistics, the sample size formula provided the required minimum number of responses considering the expected number of no responses. The calculation further considered the sampling error, confidence level as well as the degree of variability with respect to the distribution of respondents within the sampling frame. Based on the calculated sample size, a total of 143 participants were identified within the sampling frame.

3.6. Data Collection

Data collection for the research data included (i) technical data, (ii) administered questionnaires, and (iii) planning data from document reviews in research questions in the study. Accurate data leads to achievement of research goals while inaccurate data impacts the whole research process and invalidates the results.

3.6.1. Questionnaire

A semi-structured questionnaire was administered through focal points to all individuals that consented to participate in the study (refer to Appendix 1). The structured part collected participants' demographic data while the open-ended part captured qualitative data. Additionally, some questionnaires were sent to various institutional offices that operate within the study area.

Based on the calculated sample size, a total of 90 questionnaires were directly administered while the remaining 53 were sent through to selected institutions. Direct administration of the questionnaires was successful as all the targeted participants on the days that the area was visited were able to respond to the questions having been taken through a briefing process before questionnaire was administered. However, for the questionnaires that were sent directly to selected institutions, only a response rate of 30% was achieved and this was mainly attributed to non-availability of designated personnel that could officially respond to the questionnaires on behalf of the institutions within the time frame that was given for data collection. Although there were several requests for increased time to facilitate completion of the questionnaires by several institutions, the request could not be granted beyond the allocated time as access to the area is very difficult and the researcher had already undertaken the planned trips for technical data collection.

3.6.2. Technical Data

Technical data was collected using the TEMS Professional Discovery Equipment and radio frequency (RF) analyzer providing terrain profiling for Kunenekude in relation to other transmission sites as well the coverage gaps in relation to the strength of the mobile signal around the study area. TEMS is a basic tool used by telecommunication service providers to measure, analyze and optimize mobile networks. It facilitates network drive tests, benchmarking, monitoring and analysis that are very essential operations in the planning process for any mobile network.

The use of both technical data and primary data from questionnaire responses facilitates enhanced analysis for both the challenges of terrain on infrastructure development as well as the impact that unavailability of mobile service has on the public and the economic development of the area. The correlation between the two aspects provides an added assessment dimension for alternative options in terms of mobile signal coverage. Secondary data was also used especially with respect to the planning surveys done for the development of sites in Neno, Neno Turn-Off and Mwanza.

3.6.3. Theoretical Coverage and Planning Data

The performance of a GSM network is basically described in terms of accessibility and coverage among others. In terms of network planning, a field assessment of the area under study was done using TEMS that assesses the coverage deficiency. Apart from the planning data and terrain profile analysis, RF analysis was done from the targeted central site around the hospital to all three nearby sites i.e. Neno, Neno Turn-Off and Mwanza in order to establish a transmission path profile and a possible line-of-sight that would be used to provide a link to the identified site within the study area.

TEMS works on the principle of verifying the presence of a radio-frequency signal (RF) in a particular area. This is done by measuring the strength / level of the mobile signal detected within the focus area. TEMS software installed within a laptop as per Figure 3.5, interprets the received signal strength and plots the signal pattern which is compared with recommended minimum levels to determine the presence / absence of coverage in an area. Through the recommended drive tests, the impact of terrain in any area is thus assessed based on the findings of the system through the drive routes within the area of focus.

Figure 3.5 TEMS professional discovery equipment

3.7. Data Analysis

Data analysis involves structuring information to reveal the relationship between various factors to show patterns and trends of the obtained results. The collected data was analyzed and displayed through several key aspects namely;

(i) Terrain profile for Kunenekude in relation to all neighbouring transmission sites.

(ii) Level of coverage for the area before and after assessment based on the drive tests.

(iii) Relationship between mobile coverage and socio-economic impact on the population within the study area.

Data analysis was undertaken simultaneously with data collection in order to reduce the level of errors and observational notes were duly incorporated as part of the data analysis. Quantitative data was analyzed using statistical packages to portray the graphical relational data and test the hypothesis. On the other hand, qualitative data was organized and analyzed manually through the comparative analysis approach.

The analysis allowed comparison of changes between variables as well as identifying the level of relationship between variables. The analyzed data further provides credible evidence for both the social and technical aspects of the research. Descriptive data analysis was used to identify the representation and the statistical significance of variable relationship was ascertained based on the identified significance and confidence levels.

CHAPTER 4

RESULTS AND FINDINGS

4.1. Introduction

This chapter presents the results and findings of the study based on the research in relation to the developed hypothesis exploring the relationship between topography and communication services as well as its impact on socio-economic development of the area.

4.2. Topography

Topography is an independent variable that has an impact on the service coverage. Technical analysis of the area under study assessed the presence of a mobile signal from three coverage sites namely Neno Boma, Mwanza Border and Neno Turn-off. The three identified sites are within a radius of 25 km from central Kunenekude. Using TEMS, the coverage is simulated through drive tests around the study area. For an area to get mobile service coverage, a transmission link extending connectivity from an existing transmission site is required so as to provide the necessary service coverage to a designated transmission site within the area under study.

4.2.1. Neno Boma

Neno Boma has a straight line of sight (LOS) distance of 18.4 Km from central Kunenekude and the path profile of the two points indicates a terrain profile that does not provide a direct line of sight between the two points. The highest point of elevation along the path provided a barrier at 3.68 Km from Kunenekude thereby rendering usage of the site at Neno Boma not feasible for extending the transmission link to provide mobile telecommunication services to Kunenekude. The path profile for Kunenekude - Neno Boma site is provided in Figure 4.1.

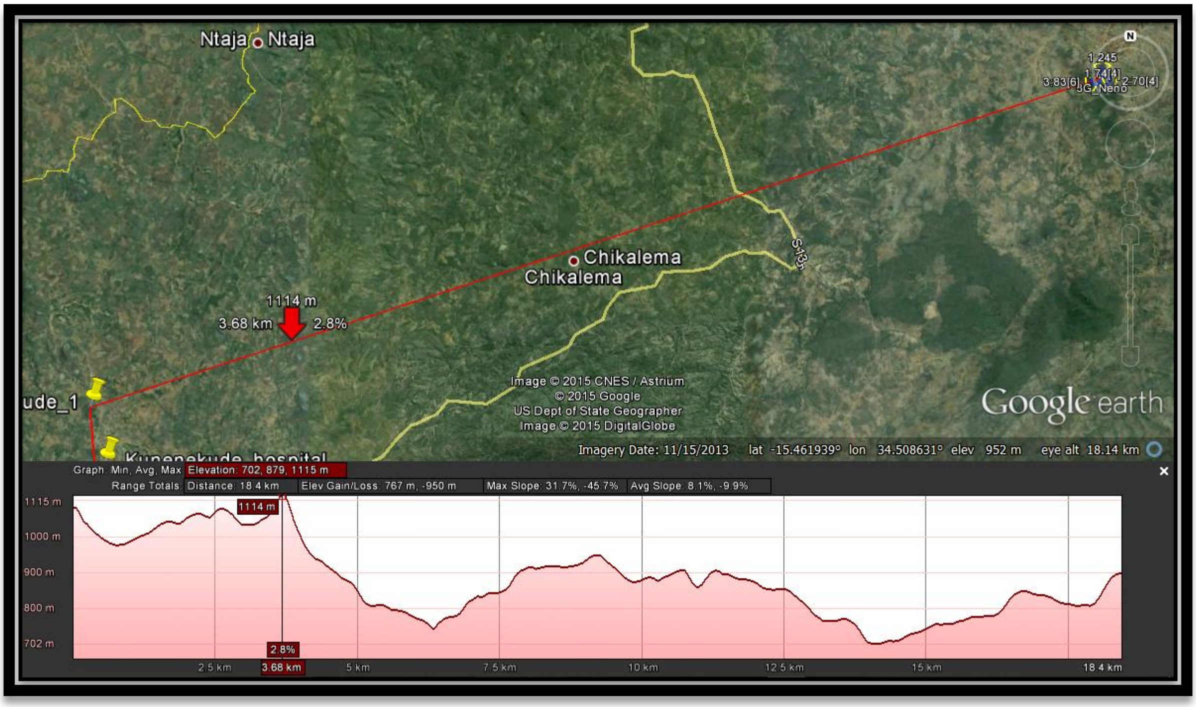


Figure 4.1 Neno Boma – Kunenekude path profile

4.2.2. Mwanza Border

Mwanza Border has a straight line of sight distance of 14.1 Km from central Kunenekude and the path profile of the two points indicates a terrain profile that does not provide a direct line of sight between the two points. Several high points of elevation along the path provided barriers to Kunenekude thereby rendering usage of the site at Mwanza border not feasible for extending the transmission link to provide mobile telecommunication services to Kunenekude. The path profile for Kunenekude - Mwanza Border site is provided in Figure 4.2.

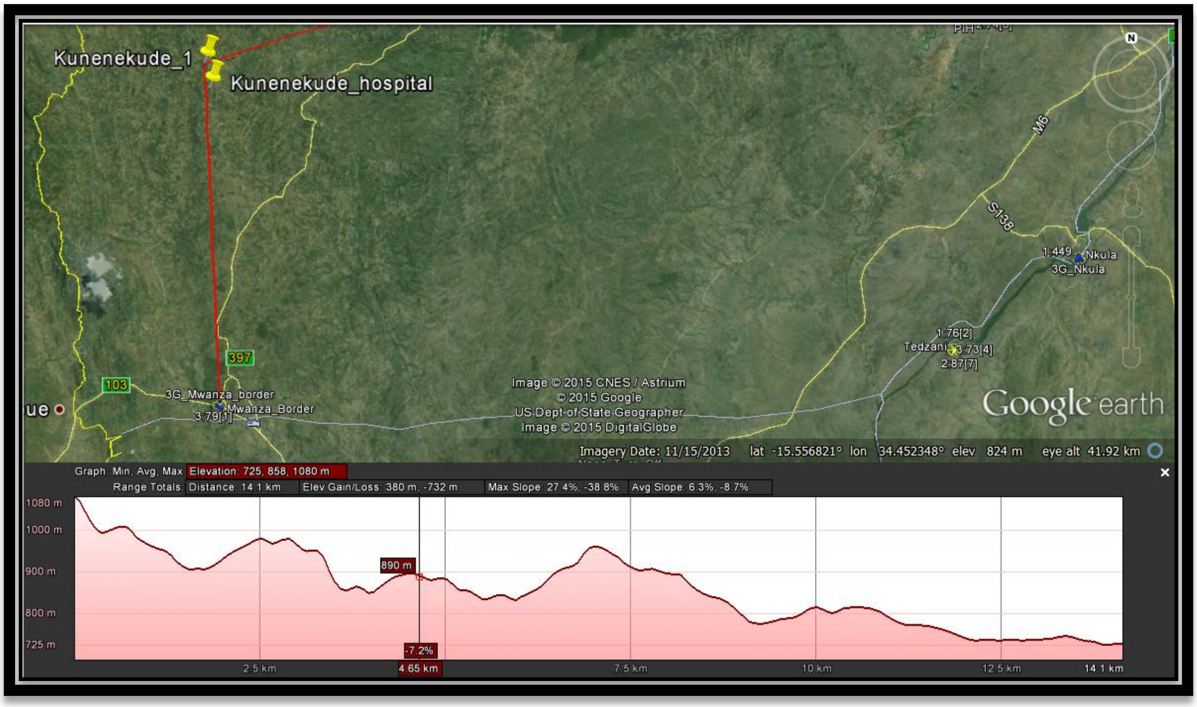


Figure 4.2 Mwanza Border – Kunenekude path profile

4.2.3. Neno Turn-Off

Neno Turn-Off has a straight line of sight distance of 24.1 Km from central Kunenekude and the path profile of the two points indicates a terrain profile that provides a direct line of sight between the two points. The availability of a direct line of sight between the two points therefore facilitates the feasibility of extending the transmission link to provide mobile telecommunication services to Kunenekude area.

