ASSESSMENT OF MOBILE TELECOMMUNICATION MASTS SPATIAL DISTRIBUTION EFFECT ON THE ENVIRONMENT OF MINNA, NIGERIA

BY

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ABSTRACT

GSM base station popularly called telecommunication mast is an important infrastructure required for effective communication system. However, if not properly managed it can impact negatively on the environment and residents health. Therefore, this study attempts to examine the spatial distribution of GSM mast in Minna and its implication on the environment. The study adopts the descriptive-observational research design method. Primary data on the location of GSM mast, noise, and pollution level were collected using Global Positioning System (GPS), Testo 815 sound meter, and Rasi-700 air quality meter respectively. The data collected was subjected to descriptive statistics (frequency, percentage, mean, standard deviation) and spatial analysis (Nearest Neighbourhood Analysis). The study revealed that a total of 74 network antennas belonging to four network operators (MTN, GLO, Airtel, 9Mobile) were identified on 58 GSM mast distributed across Minna. Seventy-two (72%) out of the 58 GSM mast are occupied singly by individual network operators, while only twenty two (28%) are co-located. The study further established that all the GSM mast in Minna exhibit a clustered distribution pattern, save for those that belong to MTN mobile, while non-compliance to 10m setback by NESREA and 1000m tower-tower regulation was also observed among all the GSM operators. The study therefore, concludes that there is a proliferation of GSM mast in Minna with minimal adherence to NCC and NESREA regulation. Therefore, the study recommends strict enforcement of NCC and NESREA installation guidelines in other to minimize the impact of the GSM mast on the environment and the people at large.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

According to the National Communication Commission (NCC, 2014), the global system for mobile (GSM) communications has dominated the Nigerian telecommunicationindustry; as it accounts for about 98% share of the market. Four GSM operators (Airtel, Etisalat, Globacom, and MTN) control the industry in Nigeria. The number of deployed transceiver base stations (BTSs) or mast sites by the four operators grew from zero in 2001 to about 44,000 in May 2014 (Ekataand Kostanic, 2014). The use and deployment of cellular phones and other wireless communication facilities around the world are phenomena; it has not only reduced the world into a global village but more importantly into a global household (Olukolajo *et. al*, 2013).

The GSM, as it is popularly called, is one of the fastest growing means of communication in Nigeria and the world at large **(**Shalangwa, 2010**)**. Nigeria is one of the largest users of GSM for communication in Africa; over 50% of the total population in Nigeria depends on the GSM as the quickest means of communication (Zain, 2005). There are four GSM providers in Nigeria with a subscription base of over 163.05 million people (National Bureau of Statistics (NBS), 2017). Since the introduction of the mobile phone in Nigeria in the early 2002, it has played a vital role in the dissemination of information (communication, SMS and Data for internet usage). The sector had recorded a high growth from 2.27 million subscribers in 2002, when the first mobile license was issued, to 163.05 million at the end of the first quarter of 2015 (NBS, 2017).

Out of the four GSM providers, MTN dominated with 61.21 million subscribers (42.84 percent), while Etisalat is the least, with 22.3 million (15.69 percent), (NBS, 2015).The launch of Global System for Mobile (GSM) Communications in Nigeria in 2001 heralded a dawn of relief to teeming Nigerians (Olukolajo *et al.,* 2013). What was once solely a business tool; wireless phones are now a mass market consumer device contributing positively to the Gross Domestic Products (GDP) of various countries and providing job opportunities to millions of youths, professionals and even petty traders (Otubu, 2012).

GSM base stations and cellular telecommunication masts represent part of the infrastructure required foran effective communication system. In order to have effective network coverage, several base stations are locatednear the target users; the reason telecom operators also site their masts in residential neighbourhoods. The base stations transfer signals between mobile telephones and a network for mobile or normal telephony by means of radio frequency electromagnetic fields. Telecommunication Base trans-receiver stations (BTSs) are designed to enhance communication radio-frequency network signals for the rapidly expanding digital telecommunication users both in urban and rural communities (Turletti *et al*., 1999). It also facilitates the extension of communication network accessibility to suburban and rural communities lacking access to telecommunication services. Typical BTS consists of telecommunication mast on which are installed radio frequency transmitters and receivers, powered by digital electronic boasters which are installed in shelters within the BTS site.

Even with the numerous benefits of GSM communication, several environmental issues have been attributed to the introduction of this technology. This includes the indiscriminate siting and erection of base trans-receiver stations all over Nigeria. A conservative estimate of over 20,000 Base trans-receiver stations is scattered around the country. Many of the BTSs are sited within residential, commercial, industrial and transit routes. Aside from the risk of chronic human and environmental exposure to radiations and other environmental and safety matters, air quality damage appears to be of priority (IFC, 2007), since many of the base trans-receiver stations are powered by diesel-run power generating sets. Diesel runs combustion engines are known to release fugitive emissions and other air pollutants (Dürkop and Englert, 2004). Thus, the atmosphere receives gaseous and particulate pollutants from BTSs operations.

The health-related implications of gaseous and particulate release are of great concern (Sarnat, 2011). Some gaseous releases also have detrimental consequences such as the destruction of the ozone layer, global warming and incidence of acid rain (Sivasakthivel and Siva, 2011). As a result, atmospheric emissions resulting from BTSs operations are of environmental concern. Hence the characterisation of air quality in vicinities around operating base trans-receiver station sites areessential in order to ascertain the human and environmental risk associated with base trans-receiver station operation (Olatunde and Olatunbosun, 2013).

However, a lot of Nigerians are saddened by the adverse effects of telecommunications base stations on their lives and property. The situation is made knotty by the indiscriminate installation of base stations close to residential areas and those with large volumes of human activities. It is the closeness of base stations towhere people live and work that exposes people to the hazards associated with them. Apart from death and injuries caused by the falling of some telecoms masts, the noise pollution arising from the generators used in the base stations, solid waste of telecom masts gadgets and oil spillage from the generators, people whose residence are located close to base stations are continuously being exposed to radiations emitted by these stations. (Iortile *et. al*, 2013).

1.2 Statement of the Research Problem

The rapid development boom recorded in the Nigerian telecommunications industry within the last two decade has led to the proliferation of telecommunication infrastructure across the country. This phenomenon is rampant and visible in all parts of the country, particularly in urban areas. The cityscape of the urban areas is distorted with mast towers and satellite dishes on almost every available space. Majority of this mast is sited without consideration for the impact they will have on the health and wellbeing of residents as well as its implication on urban aesthetics and functional attributes of the metropolis (Lawanson, 2009).

In response to the foregoing argument, the Federal Government of Nigeria through statutory agencies like the National Communication Commission (NCC), NESREA and Town planning board have developed guidelines for the siting, construction and installation of masts in the country in other to reduce the health and environmental hazards associated with this technology. Yet, the indiscriminate siting and construction of masts in most urban centres is still on the increase, and Minna urban space is not immune to this menace.Telecommunication masts are indiscriminately located within residential areas in Minna without recourse to the state urban planning regulation, NCC and NESREA guidelines. The implication of this trend on human health and the environment is significant (Aderoju *et al.*, 2014).

Furthermore, it is also important to note that quite a number of studies (Ezeokwelume, 2011; Babatunde and Adewuyi, 2013; Akin and Magret, 2014; Iortile and Agba, 2014; Adeniji *et al.*, 2015) as been conducted on the subject matter by scholars from different disciplines in and outside Nigeria. These studies have contributed immensely to knowledge in various ways, among which include, establishing the locations of the mast, the inventory of mast, implication of mast location in residential and commercial areas, and the proximity of mast to different land uses. However, the extant literature review shows that little or no study has been able to establish or document the level of conformity of the telecom mast operators to NCC, NESREA, and Planning regulations.

Assessing the performance of the telecom operators is the first attempt towards sanitising the industry in terms of mast location and maintenance in the country. However, the study of Aderoju *et al.* (2014) on “space-based assessment of the compliance of GSM operators in establishing base Transceiver Station (BTS) in Abuja Municipal Area of Nigeria" is an exception. The study was able to spatially identify the location of BTs in Abuja municipal area while aggregating the performance of the telecom operators. However, the study of Aderoju *et al.* (2014) only focused on distance as the only indicator for measuring performance; yet could not provide a well disaggregate performance level of the telecom operators. The performance of the telecoms operators is multidimensional and must be treated as such; issues of waste disposal, maintenance of equipment and site must also be incorporated in the assessment.

Secondly, previous studies in this direction have established the health implication of mast near residential and commercial land-use. However, these studies failed to account for the number of people at risk as a result of the indiscriminate location of the BTS mast. The description of the health implication of mast locations in space as exemplified in the studies of Sabah, (2013), Olatunde and Olatunbosun, (2013) Santini *et al.* (2002) did not present a true picture of the problem. These studies did not provide adequateinformation on the number of people exposed to health and environmental risk of each of the telecommunication operators operating in Nigeria. It is essential for studies of this nature to estimate the number of people at risk and to determine the culpability of the telecommunication operators. Lastly, going by the studies reviewed, reasonable effort in terms of research has been directed towards the subject matter in some part of the country. However, little is known about the distribution pattern, compliance to standard and the number of people at risk of BTS mast in Minna, Niger State.

Finally, three major research gaps have been identified from previous studies on location and siting of BTS mast. First, is that studies on the subject matter focus on determining compliance basically from the physical perspective of the average distance between the mast and the surrounding land use, without consideration for other factors. Moreover, where this is done, the area under risk is only estimated while neglecting the number of people that are likely to be affected or exposed to the risk of the BTS mast. Lastly, studies of this nature are yet to be carried out in Minna. This study is, therefore, an attempt to fill the aforementioned gap identified from previous studies.

1.3 Aim and Objectives of the Study

1.3.1 Aim

The studyaim to assess thespatial distribution of telecommunication masts inMinna with a view to determining its implication on environmental sustainability.

1.3.2 Objectives

The specific objectives of this study are as to:

i. Identify base mast stations within Minna town.
ii. Examine the spatial distribution pattern of telecommunication masts in Minna.
iii. Determine the level of compliance of network providers toNCC and NESREA standard and its implication on the environment.

1.4 Research Questions

Going by the gaps identified in Literature, the following research questions were drawn.

i. Where are the network masts located in Minna?
ii. What is the pattern of distribution of the telecom mast in Minna?
iii. Do the network providers conform to standards in siting and location of masts in Minna?
iv. What is the likely environmental implication of the current distribution pattern of masts in Minna?

1.5 Scope of the Study

This study was carried out within the geographical space of Minna town, which consists of 29 neighbourhoods that cut across two LGAs (Chanchaga and Bosso) in Niger State. The study focused on assessing the impact or environmental-related problem that may arise or affect the people as a result of the existing distribution pattern of the mast in Minna. This was achieved by establishing the location of the existing mast, and the characteristics in terms of proximity to different land use and conformity to NCC and NESREA standards. The level of non-conformity to the specified standard by telecoms operators was established. Furthermore, the study will also try to determine the characteristics and number of households vulnerableto the environmental hazards of BTS mast location in Minna; while exemplifying the spatial distribution pattern for each of the network provider and the level of conformity to specified standards of mast location according to NCC and NESREA guidelines.

1.6 Justification of the Study

This study will highlight the location and number of available Global System for Mobile telecommunications (GSM) Base Transceivers Stations in the studied area. It will also help researchers, the National Communications Commission (NCC) and the National Environmental Standards and Regulations Enforcement Agency (NESREA) in understanding the perception of residents on the health effect of the electromagnetic radiations from GSM BTS. Furthermore, the outcome of this study will help to establish the relationshipbetween the location ofGlobal System for Mobile telecommunications (GSM) Base Transceivers Stations and its effect on the health of residents.Findings from the study will also assist medical practitioners in rendering better health care services. Moreover,this will also serve as an eye-opener to NCC and NESREA that will propel them into formulating stringent policies that will make telecommunication operators comply with the specified standards of setting up a GSM Base Transceivers Stations.

1.7 The Study Area

1.7.1 Location of minna

Niger State lies on latitude 8^{o}:00' to 11^{o}:30' North and Longitude 03^{o} 30' to 07^{o} 40' East. The State is bordered to the North by Zamfara State, West by Kebbi State, South by Kogi State, South West by Kwara State, North-East by Kaduna State and South East by FCT. The State also has an International Boundary with the Republic of Benin along Agwara and Borgu Local Government Areas to the North West. (See Figure 1.1).

1.7.2 Population

According to the 2006 Population and Housing Census, Bosso Local Government Area had a population of at 147,359 people, a land area of 1,606.1km^2, and population density of 92km^2 While Chanchaga Local Government Area had a population of at 201,429 people, a land area of 73.4 km^2, and population density of 2,744km^2 (NPC, 2006).

1.7.3 Weather and climate

The state experiences two distinct seasons the dry and wet seasons. The annual rainfall varies from about 1,600mm in the south to 1,200mm in the north. The duration of the rainy season ranges from 150 to 210 days or more from the north to the south. Mean maximum temperature remains high throughout the year, hovering about 32°f particularly in March and June, however, the lowest minimum temperature occur usually between December and January when most parts of the state come under the influence of the tropical continental air mass which blows from the north. Dry season in Niger State commences in October (Owoyele, 2014).

1.7.4 Drainage and relief

In the climate zone, temperatures are high throughout the year. From 1994 – 98, the mean annual minimum temperature of Abuja and Minna were 1838^{0}c,22.05^{0}c, 20.9^{0}c and 21.21^{0}c respectively. The mean annual maximum temperature from 1994 – 98 were 34.28^{0}c (Abuja) (and 30.55^{0}c) (Minna). The temperature recorded during the fieldsurvey in those study was

26.60^{0}c. The gentle favourableclimatic conditions of the area coupled with its rich landscape made it possible for the people to settle. Minna has the same characteristics with Abuja region which experiences wet and dry season characteristics of a tropical climate with varying season from April/May to October with heavy rainfall from July to September.

1.7.5 Soil and vegetation

Three major soils types can be found in the state. These include the ferruginous tropical soils, hydromorphic soils and ferosols. The most predominant soil type is the ferruginous tropical soil, which are basically derived from the basement complex rocks, as well as from old Sedimentary rocks, such ferruginous tropical soils are ideal for the cultivation of guinea corn, maize, millet and groundnut (Owoyele, 2014).

Hydromorphic or water logged soils are largely found in the extensive flood plain of the Niger River. The soils are poorly drained and are generally grayish or sometimes whitish in colour due to the high content of silt, ferosols which developed on sandstone formations can be found within the Niger trough.These can be seen along the major highways in the state. The southern guinea savannah covers the entire landscape of the state. Like in other states of similar vegetation, it is characterized by woodlands and tall grasses interspersed with tall dense species. However, within the Niger trough and flood plains occurs taller trees and a few oil palm trees. In some areas traces of rainforest species can be seen.

1.7.6 Socio economic activities

Niger State possesses fertile land as a cherished asset and the potentials are yet to be fully explored. The even climate rich annual rainfall and availability of wide variety of mineral and agricultural resources all attest to the economic potential of the state. Every government that has come to power endeavored to provide good infrastructure such as road, electricity, water and communication facilities to make way for interested investors. Some natural and mineral resources found in the State include Talc, Gold, and Ball clays, Silica, Sand, Marble, Copper, Iron, Feldspar, Lead, Kaolin, Cass trite, Colum bite, Mica, Quartzite and Limestone. Evidence also abounds as to the availability of sources of power i.e the three hydro-electricity power stations situated at Kainji, Jebba and Shiroro (Owoyele, 2014)..

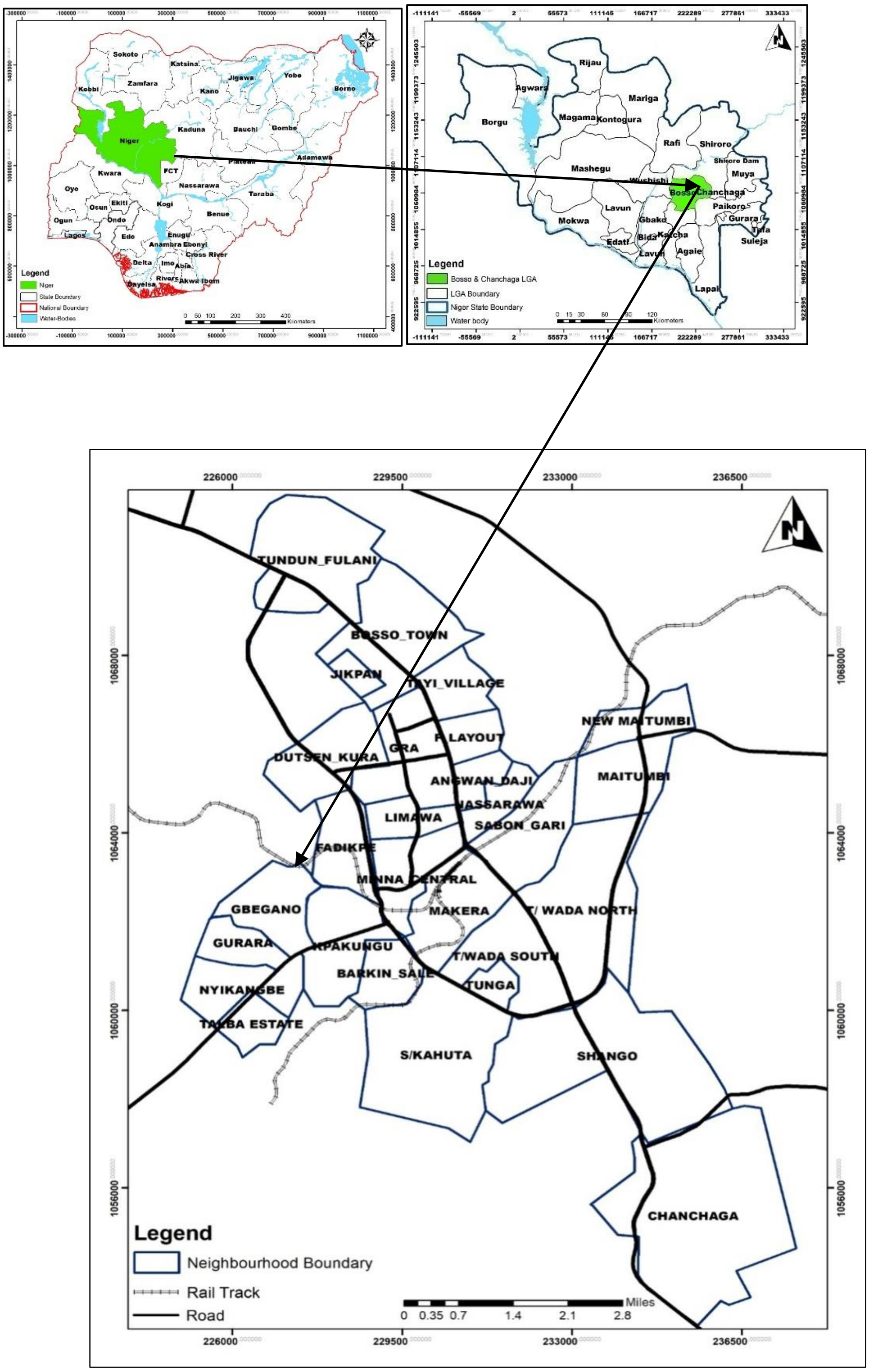

Figure 1.1: Map of the Study Area

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

Although several literatures confirm that radiation at high levels over a period of time affect people living around radiation sources such as cell towers, transmission power lines and so on, however, one salient point is that the buildings are first overwhelmed by high levels of radiation before the inhabitants fall victims of its hazards. (Ahlbom *et al*., 2001) argued that it is not just fielding above 0.4μT that matters but in homes where the average field over 24hrs is greater than 0.4 μT.

Ubabudu (2013) investigated the effectiveness of GSM providers' services in Nigeria and concluded that the services have helped to reduce travelling and facilitated social interactions. He also noted that the services had been bemired by a myriad of issues that include, exorbitant tariffs, poor audio quality, call interference, non-delivery of short message (SMS), multiple billing system, poor customer care service, and high call dropout rate. Using the MTN GSM network as a case study, Mughele *et al.,* (2012) studied the network's congestion complaints. The authors attributed the problems to equipment vandalisation, poor weather, and high-rise buildings in the line of sight of masts rather than poor RF planning and network design that some experts suspected. Adegoke *et al.,* (2011) evaluated the quality of GSM services in Nigeria and concluded that consumers were unsatisfied with the level of services provided in the country. According to Dalil *et al.,* (2016), GSM networks in Nigeria would perform at an acceptable level if the operators optimized their networks. While the preceding studies pertain to services, there are others that focus on the safety of the RF power emitted by GSM base stations.

Nwankwo *et al.* (2012) performed an assessment of the radiated RF power and exposure level of BTSs in the city of Lokoja in Nigeria and found out that the intensity of the radiated power varied from BTS to BTS. The researchers also noted that the intensity of the power decreased with distance from a BTS. Similarly, investigation of the spatial exposure to RF emission from GSM base stations in the University College Hospital environ in Ibadan, Nigeria, Ajiboye and Osiele (2013) found that RF field exposure in the area was within the safe limits prescribed by ICNIRP. Nwankwo *et al.*, (2012) found that the level of RF energy emitted by base stations in the small city of Ajaokuta, Nigeria was well below the ICNIRP safety limits. Their finding was based on the study carried on the four major GSM operators in the area. In a case study, Ahaneku and Nzeako (2012) investigated the level of RF power radiated by GSM base stations in the University of Nigeria, Nsukka. The study concluded that the total exposure to humans in the university environment was within the safety level recommended by ICNIRP and ANSI. Akpolile *et al.* (2014) examined the health implications of exposure to GSM antennas (masts) in selected areas of Delta State, Nigeria. The study established that the level of exposure to GSM RF in the areas was below ICNIRP recommended limits that pose health risks. In assessing the measurement methods of RF exposure, Ayinmode and Faral (2013) argued that different methods and instrumentation are used depending on the equipment type, population size, sampling, study duration, and cost.

2.2 Theoretical Framework

2.2.1 Classical Location Theory

In classical location theory, the spatial pattern of economic activities is explained mainly in terms of transfer costs which include both freight charges (i.e. transport cost) and the cost of insurance on materials and goods; route and losses incurred by the deterioration of or damage to materials and route. The expense and inconvenience of shipping finished products to distant customers and procuring raw materials from distant sources induce producers to locate near their markets or raw materials (Akhimien, 2005). Which of the market or raw material source eventually attracts an activity depends on the relative cost of assembling materials and distributing finished products. Many industrialists, therefore, tend to locate where aggregate transfer costs are at a minimum (Omole, 2001).

Transfer costs are usually reduced by bringing producers and consumers closer together on the transport and communications network. Therefore, profit-oriented enterprises respond to transfer costs by seeking to reduce them. Transfer costs, in essence, operate to cause a concentration of economic activities at strategic points on the transport and communications network and all types of production find favourable locations at transshipment and junction points on the transport network.

The notion of transfer costs has strong implications for the spatial distribution/location of public facilities. Public facilities have many important characteristics, two of which are particularly relevant for our present purpose.As a result of these two characteristics, public facilities generally locate primarily with an eye to distribution and are thus oriented towards the consumer market.

i. The services they produce are mostly for final consumption, and

ii. Public services generally require personal contact between producers and consumers.

Location theory also makes important points about the spatial distribution of producers and consumers. The locational relation among producers competing for markets is usually one of mutual repulsion. This is because producers search for markets where competition is at a minimum. If the good supplied is standardised, affording no grounds for consumer preference apart from cheapness, each market point will buy from whatever production centre can supply it most cheaply. The delivered price of any good or product at any market is equal to its cost at the factory plus distribution costs. Consequently, the spatial pattern of producers and consumers is a function of competition between producers and is largely resolved by the structure of transfer costs.