The path profile with a direct line of sight allows the site at Kunenekude to be used for the provision of mobile telecommunication services within the study area. However, the availability of a direct line of sight on its own does not guarantee service coverage for an area hence the need for mobile signal coverage analysis to determine the extent of possible coverage with respect to the topography of the area. The path profile for Kunenekude - Neno Turn-Off site is provided in Figure 4.3.

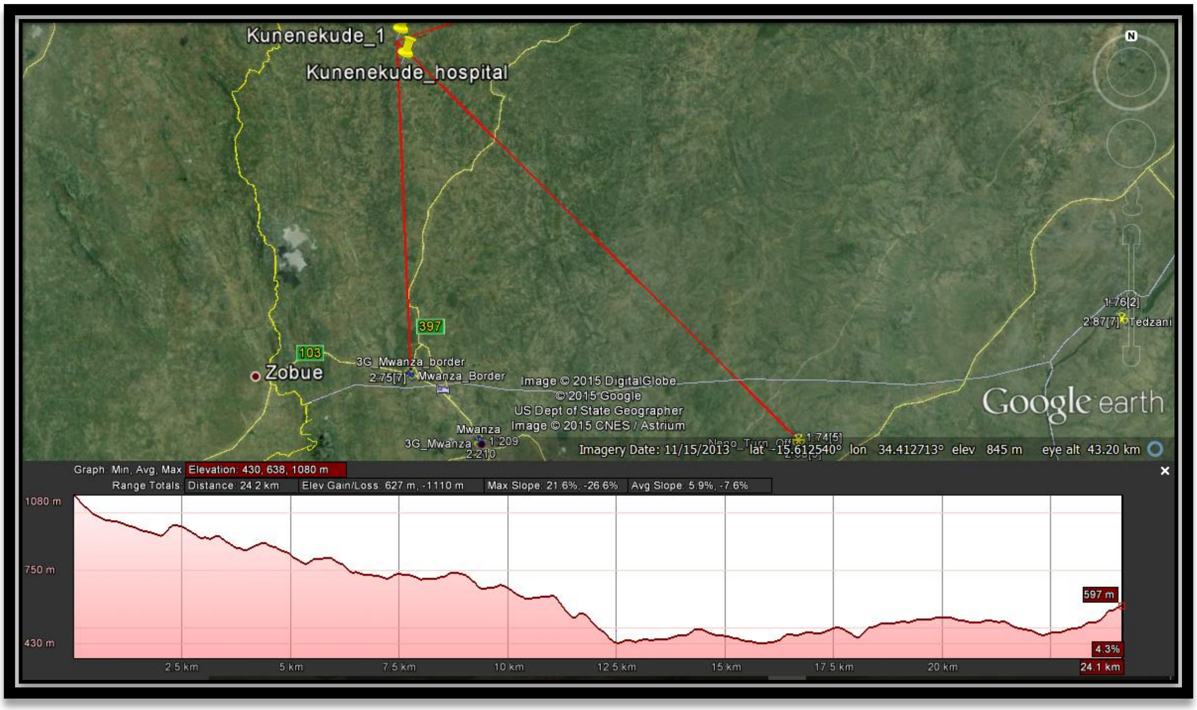


Figure 4.3 Neno Turn-Off – Kunenekude path profile

4.3. Technology

Technology is another independent variable that has an impact on the overall mobile service coverage for an area. Mobile technology has evolved from the initial first generation (1G) technology to the current fifth generation (5G) technology that is being trialed and implemented in several developed countries. Deployment of GSM falls within the 2G technology generation which provides basic mobile communication services i.e. voice, text and limited data services. The TEMS assessment for Kunenekude provided the strength of mobile signal received in and around the area which provides a framework for the analysis of which services can be sustained in relation to the technical requirements for GSM service. The technical requirements for each service are a factor of the technology in use hence higher generation technologies require better signal strength to support advanced services. The GSM coverage pattern and required reception parameters obtained for Kunenekude are provided in Figure 4.4.

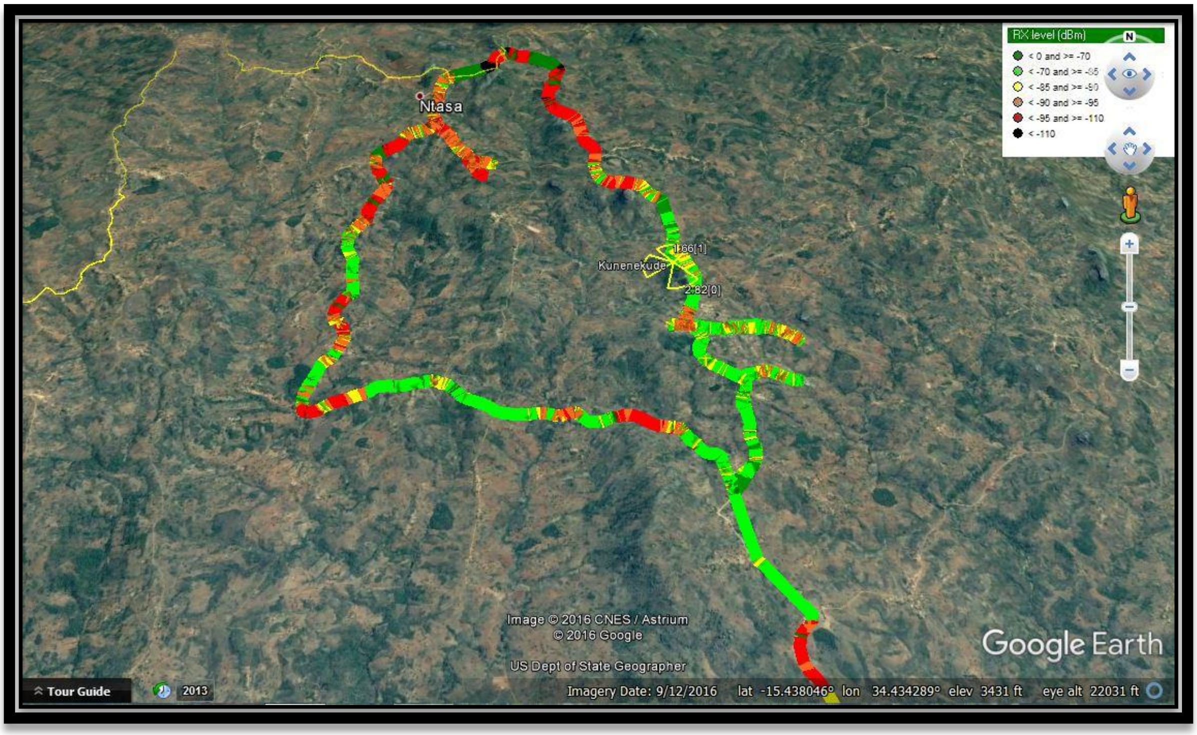


Figure 4.4 Kunenekude predicted coverage profile

The drive tests done for Kunenekude as per the predicted coverage profile also provided data for the link budget analysis that gives the full account of all gains and losses from the transmitter (TX) through the medium (free space) to the receiver (RX) in a wireless communication system. Ibrahim, Alsharekh, Almanee, Alturki & Islam (2019) states that in any wireless transmission, there are continuously losses occurring from various sources during the transmission. When planning a communication for long distance to a remote two points, one of the key considerations is to have a successful link requirement so that the signal delivered to the receiver should be obtained a minimum level of performance in line with minimum GSM requirements.

Link budget analysis accounts for all the gains and losses from the transmitter (TX) through the medium (free space) to the receiver (RX) in a wireless communication system. Link budget considers the parameters that decide the signal strength reaching the receiver. The factors such as antenna gain levels, radio TX power levels and receiver sensitivity figures must be determined to analyze and estimate the link budget.

Table 4.1 GSM signal level requirements

Signal Level (dBm)	Indicator	Status	Remark
< 0 and ≥ -70	*Deep Green*	*Excellent*	*All services available*
≤ -70 and ≥ -85	*Light Green*	*Very Good*	*Can sustain all services*
≤ -85 and ≥ -90	*Yellow*	*Good*	*Sustainable (data-based services might be slow)*
≤ -90 and ≥ 95	*Orange*	*Fair*	*Break-up and intermittent voice / hardly any data available*
≤ -95 and ≥110	*Red*	*Poor*	*Dropped calls / no data services*
≤ 110	*Black*	*Very poor*	*No services available*

4.4. Access and other Facilities

Based on the conceptual framework, access and other facilities is an intervening variable that impacts the delivery of mobile communication services. The ease of access to an area is very crucial to the provision of services especially in rural areas as most of the sites are off the commercial power grid and are run on alternative power sources i.e. generators that need constant re-fueling to keep the sites up and running. Good access especially in terms of road network is one critical aspect in infrastructure development as it plays a key role in providing linkage between the services and the population. Kunenekude topography not only affects the location of communication service infrastructure to serve the area but also limits the settlement pattern as most people end up located in the periphery of ideal sites suitable for accessing communication services. Kunenekude is particularly challenging in terms of access especially for vintage sites ideal for deployment of transmission towers required for coverage of the area. Figure 4.5 shows the limited access to vantage transmission sites for coverage of the area.