In locating private and public facilities, the common objective of policy-makers is either to maximise utility or to minimise costs. However, public and private decision-makers differ in their definition of utility and cost. Since the major goal of shareholders or owners of private facilities is to maximise their profits, private locational decisions are necessarily profit-oriented. For all private enterprises, the ultimate basis of choice of location is the rate of earnings (wages, profits, or interests) obtainable at different locations (Aguda, 1997; Omole, 2001). Regularity and security of earnings are also important. Consequently, communities with stable economies are generally more attractive to entrepreneurs seeking to locate enterprises. Equally important is the expected trend in earnings. Thus, from private locational decisions, the important factors are stability and security of returns and bright prospects.

While private enterprises mainly seek monetary profits for a comparatively small group of individuals, public decision-makers aim at maximising social utility or minimising social costs for those who use the services provided. In such situations, the definition of utility and cost for the user in human terms takes the place of variables structured solely in terms of monetary returns to the producer. The goal of public locational decisions could, for instance, be to minimise aggregate travel for a given population while simultaneously ensuring that all consumers have access to facilities. These objectives undoubtedly have welfare undertones. Such minimisation problems are usually subject to some constraints like the number and size of facilities and the number of people to be served. The smaller the aggregate travel, the more efficient the set of facility locations and the more accessible the services to the user population.

Public and private decision-makers differ in their locational objectives, especially as their locational decisions are made within different frameworks. Monetary criteria are the basis of most private locational decisions. On the other hand, about public facilities, non-monetary criteria become especially evident. The relevant variables in most public locational decisions refer to social or human entities to which it is extremely difficult to assign monetary values. It is impossible, for instance, to know how many monetary benefits result from suitable access to police protection, fire services, or medical facilities. Hence one of the primary objectives of public locational decisions is the maximisation of accessibility to facilities. It is against this background that the spatial pattern or distribution of health-care facilities was examined in order to identify the locational characteristics of this category of public facilities.

2.2.1.1 Electromagnetic Radiation Models

Power density is defined as the power per unit area normal to the direction of propagation usually expressed in units of Watts per square meter (W/m^2), or for convenience in units such as milliwatts per square meter (mW/m^2), or even in microwatts per square centimeter ($\mu W/cm^2$). Sources of electromagnetic energy (Liu *et al.*, 2008), range from man-made sources such as commercial broadcast stations and automobile ignition systems to natural sources such as galactic noise and lightning. Considering the signal transmission from cell towers, Power density P_d at a distance R is given by (Girish, 2010; Sujoy, 2011):

$$P_d = \left(\frac{P_t \times G_t}{4\pi R^2}\right) Watt/m^2 \qquad 2.1$$

Where, P_t = Transmitter power in Watts,G_t = Gain of Transmitting antenna, R = Distance from the transmitting antenna in meters.

Power received $P_r$by an antenna at a distance R is given by:

$$P_r = \left(\frac{P_t \times G_t \times Area}{4\pi R^2}\right) Watt/m^2 \qquad 2.2$$

$$P_r = P_d \times Area\ Watt/m^2 \qquad 2.3$$

Power absorbed by human body can be calculated using the equations 2 and 3 and the human body area is measured as illustrated in Figure 2.1 and the distance from the cell tower is also measured as shown in Figure 2.1.

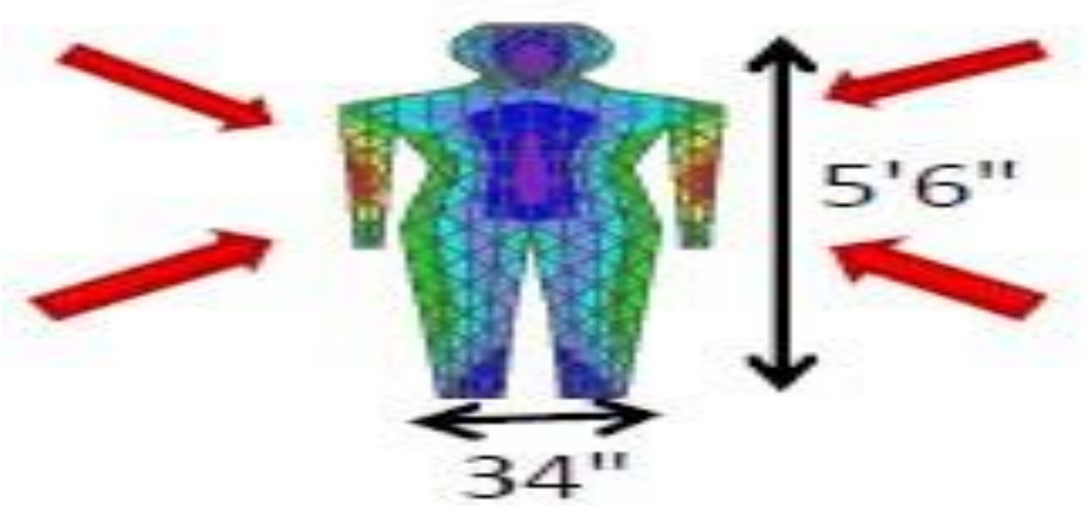

Figure 2. 1:Human Body Measurement
Source: (Girish, 2010)

2.3 Review of Empirical Studies

2.3.1 Empirical Studies on Radiation Measurement

According to Halim *et al.* (2009) who carried out radiation measurements with a Geiger-Mueller LND712 detector, Radiation Alert Monitor 4, calibrated by Cesium 137 twelve month a year detected natural background radiation rate exposed by man around base station. Sabah (2013) in a study carried out measurements at various places near the cell towers inside residential areas in Kirkuk-Iraq and found that the radiation levels were above the recommended values.

In France, Santini *et al.* (2002) in their study on the health of people living in the vicinity of mobile base stations, observed that the people who lived closest to the cellular antennas had the highest incidences of the following disorders: fatigue, sleep disturbances, headaches, feeling of discomfort, and difficulty in concentrating, depression, memory loss, visual disruptions, irritability, hearing disruptions, skin problems, cardiovascular disorders, and dizziness. Eger *et al.* (2004), examined in Germany whether people living close to cellular transmitter antennas were exposed to a greater risk of becoming ill with malignant tumors. Wolf and Wolf (2004) presented in Israel that, based on medical records of people living within 350 meters of a long established phone mast, showed a fourfold increased incidence of cancer compared with the general population of Israel, and a tenfold increase specifically among women, compared with the surrounding locality further from the mast.

Oberfeld *et al.* (2004) in their study of biological effects of EMF's in Spain discovered that;thesignificant ill-health effects among those living in the vicinity of two GSM mobile phone base stations have depressive tendency, fatigue, sleeping disorder, difficulty in concentration and cardiovascular problems were the strongest five associations. Also People living within 50 to 300 meter radius as illustrated in Figure 2.2, are in the high radiation zone and are more prone to ill-effects of electromagnetic radiation.

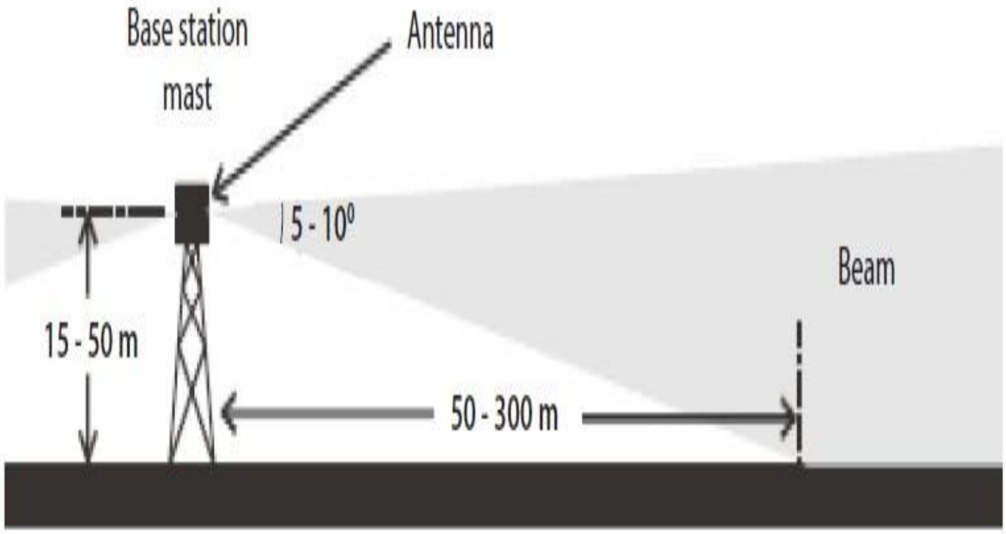

Figure 2. 2: Direction of coverage due to a Base Station Antenna
Source: Adopted from (Mousa, 2011)

2.3.2 The Effect of Telecommunication Masts

The effect of mobile phone radiation on human health is the subject of recent interest and study, as a result of the enormous increase in mobile phone usage throughout the world (Kovach, 2007). Mobile phones use electromagnetic radiation in the microwave range. Koprivica *et al.* (2013) opined that as a result of dense installations of the public mobile base station, additional electromagnetic radiation occurs in the living environment. Kovach (2007), complained that exposure to electromagnetic radiation (EMR) is growing and becoming a serious health threat. He also pointed out the huge public health crisis looming from one particular threat: EMR from cellular phones, both the radiation from the handsets and from the tower-based antennas carrying the signals which studies have linked to the development of brain tumours, genetic damage, and other exposure-related conditions (Kovach, 2007). Part of the radio waves emitted by a mobile telephone handset is absorbed by the body.

Mobile phone radiation and health concerns have been raised, especially following the enormous increase in the use of wireless mobile telephone throughout the world mobile phone use EMR in the microwave range and it is believed that this is harmful to human health (Adekunle *et al.,* 2015). These concerns have induced a large body of research (both epidemiological and experimental, in non-humans animals as well as in humans (Koprivica *et al.,* 2013). According to IEEE standard (2005), the induction of currents by oscillating magnetic fields causes solar storms which disrupt the operation of electronic electrical systems, causing damages to power distribution transformer. It was once traced to the cause of blackout in the U.K in 1989 and interference with EMF signals (IEEE Standard, 2005; Aalto *et al.,* 2006) . Extremely high power electromagnetic radiation can cause electric currents strong enough to create sparks when an induced voltage exceeds the breakdown voltage of the surrounding medium, for example, air. These sparks can then ignite flammable materials or gasses, possibly leading to an explosion. It is referred to as hazard of electromagnetic radiation Ordinance (Aalto *et al.,* 2006).

Touching or standing around an antenna while a high-power transmitter is in operation can cause severe burns as obtainable in microwaves (Masaki *et al.,* 2009). Laboratory experiments by revealed that short-term exposure to high levels of RF radiation (100-200 mW/cm^2) can cause cataracts in rabbits. This is why welders wear tinted glass. Two areas of the body the eyes and the testes can be particularly susceptible to heating by RF energy because of the relative lack of available blood flow to dissipate the excessive heat load. Temporary sterility, caused by such effects as changes in sperm count and sperm motility, is possible after exposure of the testes to high-level RF radiation(Aalto *et al.,* 2006).

The UK Department of health set up the stakeholder advisory group on extremely low-frequency EMFs (SAGE Report, 2011) to explore the implications and make recommendations for a precautionary approach to power,density, frequency, electric and magnetic fields in light of any evidence of a link between EMF and childhood leukaemia. The first interim assessment of this report reveals that the link between proximity to power lines and childhood leukaemia was sufficient to warrant a precautionary recommendation including an option to lay new power lines underground where possible and to prevent erecting of new residential buildings within 60m (197 ft) of existing power lines. According to Cleaver and Mitchel (2000) of University of Basel in Switzerland, intermittent exposure of human cells to a 50Hz EMF at a flux density of 1T or 10G induced a slight but significant increase of DNA fragmentation in the comet asset. The level of exposure is above currently established safety exposure limits. The Belgian government on their (website) recently said new regulations would soon apply for sales of mobile phones especially for children under seven years of age. The intention is to raise awareness among mobile phone users on health hazards associated with electromagnetic radiations.