Figure 4.5 Kunenekude vantage points

The settlement pattern for the area is another factor that impacts service delivery as coverage must be targeted where the population is so as to maximize the benefits from the service. Mobile service benefits are assessed based on the average revenue per user (ARPU) that can be realized when the network is deployed in an area. For a place with sparsely populated population located outside or on the fringes of the coverage, the ARPU cannot compensate for the cost of running the network hence planning experts will not favour deployment of services to such places.

The assessment of respondent's views considered five key factors namely (i) duration of stay for respondents, (ii) distance of respondents from Kunenekude central, (iii) critical factors affecting the delivery of mobile communication services, (iv) value added services obtained from mobile communication services, and (v) distance of respondents from vantage transmission points. The assessment of the five parameters presented in Table 4.2 to Table 4.6 facilitated linkage of the findings to the key technology-based parameters.

#	Duration of Stay in Kunenekude	Number of Respondents	Percentage (%)
1	*0 – 5 Years*	*35*	*30 %*
2	*5 – 10 Years*	*29*	*25 %*
3	*10 – 20 Years*	*21*	*18 %*
4	*> 20 Years*	*9*	*8 %*
5	*Visiting Respondents*[1]	*22*	*19 %*
TOTAL		***116***	***100 %***

Table 4.2 – Duration of stay in Kunenekude

#	Distance from Kunenekude Centre	Number of Respondents	Percentage (%)
1	*0 – 1 km*	*33*	*28 %*
2	*1 – 5 Km*	*42*	*36 %*
3	*5 – 10 Km*	*16*	*14 %*
4	*10 – 20 Km*	*8*	*7 %*
5	*> 20 Km*	*3*	*3 %*
6	*Visiting Respondents*[2]	*14*	*12 %*
TOTAL		***116***	***100 %***

Table 4.3 – Distance from Kunenekude centre

[1] Visiting respondents comprised of people that do not live in the area of study

[2] Visiting respondents comprised of field workers who were met in the area during data collection.

#	Critical Service Provision Factors	Number of Respondents	Percentage (%)
1	*Hilly topography*	*61*	*53 %*
2	*Lack of supporting infrastructure*	*25*	*22 %*
3	*Inadequate economic activity*	*18*	*15 %*
4	*High illiteracy rate*	*12*	*10 %*
TOTAL		***116***	***100 %***

Table 4.4 – Critical service provision factors

#	Value Added Services (VAS) Usage	Number of Respondents	Percentage (%)
1	*Mobile money services*	*55*	*47 %*
2	*Internet / data services*	*43*	*37 %*
3	*Utility services*	*11*	*10 %*
4	*Market information*	*4*	*3 %*
5	*Travel information*	*2*	*2 %*
6	*Others*[3]	*1*	*1 %*
TOTAL		***116***	***100 %***

Table 4.5 – Value added services (VAS) usage

[3] Included health information and other information tips

#	Distance from Vantage Transmission Points	Number of Respondents	Percentage (%)
1	*0 – 5 Km*	*12*	*10 %*
2	*5 – 10 Km*	*18*	*16 %*
3	*10 – 20 Km*	*52*	*45 %*
4	*20 – 30 Km*	*20*	*17 %*
5	*> 30 Km*	*14*	*12 %*
TOTAL		***116***	***100 %***

Table 4.6 – Distance from vantage transmission points

The settlement pattern of Kunenekude impacts the delivery of service as the cells required to provide coverage are designed to align with the settlement pattern. Due to the scattered settlement pattern, only macro cells with a maximum coverage radius of up to 30 km are therefore ideal for areas with the terrain challenges encountered in Kunenekude. The settlement pattern for the area is also ascertained from the respondents of the questionnaire which shows that about 78.4% of population is within a 10 km radius of the central area for Kunenekude. However, the location of the transmission site in relation to the settlement pattern is key to effective coverage of the area.

4.5. Network Coverage Area

The dependent variable in the conceptual framework is the network coverage area that is influenced by the independent and intervening variables. The coverage area is a result of the defined cell size that is a factor of coverage sectors based on the planning parameters. While the planning parameters for the cell are ideally similar, the coverage for the sectors is affected by other factors i.e. terrain where the topography varies within the targeted radius. The drive test coverage analysis along the key economic points of the area under study provided all options for signal coverage based on the prediction profile as simulated by the TEMS analytical tool. The coverage pattern provides further assessment with respect to the impact of topography on mobile service provision from a technical perspective. Topography of the area also manifests a long-standing challenge arising from thinly distributed population. Cramer, B.W. (2019) highlights that, inhabited towns in topography challenged areas are often in steep river valleys in which the rugged landscape blocks line-of-sight propagation of mobile signals, while that same landscape also thwarts transportation to areas that could be utilized for strategically placed antennas. Higher elevation areas which are not habited are the ones that receive coverage from network towers at similar elevations a considerable distance away as evidenced by the partial coverage from the three neighbouring sites surrounding Kunenekude.

Kunenekude which is 25 km away from the three transmission sites namely Mwanza Border, Neno Boma and Neno Turn-Off receives limited / partial coverage which is a result of the impact of the identified independent and intervening variables. The topography of Kunenekude presents many black spots / not spots as evidenced by the satellite coverage pattern in Figure 4.6.

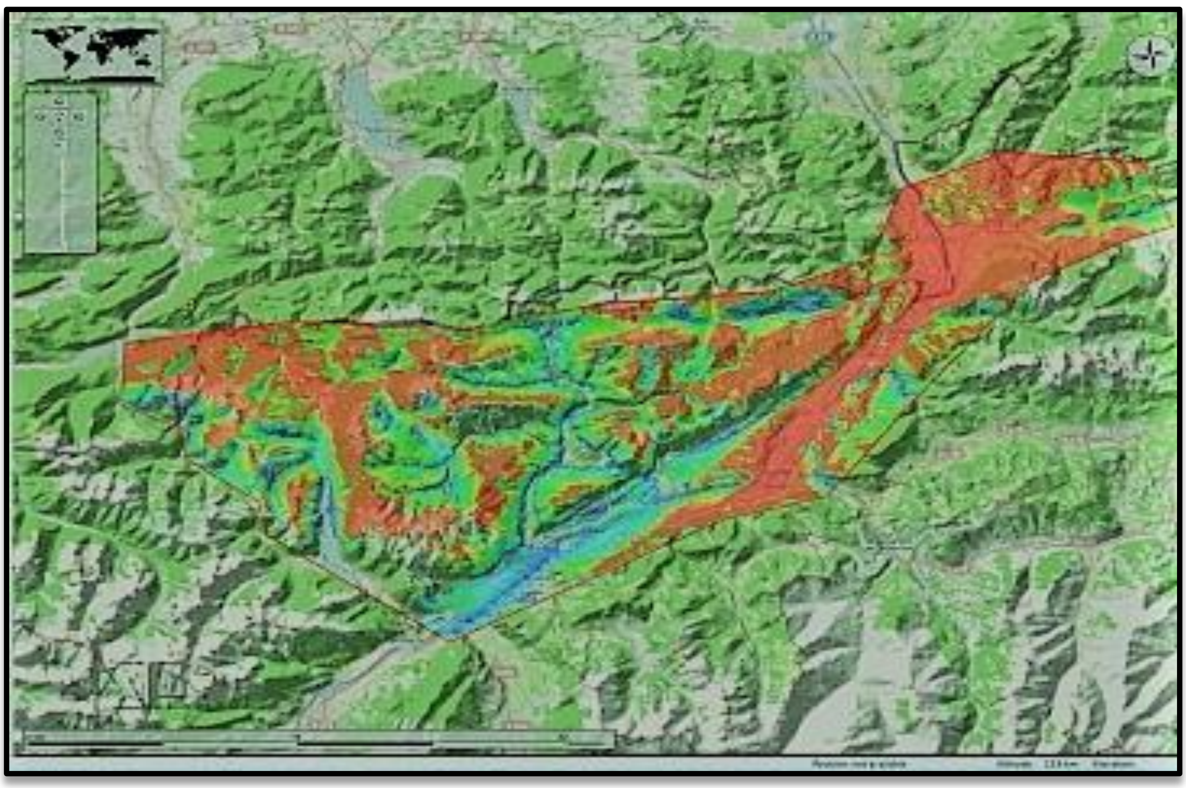


Figure 4.6 Kunenekude satellite coverage pattern

CHAPTER 5

DISCUSSIONS

5.1. Introduction

This chapter outlines the discussions based on the research findings from the study. The objectives and hypothesis of the research forms the basis of the interpretation of the study assessing the impact of topography on mobile communication service delivery and linking mobile communications infrastructure deployment to socio-economic development.

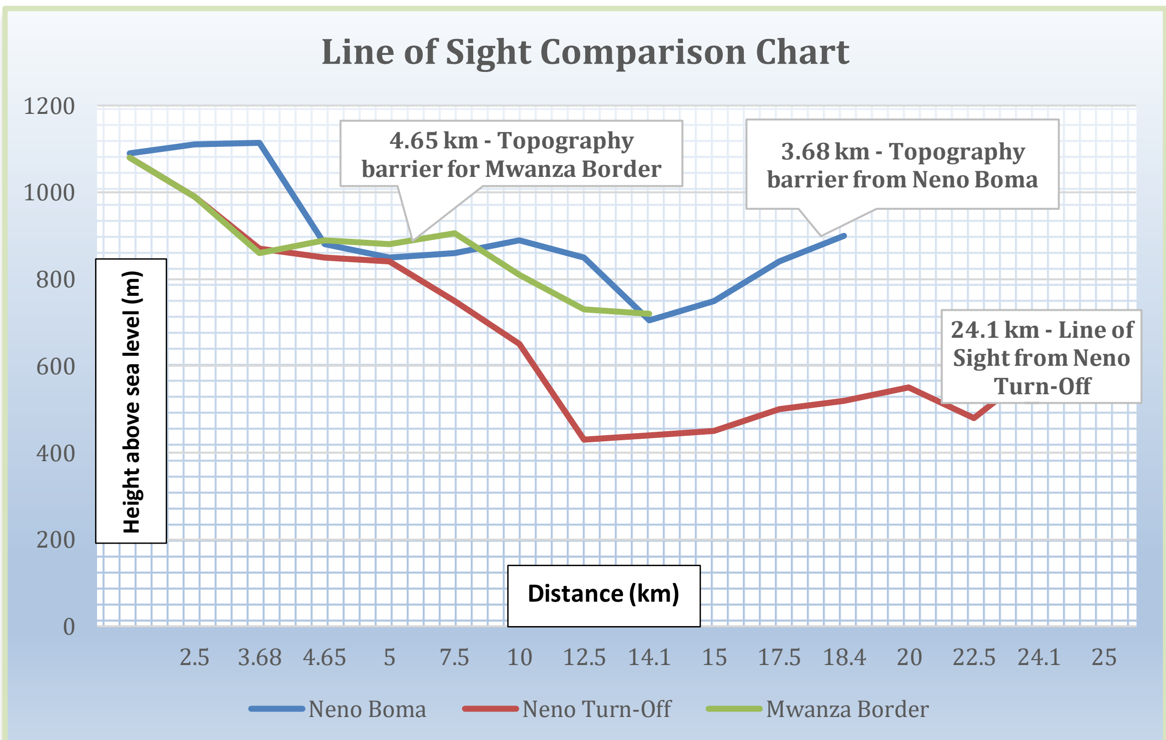
5.2. Topography Impact on Mobile Service Coverage

Topography has been identified as the number one cause of coverage blackspots / not spots in mobile communications networks and service providers around the globe are always trying to address this challenge by optimizing their networks to meet coverage and service quality requirements. When objects stand in the path of the radio waves, there is a resultant signal shadow that consequently affects the quality of the received signal. In many topography challenged areas, this phenomenon results in limited or no service coverage. The impact of topography on mobile service coverage was reviewed and assessed in order to facilitate alternative options that are available for areas with such challenges as Kunenekude.

5.2.1. Network Planning and Design

Aguiar, Pinheiro, Neto, Cunha, & Pinheiro (2009) states that network design usually starts at the cell planning stage. While network planning looks at several factors, coverage is a key determinant for the overall planning process. Network planning is a process that consists of several activities whose final target is to define an optimal cost-effective network design, which is then built as a mobile cellular network. One of the basic requirements for cellular network planning process is the coverage, which is related to how the end-user experiences the mobile services in a specific geographic area (Huerta-Barrientos & Elizondo-Cortés, 2013). When coverage is the ultimate goal, network engineers look for sites with high altitudes and free of obstacles to reach larger coverage distances. The extension of mobile communication services to Kunenekude required linkage with other existing sites in the GSM network. However, the topography of Kunenekude only provided one access option (Neno Turn-Off) that could facilitate linkage to the GSM network to allow mobile service coverage to Kunenekude. A line-of-sight distance of 24.1 Km is available from Neno Turn-

Off which although providing the required link, is the longest as compared to Neno (14.1 Km) and Mwanza Border (18.4 Km). The longer LOS although providing coverage extension to Kunenekude is not a guarantee that coverage will be feasible as a corresponding vantage point has to be identified for Kunenekude from where coverage for the area can be assessed. Graph 5.1 shows the analysis of line of sight (LOS) from the three nearby sites to Kunenekude comparing the terrain profile and feasibility of extending coverage to the area under study. The availability of a line of site was the first stage of assessment before identification of a vantage transmission site for coverage with respect to the population that require the mobile service coverage.



Graph 5.1 Line of sight (LOS) comparison

Following the identification of a line-of-sight between Neno Turn Off and Kunenekude, a link budget assessment was done for the link in order to ascertain the level of received signal at the identified vantage site in Kunenekude. Key considerations for the budget include the information capacity and rate of error to calculate the signal strength required to not only reach the receiver, but to also reach with some level of high power or margin of loss, considering for the unexpected propagation impairments. Once the transmitter activates with the power capacity consists of the system gains and internal losses to determine the level of actual predicted power at the receiver. In order to ensure a consistent link between the transmitter and the receiver, the level of power delivered to the receiver should be obtained a minimum level of performance that required as per the final link budget shown in Table 5.1.

Parameter	Kunenekude	Neno Turn Off
Latitude	15 27 20.88 S	15 36 29.30 S
Longitude	034 29 21.75 E	034 38 55.00 E
Easting (m)	659790.2	676748.2
Northing (m)	8290705.9	8273725.0
UTM zone	36S	36S
True azimuth (°)	134.64	314.60
Vertical angle (°)	-1.20	1.04
Elevation (m)	1086.05	601.01
Antenna model	A11S12HD (TR)	A11S12HD (TR)
Antenna file name	a11s12hd	a11s12hd
Antenna gain (dBi)	40.40	40.40
Antenna diameter (m)	1.20	1.20
Antenna height (m)	30.00	45.00
Frequency (MHz)	11086.00	
Polarization	Vertical	
Path length (km)	24.01	
Free space loss (dB)	140.97	
Atmospheric absorption loss (dB)	0.37	
Net path loss (dB)	60.54	60.54
Radio model	11G_XMC2_256Q_56M_363M	11G_XMC2_256Q_56M_363M
Radio file name	11gxmc2256q56mx	11gxmc2256q56mx
TX power (dBm)	26.00	26.00
Emission designator	56M0D7W	56M0D7W
EIRP (dBm)	66.40	66.40
TX channel assignments	10821.00V	11351.00V
RX threshold criteria	1E-6 BER	1E-6 BER
RX threshold level (dBm)	-64.50	-64.50
Receive signal (dBm)	-34.54	-34.54
Thermal fade margin (dB)	29.96	29.96
Dispersive fade margin (dB)	43.37	43.37
Dispersive fade occurrence factor	1.00	
Effective fade margin (dB)	29.96	29.96
Climatic factor	1.50	

Parameter	Kunenekude	Neno Turn Off
Terrain roughness (m)	42.67	
C factor	0.39	
Average annual temperature (°C)	10.00	
Fade occurrence factor (Po)	3.619E-002	
Worst month multipath availability (%)	99.99586	99.99586
Worst month multipath unavailability (sec)	108.80	108.80
Annual multipath availability (%)	99.99896	99.99896
Annual multipath unavailability (sec)	326.40	326.40
Annual 2 way multipath availability (%)	99.99793	
Annual 2 way multipath unavailability (sec)	652.81	
Polarization	Vertical	

Table 5.1 Neno Turn Off – Kunenekude Link Budget

The link budget analysis in Table 5.1 provided a receive signal -34.54 dBm which is within the acceptable GSM range to provide the service within an area. However as indicated, the vantage point on its own does not guarantee population coverage as the aim is to provide coverage to the people within their locality. Kunenekude is therefore impacted because people are located in low lying areas which are impacted by the terrain thereby not getting the signal from the vantage points which are on high altitude. The analysis of the signal strength in surrounding areas is provided in Figure 4.4 which outlines the level of reception around the area based on the drive test that was conducted. Additionally, Figure 5.2 further provides the simulated coverage profile within the area which shows that from the identified vantage point, a good portion of the area still lies outside the effective coverage zone. To counter this challenge, additional transmission points in low lying areas closer to the settlement areas will have to be identified as long as there is a line-of-sight to extend coverage and serve the remaining areas within Kunenekude.

5.2.2. Settlement Patterns

Huerta-Barrientos & Elizondo-Cortés (2013) highlights that the target for the coverage planning process is to find the optimal geographical locations for radio frequency antennas and determine the number of these in order to build a continuous coverage between them. Theoretically, the model of mobile cellular networks is developed by hexagons (cells) where each hexagon represents the ideal coverage of a tri-sector antenna. However, the model can also be formed by circles (cells) where each circle represents the ideal coverage of an omni-directional antenna depending on the size of the geographical area to be covered. Cells are classified as macro, micro, or pico cells based on the coverage requirements and size as shown in Figure 5.1.

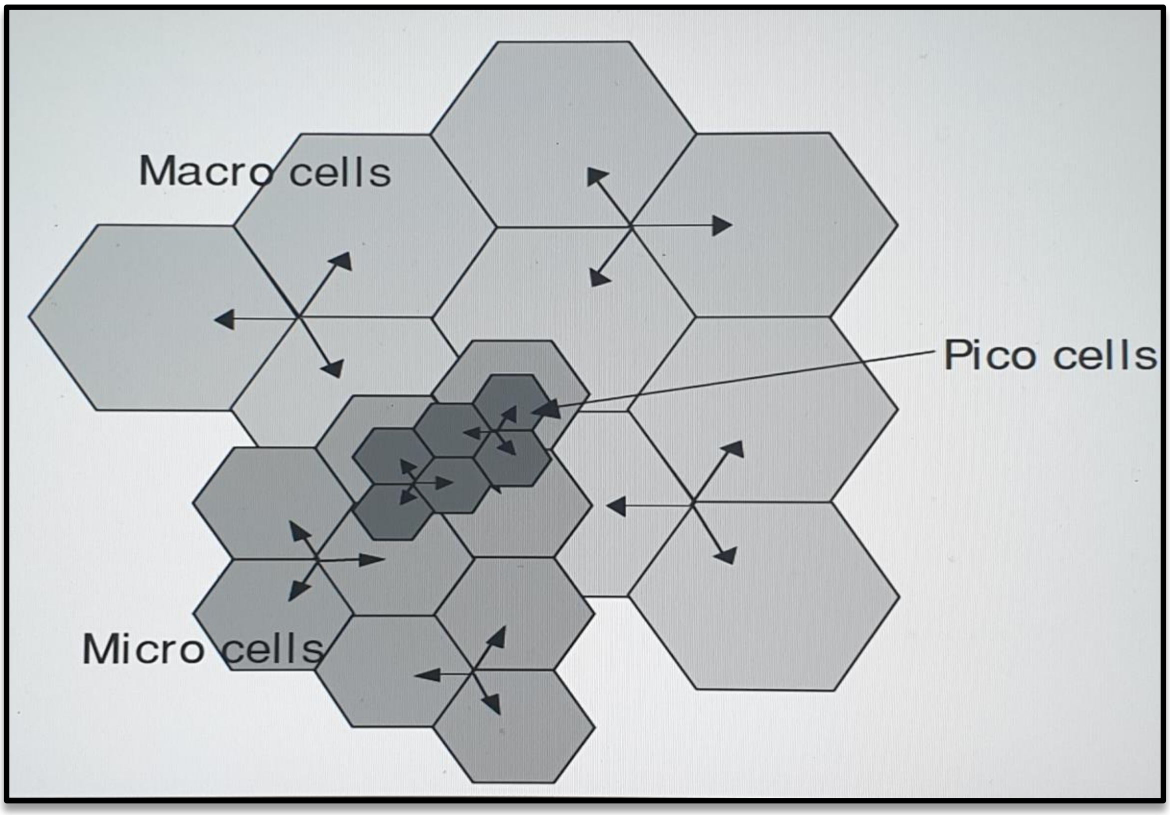


Figure 5.1 Cell coverage planning

Coombs (1999) identifies network coverage planning based on identified cell sizes. Macro cells can cover up to 30 km, micro cells range of coverage is up to 2 km while pico cells cover up to 200m. Due to the sparse population distribution of Kunenekude, macro cell planning is deployed to encounter the challenge of the physical features and topography. The terrain of Kunenekude did not allow smaller cell deployment as reduced cell size impacts the user capacity hence offsetting the numbers that can be supported by the network. The identified high-altitude point for Kunenekude does not give an all-round cell coverage to the areas within the catchment area because it is not located within the central area of Kunenekude which lies at a very low altitude. The differing points means that the settlement pattern for the central area is slightly different from the pattern around the identified vantage transmission site. The analysed coverage profile in Figure 5.2 shows a good portion of the area outside the effective coverage zone.