2.3.3 GSM Base Station and Property Value

The growing concerns of the general public over the effects of the Base Stations on property values stems from the concerns about the negative effect it impacts on health, safety and the visual effects of the towers. While experimental and epidemiological studies focus on the adverse health effects of radiation from the use of Cell Phones and Base Stations, few studies have been conducted to ascertain the effects of Base Stations on property values. Bond *et al*. (2003) in their study of the impact of cellular phone base stations on property values; found that people who live close to a base station perceive the sites less negatively than those who live further away. Although he did not establish any significant effect of the location of base station on property values, however he is of the opinion that the only reason a rational investor might continue to avoid property near a cell site would be because it was intrusive on the views received from the property or because of the adverse aesthetic effects of the Cell Phone Base Station on the property.

According to Picard (1996) reported that there are at least two instances in Canada, where the assessed value of residential properties was reduced due to the close proximity to commercial antenna towers. The justification for the reduction was the impact of the tower upon the aesthetics' of the neighbouring lands. In Colwood, British Columbia, the assessed values of sixteen residential properties were reduced by an average of 7.2% due to the aesthetic impact of a broadcasting antenna installation (Macdonald, 2001). The impact of communication towers on property value and community health is fast becoming a matter for legal tussles between the community, property owners and the wireless service provider (see Cellular Telephone Co Vs. Oyster Bay, (166 F. 3d 490, 2d Cir. 1999); Sprint Spectrum LP Vs. Willoth (176 F. 3d 630 2d Cir 1999); Mcintyre and others Vs. Christchurch City Council (1996) NZRMA 289; Shirley Primary School Vs Telecom Mobile Communication LTD (1999) NZRMA 66). In most of the cases, while the courts held that there is no sufficient evidence to prove that Base Station may lead to adverse health effects; however the courts conceded that there are evidence of property values being affected. The fall zone argument is another point of claim on property values. The point being made here is that proximate properties face the risk of being crushed down because of a falling tower. This has been proved to be a genuine case for concern especially in Nigeria.

For instance, according to Igbokwe (2006), the Lagos State Infrastructure Maintenance Regulatory Agency got a report of a collapsed mast in front of a police station at Iyana Ipaja, near Total Filling Station. "We are lucky that the mast fell on a huge three-dimensioned iron bill board. Lives would have been lost and property destroyed if it had fallen on the ground". The concern for the fall zone has made most cities and municipalities to insist on a sufficient set back between a tower and the nearest property line. In Ohio, the guidelines required that if a tower is less than 75 feet tall, the site must have 250 feet set back from the nearest property line. If the tower is 75 to 150 feet tall, the site has to have 500 feet set back. Any tower more than 150 feet must have 750 feet set back from the nearest property line (Primedia, 2004). In Nigeria, there is a proliferation of service providers with each one struggling to outdo the other in the attempts to capture as much as possible from the ever-growing demand. The consequent is the indiscriminate siting of the base station and communication antennas. Unfortunately, the effect of these on the properties and the people living around these installations has not been extensively studied. It is in the light of this, that this paper is tailored to address primarily, the satisfaction level of people living around the GSM Base Stations.

2.3.4 Radiation norms

The radiation norms adopted in some countries such as India is given by ICNIRP guidelines (ICNIRP, 1998) of 1998 for safe power density of f/200, where frequency (f) is in MHz. Thus, for GSM900 transmitting band (935-960 MHz), power density is $4.7W/m^2$ and for GSM1800 transmitting band (1810-1880 MHz), it is $9.2W/m^2$. In the same vein, based on the recommendations of an Inter-Ministerial Committee constituted by DoT in the year 2010, limiting reference levels of Electromagnetic Radiation from Mobile towers is reduced to $1/10^{th}$ of the limit prescribed by the ICNIRP with effect from September 1, 2012 (Rakesh, 2013) as shown in Table 2.1.

Table 2.1: Recommended Radiation Norms

Frequency	ICNIRP Radiation Norms	Revised DoT Norms Effective from 01/09/2012
900MHz	4.5 Watt/Sqm	0.45 Watt/Sqm
1800MHz	9.0 Watt/Sqm	0.90 Watt/Sqm
2100MHz	10.5 Watt/Sqm	1.05 Watt/Sqm

Source: Rakesh, (2013).

Considering the ICNIRP guidelines (ICNIRP, 1998), for simultaneous exposure to multiple frequency fields, the sum of all the radiation in a particular environment must be taken into consideration. Hence, the sum of the all the radiation from a base station mast serving two or more service providers' signal transmission must also be considered. Bio-Initiative report (Girish, 2010; Sujoy, 2011) in 2007 suggested some of the proposed maximum exposure values are:

Table 2.2: Exposure Levels and Its Implication on Health

S/No	Exposure Level	Implication
i.	Less than 0.1 $\mu W/m^2$ (0.00001 $\mu W/cm^2$)	No Health Concern
ii.	0.1 - 10 $\mu W/m^2$ (0.00001 to 0.001 $\mu W/cm^2$)	Slight Health Concern
iii.	10 - 1000 $\mu W/m^2$ (0.001 to 0.1 $\mu W/cm^2$)	Severe Health Concern
iv.	Greater than 1000 $\mu W/m^2$ (greater than 0.1 $\mu W/cm^2$)	Extreme Health Concern

Source: (Girish, 2010 & Sujoy, 2011)

Similarly, (Girish, 2010; Sujoy, 2011) states that; in many places in Nigeria, cell phone towers are mounted on the roof top of residential, commercial buildings especially banks, university office blocks etc. The radiation from multiple phones should be considered as well since many people have two or more phones on them as they walk about. It was recommended that safe power limit is 50μ W/m^2 with upper limit as 100$\mu W/m^2$. However, these power limits have not been adequately made public nor put into consideration by the regulatory bodies in most developing countries such as Nigeria to monitor and strictly address the issue of high radiation levels which has become a global health issue.

2.3.5 Radiation norms in different countries

According to (ICNIRP, 1998) states thatin India, radiation norms adopted guidelines for safe power density of f/200, where frequency (f) is in MHz. Hence, for GSM900 transmitting band (935-960MHz), .and power density is 4.7W/m2 and for GSM1800 transmitting band (1810-1880 MHz), it is 9.2W/m^2. The ICNIRP guidelines clearly state that for simultaneous exposure to multiple frequency fields, the sum of all the radiation must be taken into consideration. Many countries in the world have adopted much stricter maximum radiation density values of 0.001 to 0.24 W/ m^2 (1/100th to 1/1000th of ICNIRP guidelines) as shown in Table 2.3. The people in these countries have studied extensively the health hazards of cell tower radiation on buildings around the area to adopt stricter radiation norms.

Table 2.3: **International Radiation limits for different Countries**

Power Density (W/m^2)	International Exposure limits adopted by various countries
10	FCC (USA) OET-65, Public Exposure Guidelines at 1800 MHz
9.2	ICNIRP & EU recommendation 1998 – Adopted in India
3	Canada (Safety Code 6, 1997)
2	Australia
1.2	Belgium (ex Wallonia)
0.5	New Zealand
0.24	Exposure limit in CSSR, Belgium, Luxembourg
0.1	Exposure limit in Poland, China, Italy , Paris
0.095	Exposure limit in Italy in areas with duration > 4hours
0.095	Exposure limit in Switzerland
0.09	ECOLOG 1998 (Germany) Precaution recommendation only
0.025	Exposure limit in Italy in sensitive areas
0.02	Exposure limit in Russia (since 1970), Bulgaria, Hungary
0.001	"Precautionary limit" in Austria, Salzburg City only

Source: ICNIRP, (1998)

2.3.6 The importance of telecommunication in the socio-economic development of cities

According to Moss (1999) advanced communication technologies are transforming the form and function of large metropolitan regions. For centuries, the growth of cities depended on transportation linkages to facilitate the movement of people and goods. As advanced, industrialised nations rely more heavily upon information-based services, the viability of a metropolitan region will depend on its communications infrastructure to facilitate the movement of ideas and information. As the industrial age experienced a shift in the predominance of crude agricultural implements to the mechanization of tools so has the information age transformed the type of infrastructure required for effective flow of ideas and information in today's world. While these developments portend benefits for our societies, there are also concerns about the preparedness of our contemporary cities to evolve and adapt to a seamless transition.

Moss (1999) envisaged that just as the number of ships that arrived at a port was once regarded as the measure of a city's economic activity, the information that flows in and out of a city will be the appropriate indicators of a community's well-being in the twenty-first century. He went further to suggest that the emerging telecommunications infrastructure presents both a challenge and an opportunity. The challenge is to develop theoretical concepts and empirical techniques for analysing the relationship between new telecommunication systems and existing communication processes. The opportunity is to improve our understanding of how communications technology influences the organisation of work, time, and space in an advanced urban society.

George (1999) observed that the behaviour of individuals and groups in urban areas is clearly competitive. For groups or individual attempts to maximize satisfaction. This urge have led to new and innovative methods of operation, which often alter structure, and use of land resources. These alterations more than often result in problems. Yen and Mahmassani (1997) noted that the development of telecommunication technologies might affect land use patterns and play a role in the growth of economic activities and the spatial distribution of industry. They suggested two specific aspects of office-location decisions by organizations in assessing the impact from the new technology; the need for certain organizations to locate where they can access telecommunication networks; and an increased opportunity for the organizations to locate their offices in the areas where infrastructure costs are generally lower than traditional office locations such as downtown areas are factors that could influence location decision.

Gaspar and Glaeser (1998) tried to uncover the relationship between IT and face-to-face interactions and the cities that facilitate these interactions. In an empirical analysis using telephone call data, the authors concluded that these are complements rather than substitutes. As a result, the centralizing forces in cities did not seem to vanish. However, as the authors noted, it is very hard to separate the exclusive effect of IT in their regression models.

Gordon and Richardson (1997) conjectured that IT technology may lead to a dispersion of economic activities and population, possibly up to the stage where geography is irrelevant. They noted that high-rise or concentrated settlement has been dominant when transport or communication costs were high but that such costs are likely to continue to fall in the future. It might be possible to summarize that office work, rather than office workers, will do the traveling (Drucker, 1989). Salomon (1996) mentioned that there have been excessive expectations of the information age, for instance, that telecommunications can eliminate the effects of distance and as a result can have profound effects on the spatial organization of society. Even though the study claimed that a complete change of urban form could not be expected in the information age, the author agreed that there are some changes that may result from these technological changes.

There exists a gap between the introduction of new IT and the changes in the spatial pattern of firms (Capello, 1994). This is ascribed to an overestimation of technological potential and to an optimistic and superficial analysis on the relationship between the new technology and spatial restructuring. The study noted that in the long run, those technologies lead to a new production strategy such as the "just-in-time" (JIT) system and it will require a physical proximity (either in an inter-urban or intra-urban context) between firms and eventually a spatial clustering of economic activities are expected. However, as Fujita and Hamaguchi (2001) noted, firms (specifically the buyers of intermediate goods in the research) can be more dispersed if they have a better-developed transportation/ communication infrastructure as in the examples of many developed countries.

Conceptually, the geography and distribution of economic activities can be redefined based on information flows. Echeverri-Carroll (1996) noted that an effect of the geographical relationships between organisations could not be conceptualised without understanding the intra-organizational and inter- organisational computer networks that bind particular locations together. Even though spatial decentralisation continues to be relevant, the process is characterised by a much higher functional integration using the information network. It is implied that network connectivity can be a more important factor in deciding the geographical relationships than physical distance, especially in the information age.

Mokhtarian (1998) focused more on the spatial residential pattern of commuting. She noted that "the effect of the new technology is not to reduce travel but to increase the flexibility of travel and, as a result, the total number of trips may be higher with a substantial portion of travel shifted to off-peak periods. The ability to commute because of telecommuting often leads to a relocation of residences further away from work enough for total VMT (vehicle miles travelled) on a smaller number of commuting days to exceed the previous levels". On a system-wide level, this trend may result in a decentralising effect on urban form.