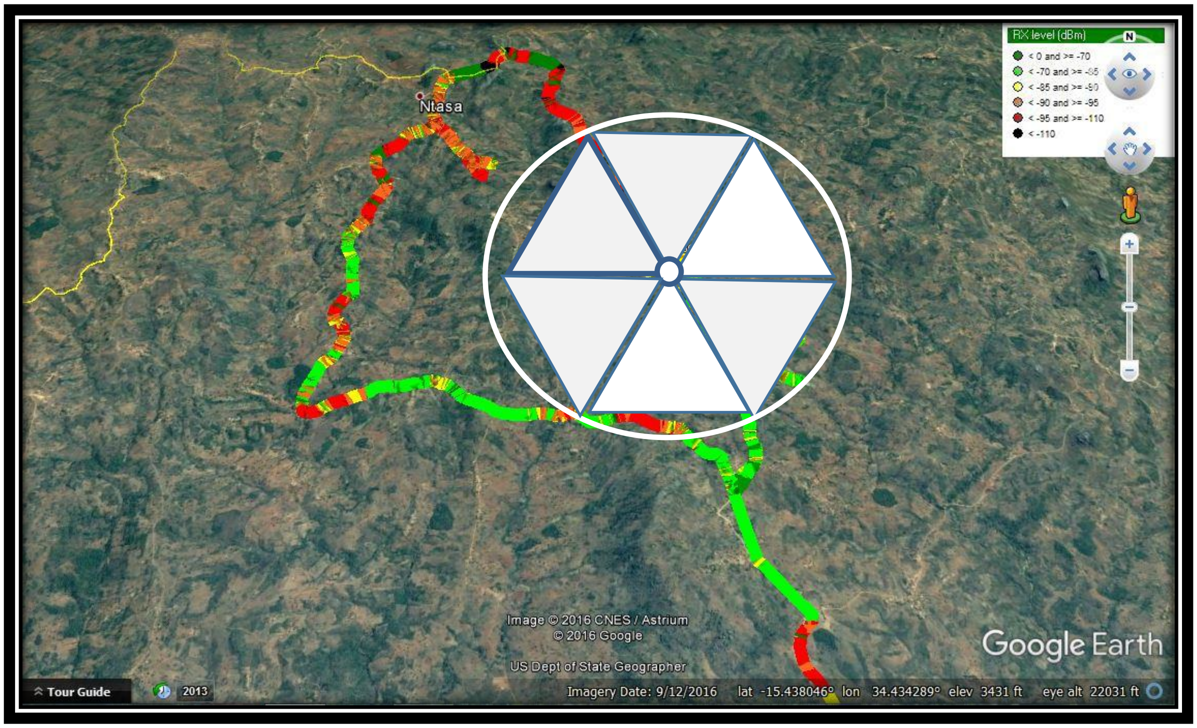


Figure 5.2 Kunenekude cell coverage profile

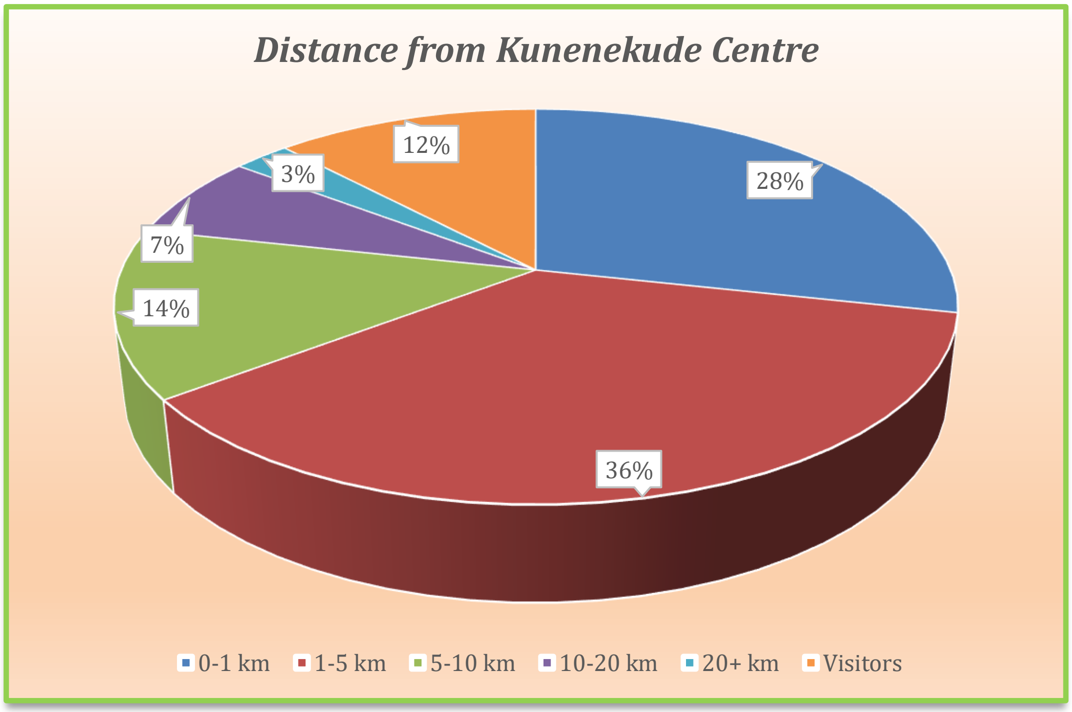
5.2.3. Key Outcome

The study findings provided great insight with respect to the impact of topography on infrastructure development and service delivery in the mobile communications sector. The relationship between infrastructure development and socio-economic development has been more and more evident with key studies being undertaken by many researchers across the world. The consequent impact on service delivery therefore requires additional infrastructure deployment which is a direct result of the challenges emanating from the topography of the area. The resultant effect is the constant movement of people to areas where their communication needs can be met.

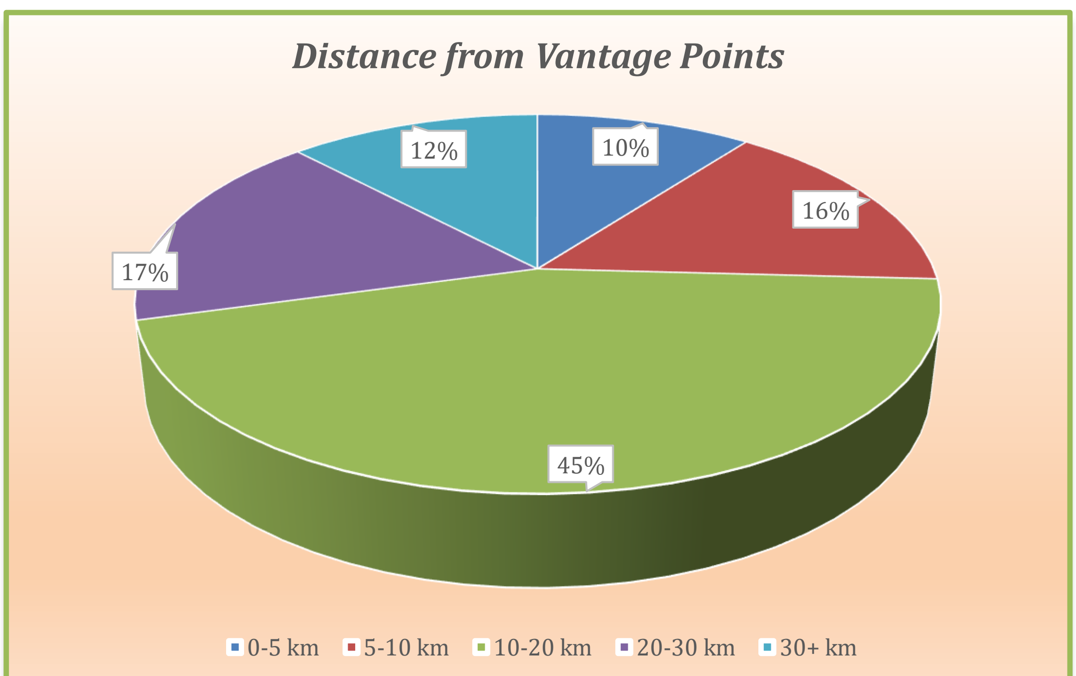
The terrain of Kunenekude means that cells with smaller coverage range cannot adequately service the area as the physical features of the topography acts as barriers to effective signal propagation. This therefore necessitates location of the transmitter sites at vantage points which may not directly resonate with the settlement pattern of the area. The operational requirements will therefore have an impact on the decision regarding the provision of services to the area. Antagonistic topography complicates significantly the network roll out process when it comes to extending coverage to rural and remote populations.

Dutta (2001) analyzes the causal links between telecommunications infrastructure and economic growth and showed that infrastructure development is an essential component for human life with economical, physical, social, and geographical importance. Graphs 5.2 and 5.3 show the spread of the population around Kunenekude centre and around the vantage transmission point respectively. However, due to topography of Kunenekude, the pattern of settlement shows that the population is settled closer to Kunenekude centre as it lies at a low level from where most of their farming activity is undertaken. 64% of the population is located within 1 – 5 km radius of Kunenekude centre making it an ideal target for coverage. However, the challenge of topography creates the barrier between the vantage point settlement and the pattern around the centre as it is on the fringes of effective coverage.

The challenge of settlement around the vantage point is also highlighted by the findings in Graph 5.3 which indicates that only 26% of the population live within 0 – 10 km of the vantage point which is the ideal coverage zone not impacted by the topography as opposed to the remaining 74 % which is spread out closer to the central area which is also the area greatly impacted by the terrain and topography of Kunenekude.