George (1999) while explaining the modifications to Alonso's model of land use pattern in Lagos metropolitan area hinged on the principle of accessibility to alternative locations. Quoting the exact words; "urban location decisions are interdependent". This interdependence very often shows itself in agglomeration of similar establishments. This creates external economies the ease of face-to-face contacts in the office zone or the fact that locating shops together minimizes commuting costs and attracts customer".

In a comparative analysis of this trend in the Chicago and Seoul regions, it was concluded by some analysts that information technology has a very influential and positive effect on the agglomeration of firms. Despite the dispersion-inducing factors of the limited availability of information technology and accessibility to a well-equipped information network in many areas restrict the locational choices of firms, and as a result the distribution pattern is more concentrated. While this might change in the future as IT facilities disperse, for now the uneven distribution of IT infrastructure is a centripetal force. This tendency also occurs in an interurban context (Jungyul *et al.*, 2003). Audirac and Fitzgerald (2003) reviewed literature on information technology and urban form and concluded that ‘’current urban planning discussion regarding the New Economy centers are based on planning, managing, and redesigning form of cities and regions in order to attract and nurture knowledge economies.

Moss (1999) examined the components and implications of the changing urban telecommunications infrastructure and its impact on research and policymaking. The study confirmed that contrary to popular belief, communication technologies have not replaced face-to-face contact. Rather, new communication systems have enhanced those cities that serve as the information centers of the world. Rather than lead to the obsolescence of cities, new communication technologies have contributed to the emergence of a handful of "world cities". Because a new and sophisticated telecommunications infrastructure is being built within large metropolitan regions to accommodate sophisticated data and voice services, those communities that are already equipped to handle such technologies are at an advantage.

Moss (1999) suggested that ‘‘we need to improve our knowledge and understanding of the relationship between new telecommunication technologies and the rich web of interpersonal communications that occurs in cities''. The evidence to date indicates that communication technologies are vital elements in maintaining and stimulating both internal and external patterns of urban communications. It is essential to recognize the distinctive roles of government and business. The private sector should be the engine of telecommunications development at the urban level. The public sector, however, should monitor private sector initiatives and use private telecommunication networks for serving public purposes.

Frenkel (2001) observed that various studies have provided evidence of the advantages of the ability of metropolitan areas to attract industries, which employ advanced technology and are strongly involved in the process of innovation. The statement emanated from the results of an empirical study of the location choice of Israeli hi-tech metropolitan area, carried out in the Northern region of Israel (which encompasses the Haifa metropolitan and its surrounding localities) and based on field-survey data obtained from hi-tech plants. The study investigated the effect of different factors on location choice and also identifies the direct contribution factor to the probability of choosing the metropolitan area as a preferred location with implications for industrial policy.

Moriset (2003) focused on the tendency of e-business towards urban concentration in Europe using France as a case study. The study assumed that the complexity of the urban sector results in an increasing variety of business location. The survey of 92 firms in the multimedia sector of Lyon shows that enterprises do not have the same location needs, neither at regional nor Multimedia and software designers are more 'footloose' than Web agencies and Internet service outsourcers, which are linked to their clients and to broadband networks. The former may locate in picturesque renovated areas, or even in rural areas. The latter tend to share high-tech-suited locations with Internet and telecom carriers in state-of-the-art, wired premises. Finally, this study considers the question of the status of a medium city and its different districts in the context of a growing information economy.

In the opinion of Rutherford (2005), there appears to be substantial convergence in the type and extent of telecommunications networks being deployed between and in major European cities to serve increasing numbers of corporate clients, thus one of the principal material elements in the development of a world city network. Through discussion and an empirical exploration of the interurban and intra-urban network development of one major telecommunications providers in Europe, however, it is shown how the planning, construction and expansion of these infrastructures remain crucially shaped by a variety of historical, regulatory, economic, physical and organizational constraints and compulsions which are specific to individuals. The mutually constitutive nature of economic and technological connectivities suggest, therefore, development of a world city network continues to have an important dimension of territorial fixity, reflecting multi-scalar entanglement of territory and globalization that forms the world cities of today.

However, Graham (2002) suggests that the societal diffusion of information and communications technologies (ICTs) remains starkly uneven at all scales. The contemporary city displays this unevenness most visibly. In cities, clusters and enclaves of 'super-connected' people, firms and institutions often mix with large numbers of people with non-access to communications technologies. In such a context, the study sought to demonstrate that dominant trends in ICT development are currently helping new extremes of social and geographical unevenness within and between human settlements and cities, in both North and the South. It went further to explore the prospect that such stark 'urban digital divides' be ameliorated through progressive and innovative policy initiatives which treat cities and electronic technologies parallel.

Mills and Whitacre (2007) observed that as residential Internet access in the United States shifts toward high-speed connections, a gap has emerged in high-speed access relative to urban high-speed access. Potential causes of this high-speed ``digital divide" include rural-urban differences in people, place, and infrastructure. Combining current population survey data from 2001, and 2003 with novel infrastructure data, the study determined the relative roles of these factors in the urban divide. Bootstrapped decompositions of logit model results demonstrate that rural-urban and in network externalities, but not in infrastructure, are the dominant causes of the high-speed residential internet access.

2.3.6.1 Mobile phones and economic development

The Grameen Phone project in Bangladesh is an example of how mobile phones can successfully increase economic growth in rural communities. In 1993 micro-credit loans were mainly given to women in Bangladesh to become ‘telephone ladies’. By selling airtime to other members of the community they were able to create their own business. Calculations showed that the average daily profit was two dollars, significantly higher than the average daily income of less than a dollar per day (Bayes *et al.*, 1999).

There is a wealth of anecdotal evidence highlighting the way in which mobile phone technology is being used to improve economic growth. Groups of farmers in Côte d’Ivoire share mobile phones to keep up-to-date with coffee and cocoa prices (Lopez, 2000). In Senegal, Manobi launched a free-access SMS market information service that sends free SMS containing relevant information to fisherman, traders and local authorities. The service aims to build users' capacity to seize market opportunities and increase their income, allowing them to choose their own speed of development and take up of advanced services when it is most beneficial for them (Manobi 2005 as cited in Rashid and Elder, 2009).

2.3.6.2 Mobile phones and social development

In 2005 Vodafone published the report 'Africa: The impact of Mobile Phones'and argued that increased mobile use and access in rural communities couldserve to "mediate contact between different people, and so [were] likely to have an effect on the size, number and nature of social networks that peopleparticipate in" (Goodman, 2005). Research conducted by Department for International Development (DFID) (2005) on the impact of telephones in India, Mozambique and Tanzania, found that lowerincome groups were more likely to spend a higher proportion of their incomeon telephony than high income groups. Keeping travel costs down, socialnetworking and emergencies were found to be the most important typesofcommunication to the rural poor.

2.3.7 Effect of radioactive radiation

Air pollution is the presence in the outdoor atmosphere of one or more air contaminants (i.e dust, fumes, gas, mist, odour, smoke or vapour) in sufficient quantities of such characteristics and of such duration as to be or to threaten to be injurious to human, plant or animal life or to property or which reasonably interferes with the comfortable enjoyment of life or property (Chakradhar *et al*., 2003). The knowledge of quality of ambient air plays an important role in assessing the environmental scenario of the locality (Canter, 1996). The quality of ambient air depends upon the background concentrations of specific contaminants, the emission sources and meterological conditions. Air pollutants can be classified as natural contaminants (fog, pollen grains) aerosols (dust, smoke, mist), gases and vapour (SO_x, NO_x).

The sources of air pollutants include mobile transportation, solid waste disposal and industrial sources. The air quality sampling and monitoring is one of the important aspects in establishing the baseline quality of the region of interest (Ubongand Gobo, 2001). This includes identification of specific air pollution parameters expected to have significant impacts and assessing their existing levels in ambient air within the impact zone of the study area, Federal

Capital City, Abuja. The base consideration of air sampling consists of samples collected being representative in terms of time and locations. Air pollution which consists of indoor and outdoor pollutants have been a public concern in Nigeria.

Indiscriminate burning of solid waste at open dumps which generates air contaminants like dust, smokes, mist and odour causes injuries to human, plant, animal and property. Air pollution comes from many different sources; stationary sources such as factories, power plants, and smelters and smaller sources such as dry cleaners and degreasing operations; mobile sources such as cars, buses, planes, trucks, and trains; and naturally occurring sources such as windblown dust, and volcanic eruptions, all contribute to air pollution. Air quality can be affected in many ways by the pollution emitted from these sources. These pollution sources can also emit a wide variety of pollutants. The Environmental Pollution Agency (EPA) has these pollutants classified as the six principal pollutant called criteria pollutants which are monitored by the federal, state and local agencies (EPA, 2014).

National ambient air quality standards are standards set for pollutants which are considered harmful to the people and the environment. National, state, tribal and local governments are responsible for ensuring that these air quality standards are met or attained through national standards and strategies to control pollutants emissions from auto mobiles, factories and other sources. There are two types of standards, primary and secondary. Primary standards protect against adverse health effects; secondary standards protect against welfare effects, such as damage to farm crops and vegetation and damage to buildings. The six criteria pollutants addressed in the National Ambient Air Quality Standards (NAAQS) are carbon monoxide, Nitrogen Dioxide, Lead, Ozone(or Smog), Particulate Matter and Sulfur Dioxide (Smith, 2009).

If the levels of these pollutants are higher than what is considered acceptable by regulatory agencies, then the area in which the level is too high is called a nonattainment area. Combustion of fossil fuels in stationary sources usually leads to the production of SO_2, NO_x, and Particulates. Domestic fuel use, mainly coal and wood, represents a significant source of the air pollution in cities, particularly cities in developing countries. Petrol fueled motor vehicles are responsible for the emissions of NO_x, CO, and Pb (where leaded petrol is still used), whereas diesel-fueled engines lead to significant emissions of SO_2, NO_x, and Particulates.

VOCs are emitted from various anthropogenic sources including road traffic, production and the use of organic chemicals (e.g. solvents), transport and the use of crude oil, the use and distribution of natural gas, and from waste disposal sites and waste water treatment. Combustion of fossil fuels in stationary sources usually leads to the production of SO_2, NO_x and Particulates. Domestic fuel use, mainly coal and wood, represents a significant source of the air pollution in cities, particularly cities in developing countries. Urban air pollution has worsened the health in the cities of both developed and developing countries.The health impacts in developing world have been driven by population growth, industrialisation and increased vehicular use (Shanker and Ramarao, 2002). Apart from having human health impacts, air pollution also adversely affects the natural environment .Concentrations of such chemicals in the air affect human health.

Health effects vary with the intensity and the duration of exposure and with the health status of the exposed person. Certain sectors of the population like the elderly, children, and those already suffering from respiratory and cardiovascular diseases, are usually at greater risk. Air pollutants usually affect the respiratory and cardiovascular system. $SO_2$and SPM bring about increased mortality, morbidity, and impaired pulmonary function. NO_2 and O_2 also affect the respiratory system with acute exposures causing inflammatory and permeability responses, decreased lung function, and increases airway reactivity.O_2 causes headaches and eye and nose irritation. Due to its high affinity for haemoglobin, resulting in blood oxygen displacement, CO can lead to cardiovascular and neuro behavioral effects. Very high levels of CO exposure also cause death. Lead (Pb) inhibits the synthesis of haemoglobin in the red blood cells in bone marrow, impairs kidney and liver function, and causes neurological damage. Rapid industrialisation has led to a severe deterioration in water quality in the lakes and rivers of some countries (Ebenstein, 2014).

2.3.8 Principles and standards guiding installation of Telecommunication Masts in Nigeria

According to Nigeria Communication Commission (2009), the following guidelinesissued on the 9th April 2009 provides the following:

Standards to be adhered to by telecommunication services providers/operators, designers, fabricators and installers of telecommunications towers towards ensuring environmental safety and sound engineering practices.

a. Takes cognizance of types and constituents of towers structures and also provides data on winds speeds in Nigeria which may be used as reference materials for engineers in the design of masts and towers.
b. Provides for public safety, safety of personnel and equipment, the responsibilities of owners, designers and fabricators of telecommunication masts and towers relating thereto are set out.
c. The demands of the local operating environment are also taken into consideration by the guidelines alongside the need to achieve substantial conformity with applicable international best practices.
d. Non- compliance with the mandatory provision of these guidelines shall be deemed to be an offence punishable under relevant provision of the Nigeria Communication Commission Act 2003 (the act); the Nigeria communications (Enforcement Processes) Regulations 2005 and other applicable laws.

2.3.9 Types of Towers and masts

1. Monopoly Towers or Post Masts:

Monopoly towers consist of tapered steel tubes that fit over each other to form a stable pole. A monopole tower should be guyed or self-supported and are fitted with climbing rungs where necessary. It should have the following features:

i. Sections should be made from hollow, heavy duty, thick steel tubes, flanged steel tubes or low- alloy, high – strength steel.

ii. Each shaft section should be a constant-tapered hollow steel section.

iii. Slip joints should be designed with a minimum of 1½ times the pole diameter at the splice.

iv. Pipe diameter should decrease from the bottom to up.

v. Monopole are to be made from galvanized hollow steel pipes or high strength steel and designed for a variety of multi-user configurations and finishes to meet local aesthetic requirements.

vi. The pipes shall be tapered to ensure that one pipe base fits into the top of another until the desired height is achieved. A joint in the arrangement should have an overlay between the two adjacent pipes.

vii. The depth of the overlay, the base width and the number of pipes in a particular monopole shall be determined by expected height of a tower, the thickness of the pipes walls, the base diameter and whether the tower shall be guyed or not.

1. **Guyed Towers**:

These are towers that are stabilized by tethered wires. The following specification and recommendation practices apply:

i. Guyed masts may be in lattice, triangular or square, tapered or straight as well as monopole structural forms.

ii. Guyed masts shall be supported and held in position by guy wires or ropes.

iii. Mast guy ropes shall be made from pre-stretched of the guy wires shall be the maximum likely to occur in the worst loading condition.

iv. Guy wires must not be over tightened in the installation of guy towers in order to avoid excessive tension which may cause alignments problems, cable rupture and permanent wrapping of tower structural parts.

2. **Self-Supporting Towers**:

a. Self-supporting towers are free- standing lattice structures

b. The use of self-supporting towers with tapered sections, and face width that vary according to height and load capacity is recommended when land availability is limited provided that it is technically feasible to install them

c. Self-supporting towers shall be designed and constructed as lattice structures should have the following features:

i. Triangular or square structure.

ii. Tube legs, angle legs, lattice legs or solid round legs.

iii. Sections in steel angle steel or steel tubes.

iv. Steel angle cross bracing.

v. Tapered sections.

vi. Face widths vary according to height and load capacity.

vii. Rest platforms provided every 20 meters of height.

viii. Work platforms provided at all height where antennas are to be installed

ix. Fitted with climbing ladder.

3. **Roof Mounts**:

Roof mounts are an inexpensive way of elevating signals above roof interference or any other obstruction. The design and installation of roof mounts has the following specification and recommendation practices:

i. Structural checks must be made to ascertains the capability of a chosen roof to withstand the additional load being imposed on it by the structure and the entire antenna array it will support.

ii. All roof mounted masts or towers must be certified by the building/structural engineer before they are installed.

iii. As a general rule, roof mounts should be limited to light weight structures of low heights and support minimal dead and dynamic loads.

iv. Roofs mounts can be installed in the penetrating or non-penetrating modes and can be self-support or guyed. However non-penetrating roof mounts are most suitable for flat surfaces.

4. **General Features of Towers**:

i. In constructing tower legs, schedule 80 pipes or angle steel should be used although hollow aluminium pipes may be used for short towers.

ii. Bracings should be of angle steel construction or aluminium in case of aluminium towers.

iii. Mast sections, when made from steel pipes, should be joined to each other through joint plates welded to the base of each section. The width of the mast section joint plates should be double the width of the wall of the pipe they are supporting.

iv. Gussets should be used in the strengthening of the weld joint between the base plate and the tower section.

v. Each plate should have four 20mm diameter holes drilled to accommodate four 18mm bolts, nuts and washers.

vi. When bolting sections together, bolts should be placed upside down with washers and nuts and topside of plates, the connecting face of plates should not be painted.

vii. Lock nuts must be used but nuts on bolts may be clinched if lock nut is not utilized.

viii. Lock washers and lock nuts should be on antenna support steel work and dish panning arms in order to avoid loss of signals.

ix. When a tower is made from angle steel, sections should be joined to each other through appropriately sized flanged, bolts, washers and lock nuts.

x. There should be adequate application of bracing to prevent towers been exposed to torque that may result in loss of signal during strong winds speed.

2.3.10 Siting of towers and masts

i. The siting of masts and towers shall take cognizance of provision of the Act and be guided by provisions of the collocation and infrastructure sharing Guidelines of the commission in such a way as to minimize their number, protect and promote public safety, and mitigate adverse visual impacts on the community. To reduce the visual impact of towers and antennas structures, stealth and/ or camouflage design of towers and antennas are encouraged.

ii. All masts and towers sited in cities shall conform to the guidelines and standards of the commission concerning all matters on radio frequency.

iii. All towers sited within residential areas must conform to the setback stipulated in the Guidelines under subsection 5 below and section 9 (9) to mitigate the effect of heat, smoke and noise pollution arising from generating sets.

iv. Telecommunication towers above 25 metres in height would not be permitted within districts delineated as residential.

v. Notwithstanding sub-paragraphy (4) of the guideline, where towers in excess of 25 metres in height are permitted, they should be placed at a minimum setback of 5 meters distance to the nearest demised property, excluding the fence. Prior permission must be obtained from the commission.

vi. Towers and masts sited in the contravention of these guidelines would be removed and the owner of the tower would bear the cost of such removal.

2.3.11 Principles and standards guiding installation of telecommunication masts in Nigeria

The Federal Capital Territory (F.C.T) Abuja also has in its development control manual, the guidelines on installation of telecommunication masts/towers in the F.C.T which is in line with Federal Government Policy bon telecommunication masts and towers, any approval seeker must possess appropriate permits from NCC, NCA and other relevant authorities. Co-location remains the department's first options unless where it is technically not feasible. This has to be beyond reasonable doubt with all applicable technical tests. Telecom mast/towers cannot exist within 500 radial meters from each other. Only backbone sites can be excluded from this requirement. Such as:

2.3.12 General requirement

a. Each applicant shall obtain an applicable form from Development Control Department for a prescribed fee.

b. The form shall be completed and submitted to the Development Control Department within 14days.

c. Each completed application form shall be returned to Development Control Department with the following documents.

i. Tittle document

ii. Lease title, agreement and power of attorney (where applicable) and certificate of incorporation

iii. Current license from the regulatory body legalizing their incorporation.

iv. Site analysis report (SAR) and Environmental Impact Assessment

v. Detailed Telecommunication designs.

vi. Detailed structural, electrical and mechanical engineering designs supported by geo-technical/soil investigation report.

vii. A comprehensive landscape plan of the proposed site.

viii. All designs shall be certified by relevant and registered professionals.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Research Design

The research design describes the methods to be adopted for the investigation of the research questions. The Research design is the planned, structured and strategy of investigation conceived so as to obtain answer questions in order to get credible and reliable information which will help and aid the progress of this research work. It also explains the procedure the result follows in getting the result, and analysis of data presentation and details on how the objectives of the research will be achieved. This study employed the survey research design, which includes the descriptive and cross-sectional survey. The cross-sectional survey helped in obtaining both primary and secondary data on the spot, and collection of quantitative data to draw relevant inferences and conclusions from residents, telecommunication agencies and major stakeholders concerned with physical planning and urban development in the study area. Identify and characterize base stations within Minna town. (Figure. 3.1)

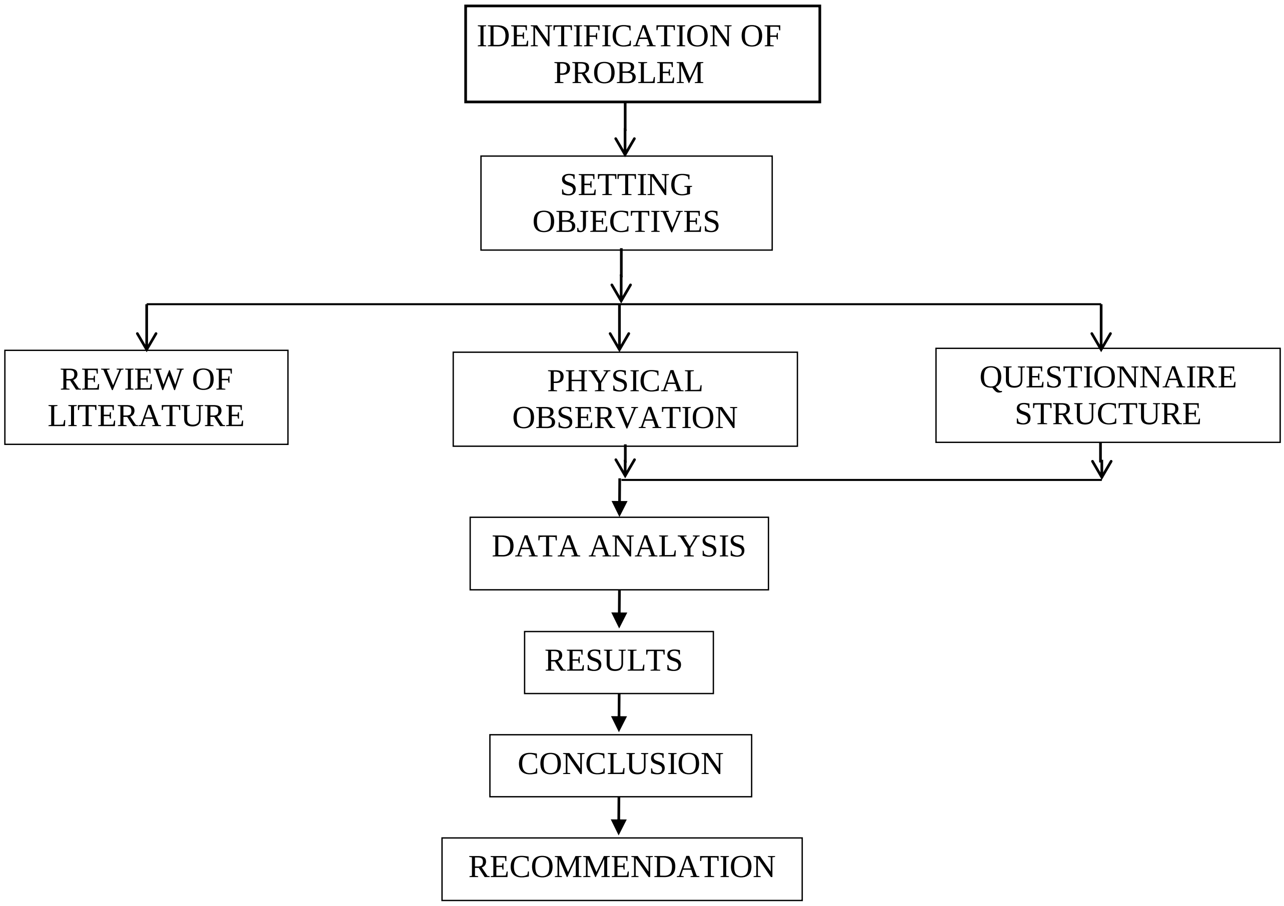

Figure 3. 1: Research Process Flow Chart

Source: Author

3.3 Source of Data Collection

The data required for this study was sourced from the primary and secondary sources. The primary datawas sourced by the researcher through field survey, while the secondary data was sourced from published or archival data. The primary and secondary data required for this study is highlighted in section 3.2.1.