Graph 5.2 Distance from Kunenekude centre



Graph 5.3 Distance from vantage transmission points

GSMA (2017) highlights that network deployment to rural and remote locations is adversely impacted by a lack of basic infrastructure such as reliable power provision, road access or public buildings. The topography of Kunenekude rendered vantage sites inaccessible and as a result, the provision of all-round coverage requires multiple vantage points to address the coverage challenge. These characteristics have a profound adverse impact on all aspects of the business case for mobile network expansion i.e. higher capital investment costs per site, higher operating costs and a significantly lower revenue opportunity. Mobile operators must, as a result, build each site in a self-sufficient manner adding to the up-front deployment costs therefore the choice of Kunenekude does not provide a viable business case to support the provision of mobile communication services due to the inherent topography challenges encountered.

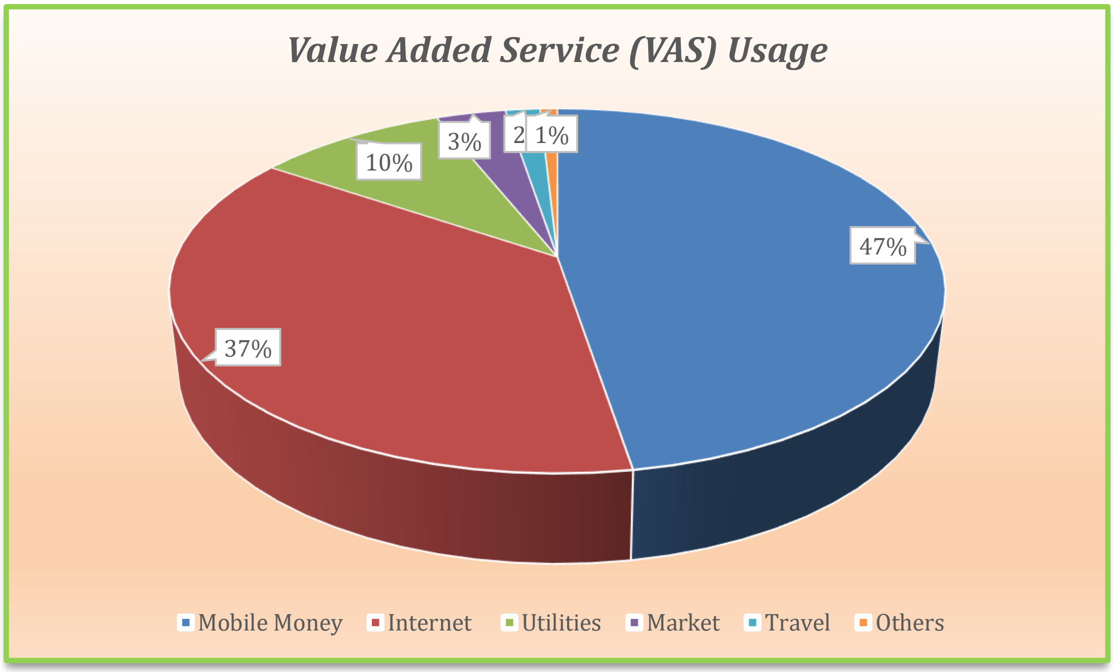
5.3. Mobile Communication Impact on Socio-economic Development

The advent of mobile communication has revolutionized the way of living in modern day society. Kamel (2007) states that mobile telephony is continuously representing more added value to individuals and organizations than a simple communication device. They facilitate social networks leading to enabling an element of social capital. Mobile communication has a transformative effect as it provides access to people, goods, services and economic opportunities that are continuously growing promising changes in the way business is being developed and conducted. Additionally, mobile communication presents huge advantages in terms of added convenience, greater personal security, and the ability to take advantage of time to do business on the move irrespective of time and distance barriers. Mobile communications provide a greater chance for many developing countries to close the gap with developed nations by harnessing the power of communications in adding value to the way of life.

5.3.1. Mobile Value-Added Services

The development of mobile communications services has led to increased data-centric services i.e. value-added services over the core telecommunications network. Gillard & Wale (2003) concluded that mobile communication has impacted people socially by adding flexibility to people’s lives in a sense that any plans could be made or adjusted at the spur of the moment giving them the ability to adapt to unforeseen changes, opportunities, and preferences. Communication plays a vital role in improving society norms as it brings key changes for people awareness, income generation, economic status, and easy access to modern facilities while saving time that can be put to other good causes. The study of Kunenekude showed that mobile communication acts as a social platform providing a vital tool and centre of focus for social activity across financial and economic transactions that would otherwise could not be possible for rural and underserved areas especially access to financial services provided by mainstream banking services. The availability of financial transactions over the mobile communication network further highlighted the ability of mobile phones to include the illiterate masses in less developed countries, thus leading to bridging the digital divide between developed and developing nations as well as within nations irrespective of age, gender, cultural background, wealth, income or hierarchical position that will have vast social implications.

The increased use of value-added services offers an opportunity for creation of small businesses and income generating activities apart from the information obtained using such services. It further helps in the creation of job opportunities for the local people with better access to services. The growth of mobile money applications is a positive spin-off from infrastructure development and the overall socio-economic development through the provision of mobile communication services. The introduction of mobile payments, mobile money and data-centric services over the mobile telecommunication network has enhanced the value of mobile communications. The non-availability of mobile communication services therefore deprives communities of access to such services. Graph 5.4 shows the utilization of value-added services based on the limited access available within the periphery of Kunenekude especially extending from Ligowe which is the nearest area that has some GSM coverage.

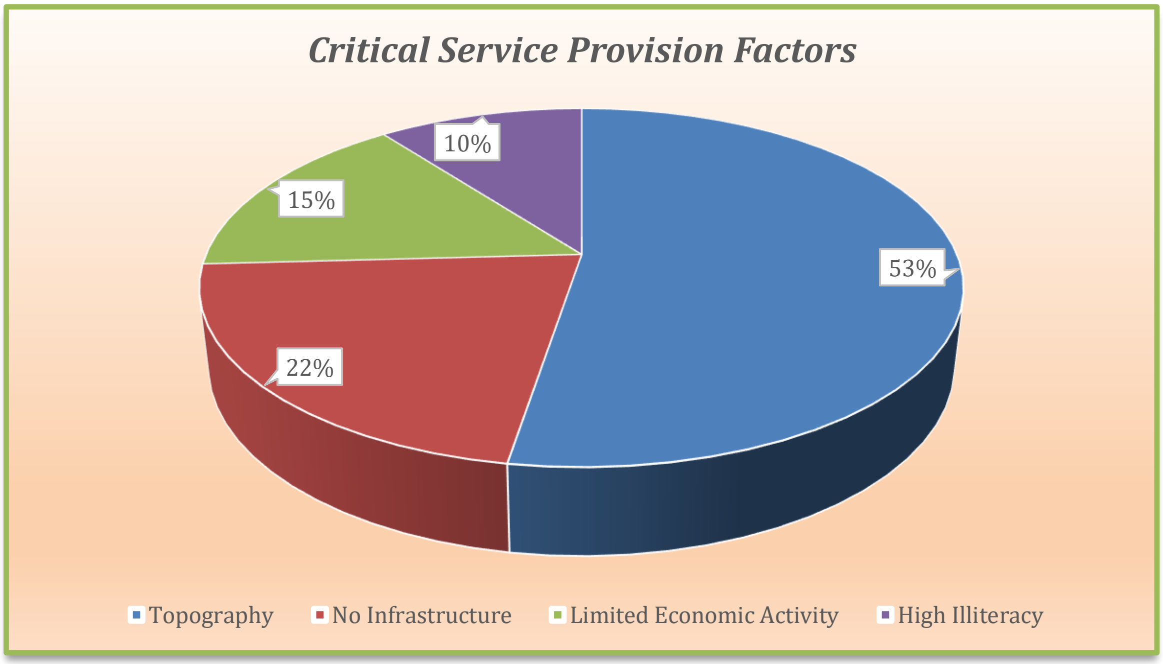


Graph 5.4 Value added services (VAS) usage

The data obtained indicates that despite the limited and sporadic availability of coverage, a good percentage (84%) use mobile money services and internet / data services as complimentary services within areas where telecommunication services are readily available on top of the normal voice services. The high usage of mobile money services (47%) is evidence of the growth that the service has enjoyed and its popularity especially in rural areas where banking services are not readily available. The introduction of new technologies creates scenarios geared towards an evolution and adaptation of old customs and values from old technologies and environments to new ones. On the economic level, such changes continuously provide value addition to individuals and organizations on top of the basic communication services. The availability of GSM services especially in nearby areas such as Ligowe has enhanced the traffic between these two areas as opposed to previous years where such services would entail travels to other coverage areas in Neno or Mwanza district.

5.3.2. Critical Deployment Factors

The provision of communication services is affected by several factors that have a bearing on the socio-economic development of an area. Shahi (2012) states that infrastructure development is aimed at providing the basic needs for people and society thereby indirectly leading to poverty reduction. Effective infrastructure development therefore provides capabilities for meeting the basic needs of the people by providing links between the cores and the periphery of the areas they live in. Infrastructure development is an essential component for human life with economical, physical, social, and geographical importance. Infrastructure development leads to the development of the social sector and the lack of mobile communication services within Kunenekude has a big impact on the socio-economic development of the area under study. Graph 5.5 shows that 53% of the respondents believe that topography has affected the availability of supporting infrastructure for the area resulting in reduced economic activity although there is great potential within the area.