3.3.1 Primary data required

The primary data required for this study is as follows:

i. Geographical coordinates of the masts
ii. Masts characteristics (ownership, security and location)
iii. The distance away from residential or commercial landuse

iv. The air pollution level at the BTS
v. The noise level at the BTS
vi. The types of waste generated and the mode of disposal, among others

3.3.2 Secondary data

i. The satellite imagery of the study area
ii. The administrative boundary of the study area
iii. The NCC guideline on mast
iv. NESREA guideline
v. Town planning edicts
vi. Environmental implication of non-compliance to standard

3.4 Instrument for Data Collection

In the course of this study, different types of instrument was used for the collection of data for the study. The instrument include checklist questionnaire, handheld GPS, digital camera, RASI-700 hand-held air quality meter and Gas detector, internet/laptop and TESTO 815 Sound level meter.

i. Checklist Questionnaire

   The checklist questionnaire was used to collect attribute information on the mast, such as ownership, year constructed, radius of influence, distance to residential landuse, among others.

ii. Global Positioning System (GPS) and Camera

   The handheld GPS was used to capture and record geographic coordinate of the mast. While the digital camera will be used to capture live images of notable on mast location

iii. RASI-700 hand-held air quality meter and Gas detector

   This instrument will be used to collect data on level of gases and radiation from the mast.

iv. TESTO 815 Sound level meter.

3.4.1 Methods of collection of air quality (AQ) and noise level samples

Air samples was measured at an average height of 2 metres above the ground level at each of the graded distances of 10m, 20m, 30m respectively, this measurement was done at the windward direction. Air sample was taken in by 12noon, 6pm in the evening and the collection of samples will on site. Ambient air load (AAL) wasmeasured, these include. Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Carbon monoxide (CO), Hydrogensulphate (H_2S), and Suspended particulate matter(SPM), Total Hydro-Carbon (THC) and ambient temperature was equally determined. Also the noise level was measured at 10m, 20m and 30 m to determine the level of noise generated by the base stations.

3.4.2 Noise exposure limits in Nigeria

Noise pollutipon is recognized as a major problem for the quality of life in urban areas all over the world. Because of the increase in the number of cars and industrialization, noise pollution has also increases. Noise in cities, especially along mainarteries, has reached up disturbing levels. Residents far from noise sources and near silent secondary roads are currently very popular. Many surveys addressing the problem of noise pollution in many cities thrpughout the world have been conducted and have shown the scale of discomfort that the noise causes in people’s ;ives. Existing evidence indicating that noise pollution may have negative impacts on human health has justified research in order to provide better understanding of noise pollution problems and control.

Table 3.1: Noise Exposure Limits in Nigeria (FEPA 1988& FMENV 1998)

Duration per day (h)	Possible exposure limits (dB)
8	90
6	92

4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

Source: Oyedepo and Saadatu (2010).

3.4.3 Air and noise pollution measurement techniques

Measurements of the concentrations of ambient air pollutants such as Nitrous oxide (NO_2), carbon monoxide (CO), Hydrogen sulfide (H_2S) and Sulfur dioxide (SO_2), Suspended particulate matter (SPM) and Total Hydro-Carbon (THC) was carried out within a 10metres radius of the mast. The procedure involves taking repeated readings at different locations. Concentrations of gases was measured through the use of the RASI-700 hand-held air quality meter and Gas detector in parts per million (ppm) and TESTO 815 Sound level meterwith measuring range of 20.3-120 dBA, accuracy of ±1.5 dBA. These handheld equipment was held at about 2m above the 3litter level and the readings was recorded within 10 seconds. All the results of air quality collected and analyzed was compared with NCC and NESREA standards**.**

Table 3.2: Nigerian Ambient Air Quality Standards

Pollutants	Time of Average	Limit
Particulates	Daily average of daily values 1 hour.	250 ug/m^3 *600 ug/m^3
Sulphur oxides (Sulphur dioxide)	Daily average of hourly values 1 hour	0.01 ppm (26 ug/m^3) 0.1 ppm (26 ug/m^3
Non-methane Hydrocarbon	Daily average of 3-hourly values	160 ug/m^3
Carbon monoxide	Daily average of hourly values 8-hourly average	10 ppm (11.4 ug/m^3) 20 ppm (22.8 ug/m^3)
Nitrogen oxides (Nitrogen dioxide)	Daily average of hourly values (range)	0.04 ppm-0.06 ppm (75.0 ug/m^3-113 ug/m^3)
Photochemical oxidant	Hourly values	0.06 ppm

Source: FEPA, 1988

3.5 Method of Data Analysis

The methods of data analysis employed for this study was discussed according to each of the stated objectives of the study.

Objective One:

The data collected for objective one (geographical coordinate, number of telecom mast identified, proximity to building, ownership, year of construction, among others) was analysed using simple descriptive tools such as frequency and percentage to describe the data.

Objective Two:

The data collected for this objective was subjected to spatial analysis and descriptive statistics. The spatial analysis tool employed is nearest neighbourhood analysis under the spatial analysis tools and Buffer tool in ArcGis 10.2 environment. This was used to determine the pattern of distribution of BTS in Minna for each of the telecom operators identified on site. Descriptive statistics tool such as mean and standard deviation was also used to established the average distance between BTS mast and the density of mast per neighbourhood for each telecom operator and across all the operators.

Objective Three:

The achieved objective three, descriptive and inferential statistical tools was employed. The descriptive statistical tools employed are frequency, percentage, mean, weighted value, standard deviation, and compliance index . This was used to describe the level of compliance of the telecom operators to NCC and NESREA standards. The variation in the level of compliance among telecom operators for each of the evaluation indicator was also established using the Analysis of Variance test (ANOVA).

Objective Four:

The level of the vulnerability was also described with the aid of descriptive tools such as mean value and index value. The level of vulnerability was also mapped across each neighbourhood in Minna in order to show the variationin the level of environmental hazards residentials are exposed to as a result of the location of BTS.

3.6 Method of Data Presentation

The presentation of data wasdone with the aid of graphical tools such as table, pie chart, bar chart, pictures and spatial analysis. The presentation of data lay more emphasis on the spatial location of telecommunication masts,effect of environmental problems and role of service operators in ameliorating the effects associated with the sitting of telecommunication mast. The summary of the research methodlogy is presented in Table 3.3.

Table 3.3: Objectives and means of Accomplishment

S/N	Research Objectives	Data Required	Instrument	Method of Analysis
1	Identify and characterise base stations within Minna town.	Locational characteristics of the mast and operator	Handheld GPS and Reconnaissance survey	Descriptive statistics (frequency, percentage) and CHI Square
2	Assess the spatial distribution pattern of telecommunication masts in Minna	GPS coordinates	Handheld GPS and Reconnaissance survey	Nearest neighbourhood Analysis, Buffer Analysis, and Descriptive statistics
3	Evaluate the level of compliance of network providers to standards.	Carbon content, noise pollution, waste disposal, distance from landuse	Checklist questionnaire RASI-700 hand-held air quality meter and Gas detector, A TESTO 815 Sound level meter.	Descriptive statistics (frequency, percentage) and ANOVA (inferential Statistics)
4	Determine the implication of the spatial distribution of masts in Minna on the environment	Data from objective three	Field survey and other relevant secondary data,	Descriptive statistics (frequency, percentage) and density mapping

Source: Authors Field Work, 2015

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Location and Characteristics of GSM Mast in Minna

4.1.1 Number of GSM operators antennas in Minna

The study identify four GSM operator mast in Minna; the GSM operators are MTN, Globacom, 9Mobile, and Airtel. Table 4.1 shows the distribution of GSM operators in Minna with their coordinates (Figure 4.1). The Table shows that a total of 74 telecommunication antennas were identified in Minna. MTN antennas were 23 in number which accounted for 31% of the total antennas identified, Globacom and Airtel mobile had 18 (24%) antennas respectively, while 9mobile a total of 15 antennas which accounted for 21%. This shows that all the telecommunication operators are adequately represented with the geographical space of Minna.

Table 4.1: GSM Operators in Minna

Telecoms Operators	Frequency	Percentage
MTN	23	31
GLOBACOM	18	24
AIRTEL	19	25
9MOBILE	15	21
Total	**74**	**100**

4.1.2 Distribution of GSM mast in Minna

Although, a total of 74 telcoms antenna were identified in Minna, only 58 GSM mast was identified and this is presented in Figure 4.1. The low number of mast compared to the number of antennas is as a result of co-location of the telecoms operators with one another. The distribution of the telecom antennas based on mast is presented in Table 4.2. The result shows that 9mobile had 67% of her mast co-located with other network antennas on a mast, while Airtel mobile had 61% of her

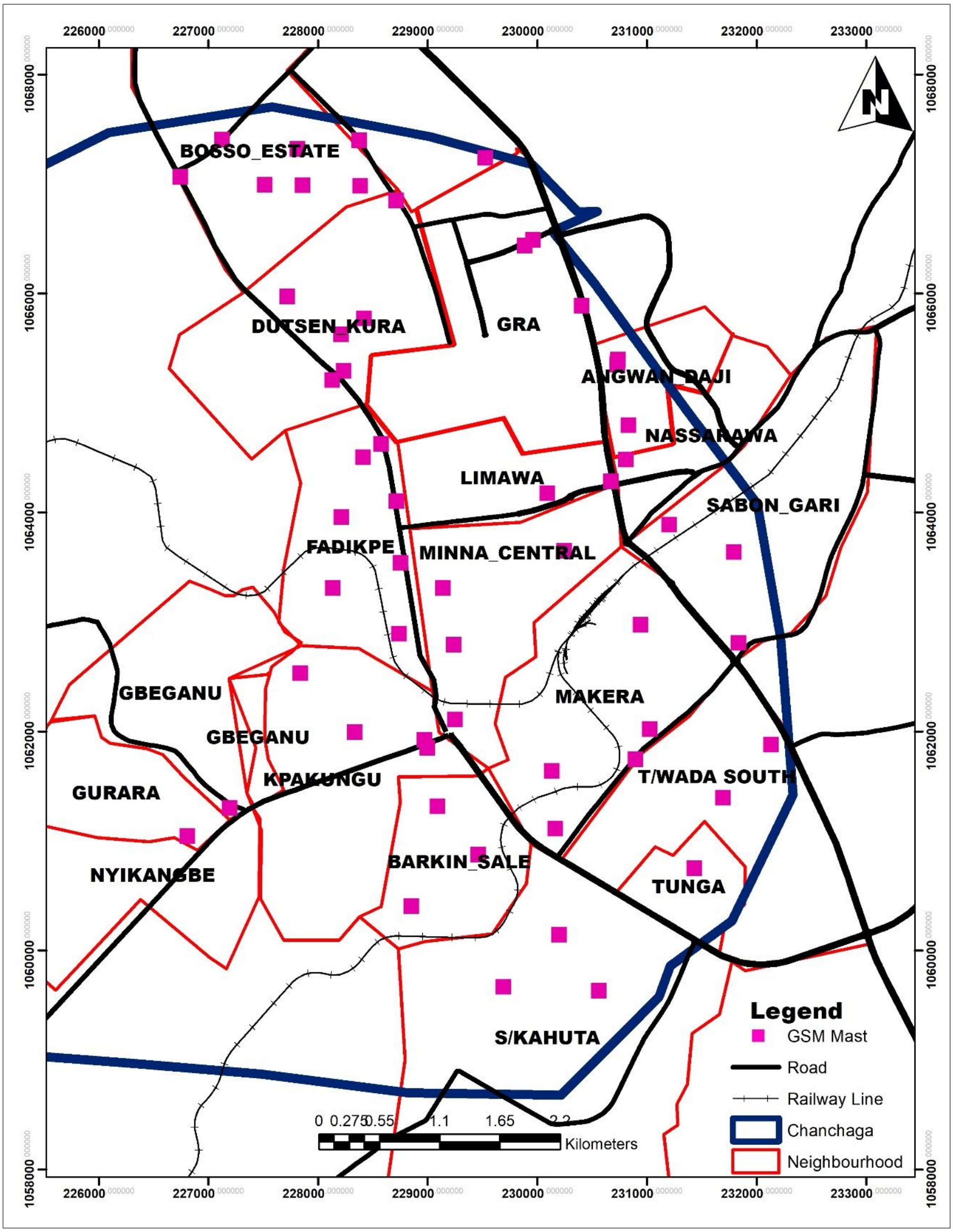

Figure 4.1 Distribution of GSM Mast in Minna

Mast co-located with other telecoms antennas, MTN recorded 39% colocation and Globacom mobile had 22% of her antennas on the same mast with one or two other telecoms antennas. This shows that 9mobile and Airtel are more complaint with the co-location directive of the Nigerian Communication Commission (NCC), which is targeted at reducing the spread and dangers of mast location on the people.