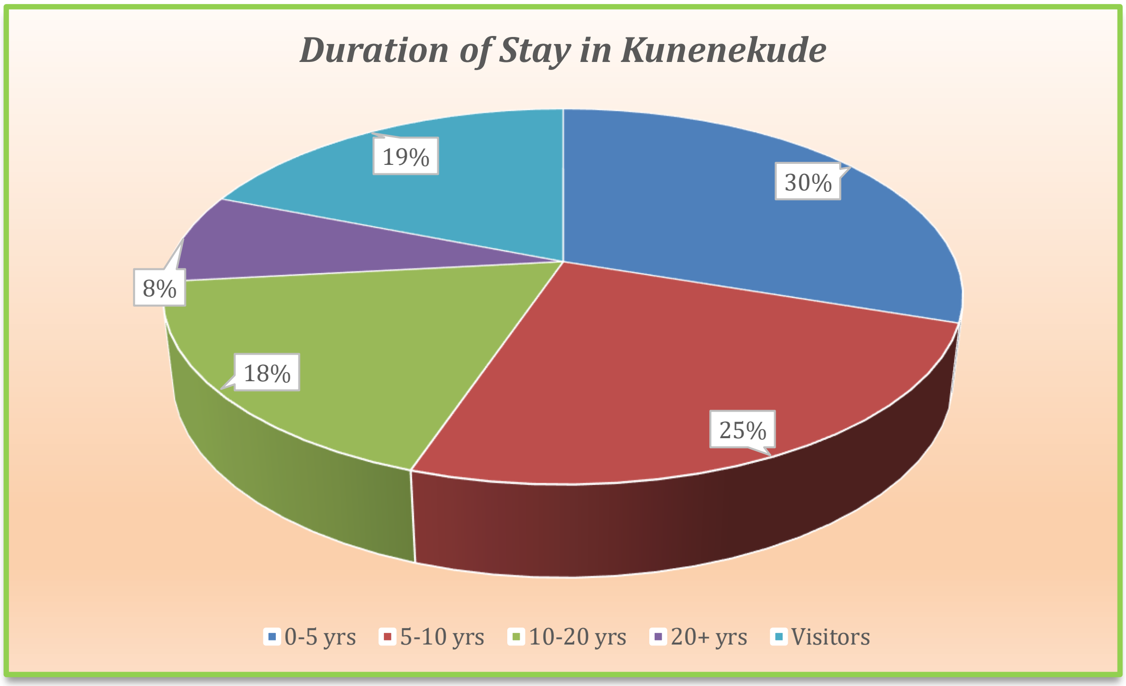
Graph 5.5 Critical factors affecting service delivery

Usman (2005) argued that telecommunications can contribute to economic development in a number of ways i.e. better market information, more distributed economic development, and increased coordination with international economic activity. The growth of mobile services is a catalyst for all the factors and evidently Ligowe has more economic activity as compared to Kunenekude owing to the presence of mobile communication services.

5.3.3. Key Outcome

Mobile telephony has facilitated improved standard of life for most people in rural areas by ensuring socio-economic transformation of their day to day lives. Mobile communication services provide considerable and sustainable benefits to communities and small businesses. ITU (2013) states that mobile communication services deploying GSM technology were introduced in Malawi in 1995 by TNM who were later joined by Airtel in 2000. The availability of respondents who have stayed in Kunenekude for a longer duration of time provided insight into the challenges they have encountered due to the lack of sufficient mobile communication services in the area. Mobile communication is essential to changing the way of life for most people. It reduces the inherent risk in commerce and the cost of doing business as people do not have to travel out of their areas as they are able to transact using their mobile devices. Graph 5.6 shows that for Kunenekude, 55% of the respondents have stayed in the area between 0-10 years, a period that has seen tremendous growth in mobile communication services but have not enjoyed the value addition that mobile communication adds to the way of life. The only way of access is to travel out of their areas to access mobile service within the periphery of the coverage received from the neighbouring sites.

The catchment area of Kunenekude offers incentives to the planning of mobile communication services as the population can easily be served using smaller cells. However, the settlement pattern shows that the population is away from the vantage transmission points making it difficult for effective coverage from the identified sites. Kunenekude topography not only affects the location of communication infrastructure but also limits the settlement pattern of the population as most of them are in the low-lying areas outside the effective coverage area. Theoretically, a macro cell should be able to provide coverage up to 20 km but Kunenekude topography impacts heavily on the coverage thereby leaving a good percentage of the population on the fringes of mobile communication services.



Graph 5.6 Duration of stay in Kunenekude

Qiang (2009) argues that for every 10% point increase in the penetration of mobile phones, there is a corresponding economic growth increase of 0.81% points in developing countries, versus 0.60% in developed countries. This correlates to the improvement of socio-economic status of the population once they have access to mobile communication services. For effective planning, all possibilities for signal coverage were considered for the area and the settlement pattern of the population from the identified vantage transmission points and Kunenekude central area to determine effective coverage for the population. From the findings, the absence of effective coverage in the area under study has a direct impact on the economic activity for the area as most of the respondents can only access services from nearby areas due to the challenges that Kunenekude presents to the development of necessary infrastructure to support essential services.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1. Introduction

This chapter provides conclusion to the findings and highlights several recommendations from the study. It also points to areas for further research that can be explored in line with the theme of linking infrastructure development to socio-economic development.

6.2. Conclusion

In conclusion, the study addressed the aims of the study as per the stated research objectives. The analysis of the findings with the help of literature review and field study, led to the conclusion that the topography has a big impact on infrastructure development and service delivery of mobile communication services which has a bearing on the socio-economic development of the area.

The hypothesis examines the impact of topography on mobile communication service delivery with a specific focus on Kunenekude area in Neno district. The study found out that topography impacts the service delivery for communication services as it impacts on the development of infrastructure as well as affecting the signal coverage for mobile communication services. Topography challenges affect infrastructure development as they lead to high costs of deployment as evidenced by additional alternative coverage options that need to be deployed in inaccessible areas in order to mitigate the risk of leaving out substantial portions of the population out of service coverage as the settlement pattern is mainly skewed and tends to drift away from such difficult terrain. The cost of providing mobile communication services to topography challenged areas is huge and cannot be compensated by the returns on investment as the ARPU for these areas is relatively low especially if it falls in the rural areas. Kunenekude is Neno district lies in one of the small and rural districts in Malawi hence not providing a compelling business case to service providers to extend coverage to the area. Additionally, the service availability in fringe coverage zones gets easily affected and might not deliver all services as per GSM requirements which affects access of value-added services thereby impacting the overall socio-economic development that is a result of good mobile communication services.

Further, the hypothesis also examines the impact of mobile communication services on socio-economic development. The study found out that the development of infrastructure is key to the provision of services as it opens opportunities for provision of services i.e. mobile communication services. Communication services mainly accessed through mobile phones has continuously represented value addition to individuals and organizations rather than functioning as a simple communication device. Infrastructure development plays a vital role for the upliftment of societies. It has a transformative effect on many communities and the absence of effective coverage for Kunenekude has been a hindrance to the population to enjoy full benefits of the socio-economic development brought about by this technology and service based on the economic opportunities arising out of it.

The study also identifies the inherent economic challenges for rural areas in accessing communication services which tallies with the assessment on the limited access to telecommunication services in Malawi. MACRA (2015) states that about 45% of households in Malawi have a mobile phone while about 36% of the individuals within the population use mobile phones. Of this population that own mobile phones, only 30% live in the rural areas and the identified barriers to owning and using mobile phones shows that apart from the major aspect of affordability (financial challenges), the lack of / limited mobile coverage was one of the major reasons for the coverage gap as evidenced by the topography challenges in areas like Kunenekude.

6.3. Recommendations

Based on the findings of the study, the analyzed data as presented in this paper brings to the fore several aspects summarized in the following recommendations.

(i) Formulation of relevant policies that will advocate a coordinated regulatory approach so that infrastructure development and sharing can be managed among service providers to reduce the cost of deploying new sites and/or alternative coverage options in areas with topographical challenges. The development of a technology neutral approach to the regulatory framework will shift the focus of operator’s competition from infrastructure and channel it towards services provided.

(ii) Enhance linkages with the National Statistical Office (NSO) at national and district level to ensure access to household and settlement data which helps estimation of coverage requirements and aids the planning of telecommunication networks. The cost of carefully planned telecommunications network is easily compensated by the returns on usage and value-added services as studies have shown that for every 10% point increase in the penetration of mobile phones, there is an increase in economic growth of 0.81% points in developing countries, versus 0.60 % points in developed countries (Qiang, 2009).

(iii) Utilize available resources provided for under the USF to ensure network expansion to rural and underserved areas which are mostly affected by challenges of service access and cannot covered by service providers due to their commercial non-viability. While USF access is through competitive bidding, it has contributed greatly to the growth of the mobile industry if professionally managed through an independent administrative body.

(iv) Deploy low power transmission sites to counter the topography challenges and provide coverage in low lying areas where most of the population is settled as opposed to high altitude transmission points whose signal is heavily impacted and attenuated by the topography of Kunenekude.

6.4. Further Research

The study has highlighted several issues in line with the hypothesis and objectives. However, it is also noted that the effective coverage requirements for topography challenged areas needs an extensive research in order to;

(i) Detail the costs associated with the alternative options for such areas. The rate of return is a product of the projected average revenue per user (ARPU) considering that value added services increase usage hence pushing the ARPU high than normal usage of basic services i.e. voice and SMS.

(ii) Assess the impact on higher generation technology services i.e. 3G and 4G services which have stringent signal reception requirements and may not be sustainable on peripheral coverage as is the case with 2G services (GSM).

REFERENCES

Alleman, J., Hunt, C., Michaels, D., Mueller, M., Rappoport, P. & Taylor, L. (2002). *Telecommunications and economic development: Empirical evidence from Southern Africa*. Technical Report. Sydney: International Telecommunication Society.

Anttalainen, T. (2003). *Introduction to telecommunications network engineering*. 2nd Ed. Boston, London: Artech House.

Bayes, A., Von Braun J. & Akhter, R. (1999). *Village pay phone and poverty reduction: Insights from a Grameen Bank Initiative in Bangladesh*. Center for Development Research (AEF), Bonn, Germany: Universitat Bonn.

Aguiar, A.B., Pinheiro, P., Neto, A.M., Cunha, R., & Pinheiro, R. (2009). A novel model for optimized GSM network design. *International Journal of Computer Science and Information Security*. *4*(1 &2), 1-4.

Huerta-Barrientos, A., & Elizondo-Cortés, M. (2013). Optimizing the cellular network planning process for in-building coverage using simulation. *Journal of Applied Research and Technology, 11*(6), 912-919. DOI: 10.1016/S1665-6423(13)71598-0.

Buchner, A., Kaserer, C. & Schmidt, D. (2008). *Infrastructure private equity*. Munich, Germany: Centre of Private Equity Research.

Clark, R., Gebreah Frew, A. & Mgombela H. (2003). *Telecommunications reform in Malawi*. World Bank Policy Research Working Paper. Retrieved on May 15, 2019 from https://www.researchgate.net/publication/2565497_Telecommunications_Reform_In_Malawi

Coombs, R. (1999). Introducing microcells into macrocellular networks: A case study. *IEEE Transactions on Communications*. *47*(4), 568-576. DOI: 10.1109/26.764930.

Cooper, D. & Schindler, P. (2006). *Business research methods* (8th ed.). New York, USA: McGraw-Hill.

Cramer, B.W. (2019). The Influence of topography and fracking on Cellular Network availability in unserved areas of north central Pennsylvania. *Journal of Information Policy*, 9(2019), 238-279.

Creswell, J. (2003). *Steps in conducting a scholarly mixed methods study*. Lincoln, USA: University of Nebraska.

Damsgaard, J. & Ping, G. (2007). A framework for analyzing mobile telecommunications market development, *Journal of Electronic Commerce Research*, *8*(3), 186-193.

Dutta, A. (2001). Telecommunication and economic activity: An analysis of granger casualty. *Journal of Management Information Systems*. *17*(4), 71-95. Retrieved from http://www.jstor.org/stable/40398505.

Eggers, W. (2018). *The Future of regulation: Principles for regulating emerging technologies*. London, United Kingdom: Deloitte Insights.

Gillard, P & Wale, K. (2003). *The impact of Telecommunications: Services on family and social relations adventures in Cyberland*. Newfoundland, Canada: Memorial University.

Gillwald, A. (2017). *From digital divide to digital inequality: The connectivity paradox*. Cape Town, South Africa: University of Cape Town.

Graham, S. & Marvin, S. (1996). *Telecommunications and the city. Electronic spaces, urban spaces*. Newcastle, United Kingdom: Newcastle University.

GSMA (2012). *Community power from mobile: TNM feasibility study*. London, United Kingdom: IFC.

GSMA (2017). *Unlocking Rural Coverage: Enablers for commercially sustainable mobile network expansion.* London, United Kingdom: GSM Association.

Gruber, H., Koutroumpis, P., Mayer, T. & Nocke, V. (2010). Mobile telecommunications and the impact on economic development, economic policy. *Journal of Empirical Economics*. 26(67), 387, 389-426. Retrieved from http://www.jstor.org/stable/41261993.

Guldmann, J. (2001). *Telecommunications infrastructure and usage in rural areas. A production function approach*. Ohio, USA: Ohio State University.

Gupta, N. (2000). *The business of telecommunications*. New Delhi, India: Tata McGraw-Hill.

Hakim, S., Albert, G. & Shiftan, R. (2016). *Securing transportation systems*, New Jersey, USA: Hoboken.

Hardy, A. (1980). The role of the telephone in economic development. *Telecommunications Policy*. *4*(4) 278-286. Retrieved from https://doi.org/10.1016/0308-5961(80)90044-0.

Hosman, L. & Fife, E. (2012). The use of mobile phones for development in Africa. Top-down meets Bottom-up partnering. *Journal of Community Informatics, 8* (3). Retrieved from https://www.researchgate.net/publication/304162209_The_Use_of_Mobile_Phones_for_Development_in_Africa_Top-Down-Meets-Bottom-Up_Partnering.

Ibrahim, A.H., Alsharekh, M.F., Almanee, M.S., Alturki, A.S. & Islam, M. (2019). Link Budget design for RF Line-of-Sight via Theoretical Propagation Prediction. *International Journal of Communications, Network and System Sciences, 12*(1). 11-17. DOI: 10.4236/ijcns.2019.121002.

Israel, G. (1992). *Sampling the evidence of extension program impact. Program evaluation and organizational development*. IFAS, University of Florida. USA. PEOD-5. Retrieved from http://edis.ifas.ufl.edu/pdffiles/PD/PD00500.pdf3/6/2011.

ITU (2013). *Market analysis and competition assessment report*. Blantyre, Malawi: ITU Publications.

ITU (2014). Implementation of Evolving Telecommunication / ICT Infrastructure for Developing Countries. Geneva, Switzerland: ITU Publications.

Kamel, S. (2007). *Socioeconomic implications of mobile technology on mobile markets*. Cairo, Egypt: American University.

Kasper, E. (2015). *A definition for infrastructure – characteristics and their impact on firms active in Infrastructure*. Munich, Germany: Technische Universitat Munchen.

Kefela, G. (2010). The impact of mobile phone and economic growth in developing countries. *African Journal of Business Management*. *5*(2), 269-275.

Kim, D.H., Jae-Ho Juhn, & Won-Gyu Ha. (1997). Dynamic modeling of competitive online services in Korea. *System dynamics: An international journal of policy modelling*, *9*(2), 1-23.

Kingombe, C. (2011). *Mapping the new infrastructure financing landscape*. London, UK: Overseas Development Institute.

Kinyanjui, R. (2018). *Mobile telecommunications technology change and the contributions in Sub-Saharan Africa: A comparative case study of Kenya and Ghana*. Hague, Netherlands: International Institute of Social Studies.

Lancaster, H. (2015). *Malawi – Telecomms, mobile and broadband: Statistics and analyses*. Sydney, Australia.

Lu, H., Rohr, C., Burge, P. & Grant, A. (2015). *Estimating the value of mobile telephony in mobile network not-spots.* https://www.rand.org/pubs/research_reports/RR641.html.

MACRA, (2015a). *Performance annual report*. Blantyre, Malawi: Author.

MACRA, (2015b). National Survey on access to and usage of ICT Services in Malawi. Blantyre, Malawi: Author.

Moldkar, D. (2013). *Spectrum audit and re-farming project*. Interconnect Communication Consultants - ICC. London, United Kingdom.

National Statistical Office (2018). *Population and housing census*. Government Gazette, Zomba, Malawi: Author.

Patel, A., & Rathod, H.S. (2011). Mobile Phone Usage Habits of Students Commuting From Rural Areas to Nearby Town- An Exploratory Study of Visnagar (Gujarat-India). *Global Journal of Management and Business Research*, *11*(6), 30-37. Available at: https://www.journalofbusiness.org/index.php/GJMBR/article/view/514.

Poot, J., Longhi, S. & Nijkamp, P. (2008). *Meta-analysis of empirical evidence on the Labour Market*. Bonn, Germany: Institute for the Study of Labour.

Qiang, C. (2009). *Telecommunications and economic growth*. Washington D.C, USA: World Bank Group.

Ricketts, M. (2002). *The economics of business enterprise*. Cheltenham, United Kingdom: Edward Elgar.

Rogers, E. (1966). *Physics for the inquiring mind*. Princeton, USA: Princeton University Press.

Roscoe, J.T. (1975). Fundamental research statistics for the behavioural sciences. (2nd ed.). New York, USA.

Salunke, A. R. & Gaikwad, A. N. (2015). *Review of unstructured architecture for voice and data services in mobile communication.* IEEE International Conference on Electrical, Computer and Communication Technologies. India. DOI: 10.1109/ICECCT.2015.7226190.

Schwartz, M., Bennet, W.R., Stein, S. (2004). *Communication systems and techniques*. New York, USA: IEEE Press.

Seo, D. (2013). *Evolution and standardization of mobile communications technology*. Pennsylvania, USA: IGI Global.

Shahi, B. (2012). *Impact of infrastructure development on society. A case of Narayan Municipality Ward.* Kathmandu, Nepal: Tribhuvan University.

Sridhar, K. & Sridhar, V. (2004). Telecommunications infrastructure and economic growth. Evidence from developing countries. *Applied Econometrics and International Development 7*(2), 37-56. Retrieved from https://ssrn.com/abstract=1250082.

Southwood, R (2011). Balancing Act: Issue 576 October 2011. London, UK. Retrieved from https://www.balancingact-africa.com/news/telecoms_en/23253/malawi-communications-regulatory-authority-amends-telecoms-licences.

Tang, T. (2012). *Infrastructure for the future*. Los Angeles, USA: AECOM.

Usman, P. (2005). *Cellular telephony is one of the greatest benefits of Nigeria's democracy*. Vworld, p. 30.

Waverman, L., Meschi, M. & Fuss, M. (2005). The Impact of Telecoms on Economic Growth in Developing Countries. *The Vodafone Policy Paper Series*, *2*(3), 10-24.

Wilson, A, Ugwunta, D., Okwo, M. & Eneje B. (2014). How telecommunications development aids economic growth: Evidence from ITU ICT Development Index (IDI) Top Five Countries for Africa Region. *International Journal of Business, Economics and Management*, *1*(2), 16-28.

APPENDICES

APPENDIX 1 – QUESTIONNAIRE FOR DATA COLLECTION

QUESTIONNAIRE ON THE ASSESSMENT OF THE IMPACTC OF TOPOGRAPHY ON INFRASTRUCTURE DEVELOPMENT AND SERVICE DELIVERY FOR MOBILE SERVICES IN KUNENEKUDE

INTRODUCTION

This questionnaire is aimed at getting your honest assessment, views and insight about the impact of the non-availability of mobile telecommunication services in Kunenekude.

The questionnaire is structured to get your general views on the topic of mobile telecommunication services and the impact that non-availability of the services might have on the lives of people living in Kunenekude.

It is my sincere hope that you will find the questionnaire user friendly to guide you through the process. In case of any clarifications please contact the undersigned.

Chisomo Momba / chisomomba@gmail.com **/ 08 88 854891 / 09 99 854891**

SECTION 1 – GENERAL

1. Name of individual (optional)

2. How long have you lived in Kunenekude?

3. How far do you live from Kunenekude centre?

4. Have you ever used mobile communication services anywhere / anytime in the past?

5. If yes in (3) above, how would you rate the importance of mobile communication? If no to (3) above, skip this question.

1) Not important
2) Important
3) Very important
4) Extremely important

6. Are you aware of the other social and economic benefits of mobile communication apart from just the basic communication services?

7. If yes to (5) above, what other services have you used before on your mobile communication platform? Please tick as applicable.

1) Mobile money (Mpamba / Airtel money)
2) Internet services (data)
3) Payment of utilities (water / electricity / DSTV etc.)
4) Accessing information on markets (ACHX), prices etc.
5) Travel information (maps)
6) Other information (please specify)

8. What major challenges have you encountered in terms of the non-availability of mobile signal in Kunenekude?

9. How far do you have to travel to access mobile telecommunication services outside of Kunenekude?

1) Less than 5 Km
2) Between 5 – 10 Km
3) Between 10 – 20 Km
4) More than 30 Km

10. What do you think is the biggest factor leading to no provision of services in Kunenekude?

1) Difficult to access because of hilly topography?
2) Lack of supporting infrastructure (roads, electricity)?
3) Not enough economic activity to benefit the service providers?
4) Rural setting with high illiteracy rate?
5) Any other reason (please explain)

11. If your opinion, do you think the provision of mobile services in Kunenekude will change the status of the area and its people? If so, explain.

12. What other benefits (economic / social) do you think mobile telecommunication services can bring to the area?

13. Do you think the Operators are doing enough to provide mobile telecommunication services in the country?

14. What role can the community play to facilitate increased infrastructure development and service delivery?

15. Any other general comments you may have?