Table 4.2: GSM Antenna Location in Minna

Telecoms Operators	**Frequency**	**Percentage**	**Frequency**	**Percentage**
	Single Antenna		**Co-Location**	
MTN	14	61	9	39
GLOBACOM	14	78	4	22
AIRTEL	8	44	11	61
9MOBILE	5	33	10	67

4.1.3 Spatial distribution of single and multiple antenna mast in Minna

Table 4.3 that a total of 42 antennas are occupied individually by either of the four telecoms operators (MTN, GLO, Aitrtel, 9mobile) which accounted for 72% of the mast in Minna. This is an indication that years after the pronouncement of the co-location rule by NCC, most of the telecoms operators are still reluctant to adhere to this law. It was revealed that only 28% of 16 mast had more than one telecoms operator antennas.

Table 4.3: GSM Mast Distribution based on the Number of Antennas

Antenna	**Frequency**	**Perentage**
Single	42	72
Multiple Antenna	16	28
Total	**58**	**100**

The spatial distribution pattern of the single and co-located mast is presented in Figure 4.2. The Figure shows that single antenna mast and multiple antenna mast were distributed in a dispersed manner across the length and breadth of Minna (Figure 4.2).

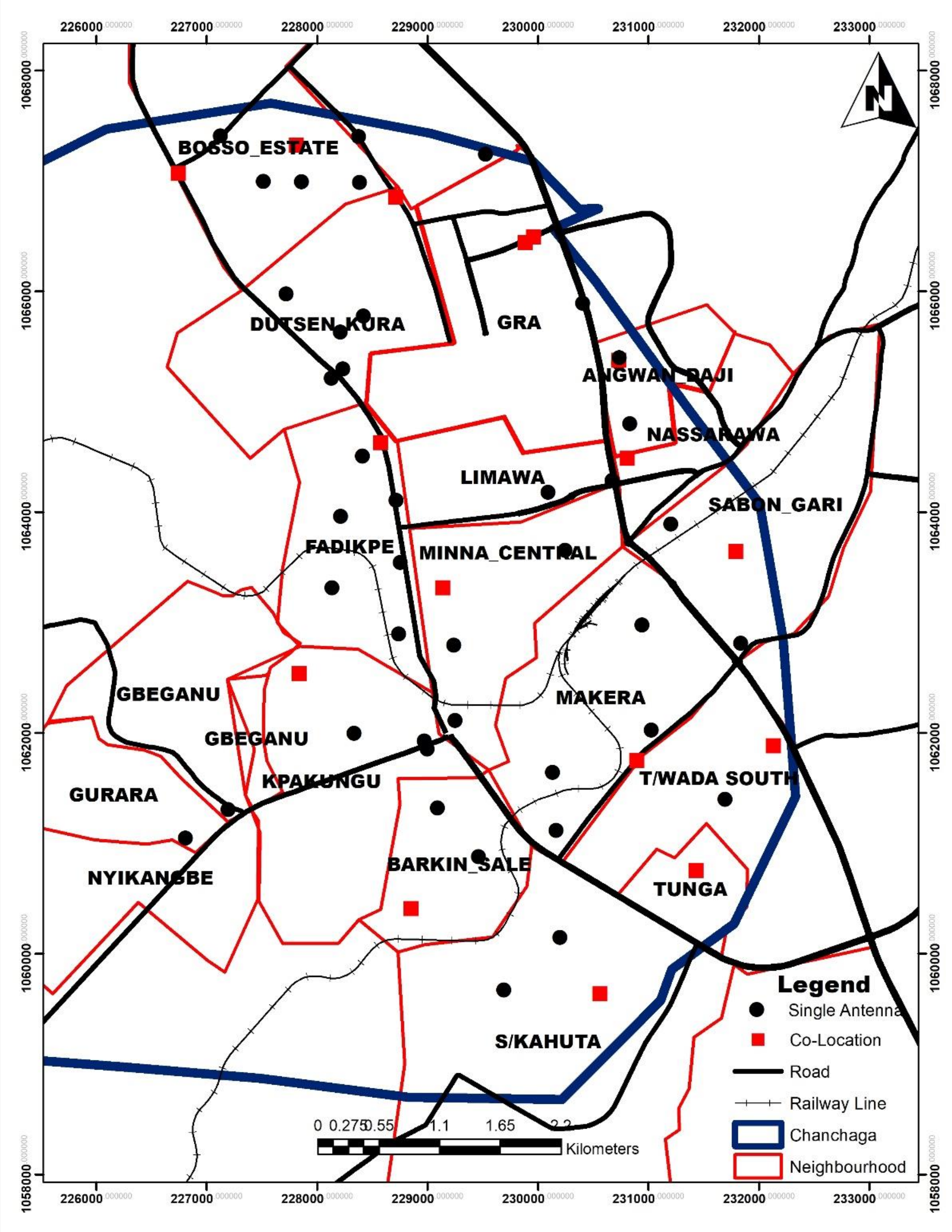

Figure 4.2: Spatial Distribution of GSM Mast based on the Number of Antennas

4.1.4 Spatial distribution of GSM mast in Minna

The study also assessed the number of telecoms mast within each of the seventeen (17) neighbourhoods of Minna. Table 4.4 shows that Bosso estate had the highest number of telecoms mast (8), which accounted for 14% of the total GSM mast in Minna. Fadikpe had 7 (12%), Dutsen Kura had 6 (10%), Kpakungu, Minna central, AngwanDaji, and Makera had 4 (7%) respectively. The neighbourhood with the least number of GSM mast are Tunga (1), Gurara (1), Gbeganu (1), and Nasarawa (1), which accounted for 2% respectively.

Table 4.4: Spatial Distribution of GSM Mast by Neighbourhoods

Antenna	Frequency	Perentage
Bosso Estate	8	14
Dutsen Kura	6	10
GRA	3	5
Gurara	1	2
Makera	4	7
Nasarawa	1	2
Gbeganu	1	2
Fadikpe	7	12
Limawa	2	3
Kpakungu	4	7
AngwanDaji	4	7
SabonGari	3	5
Minna Central	4	7
Barkin Saleh	3	5
S/Kahuta	3	5
Tunga	1	2
Tudun Wada South	3	5
Total	**58**	**100**

This shows that there is variation in the distribution of GSM mast in Minna. Some neighbourhoods are more populated with GSM mast than the others. Which implies that in neighbourhoods with more number of GSM mast are more vulnerable to the health implication of the GSM mast.

4.2 Spatial Distribution Pattern of GSM Mast in Minna

4.2.1 Spatial distribution of GSM based on minimum distance

The study assessed the spatial distribution of the various GSM mast based on their minimum distance apart. The result shows that irrespective of the GSM mast operator, the minimum distance between GSM mast in Minna is 10.5m. However, for the various GSM operators, the minimum distance between mast of the same network provider ranges from 92m which is the minimum recorded by Globacom and a maximum of 403m recorded by 9Mobile. MTN network recorded a minimum of 146m and Airtel 147m apart for their respective Mast (Table 4.5). The average distance between GSM mast in Minna is 486.75m.

However, the average distance of GSM mast apart for individual network providers varies significantly from the overall average distance recorded. The average distance apart for Globacom mast is 844.6m, MTN 860.9m, 9Mobile 1061.3m, and Airtel 1091.0m. The distance between GSM mast in Minna is classified into 3 groups of low, fair and high, and the result is depicted in Figure 4.3. The result shows that in the northern part of Minna, the distance between GSM mast of the varous operators is low (10.5-693), a similar trend is also observed in the core area of Minna. This is an indication of the sporadic distribution of GSM mast across the city center which has implication on the resident health.

Table 4.5: Distance Between GSM Mast in Minna

Statistic	MTN	AIRTEL	9MOBILE	GLO	Overall
Minimum	146.0	147.0	403.0	92.0	10.54
Maximum	1372.0	2087.0	1602.0	1427.0	910.47

Median	874.0	1013.0	1129.0	923.0	1217.0
Mean	860.9	1091.0	1061.3	844.6	486.75
Standard deviation (n)	348.2	462.4	351.6	336.7	152.32
Variation coefficient	0.4	0.4	0.3	0.4	0.40

4.2.2 Spatial pattern of GSM mast density within neighbourhoods in Minna

The study also examined the spatial variation in density of GSM mast in the respective neighbourhood in Minna. The density of GSM mast in the respective neighbourhood was determined by divinding the area coverage of the respective neighbourhood in square kilmetre with the number of GSM mast available in the neighbourhood. Table 4.6 reveals that Angwan Daji is the most densely populated neighbourhood with GSM mast is Angwan Daji (3.960) to rank first among other neighbourhoods. Fadikpe ranked 2^{nd} with a density of 2.881, Dutsen Kura ranked 3^{rd} (1.853), Bosso Estate ranked 4^{th} with a density value of 1.848, while Barkin Saleh ranked 5^{th} with a density value of 1.734. Neighbourhoods with low density include Gbeganu with a density value of 0.346 with a rank of 17^{th}, S/Kahuta ranked 16^{th} with a density value of 0.386, while Gurara ranked 15^{th} with a density value of 0.709. The density of GSM mast in Minna was classified into five classes using Jenks classification and the result is presented in Figure 4.4.

Table 4.6: Density of GSM Mast in Minna

Neighbourhood	Area Sqkm (A)	GSM Mast (N)	Density = (N/A)	Rank
GURARA	1.41	1	0.709	15^{th}
GBEGANU	2.89	1	0.346	17^{th}

S/KAHUTA	7.77	3	0.386	16th
BOSSO_ESTATE	4.33	8	1.848	4th
DUTSEN_KURA	3.23	6	1.858	3rd
GRA	3.61	3	0.831	13th
FADIKPE	2.43	7	2.881	2nd
LIMAWA	1.36	2	1.471	7th
ANGWAN_DAJI	1.01	4	3.960	1st
NASSARAWA	1.22	1	0.820	14th
MINNA_CENTRAL	2.45	4	1.633	6th
SABON_GARI	3.45	3	0.870	11th
KPAKUNGU	3.73	4	1.072	10th
BARKIN_SALE	1.73	3	1.734	5th
MAKERA	3.40	4	1.176	9th
T/WADA SOUTH	3.52	3	0.852	12th
TUNGA	0.75	1	1.333	8th

Figure 4.4 shows that Fadikpe and Angwandaji are highly dense (1.858-3.960) with GSM mast, while Bosso Estate, Dutsenkura, Minna central are classified as high (1.471-1.849) in GSM mast density. Fairly dense (0.851-1.470) neighbourhood in terms of GSM mast distribution in Minna are; Kpakungu, Makera, Tunga, and Limawa. The density of GSM mast in GRA, Nasarawa, T/Wada South, and Gurara is classified as low (0.386-0.852), while GSM mast density in Gbeganu, S/Kahuta, and SabonGari is classified as very low (0.087-0.385). The variation in GSM mast density of neighbourhood is an indication that network providers does not consider the area of neighbourhood while citing GSm mast within the neighbourhoods.

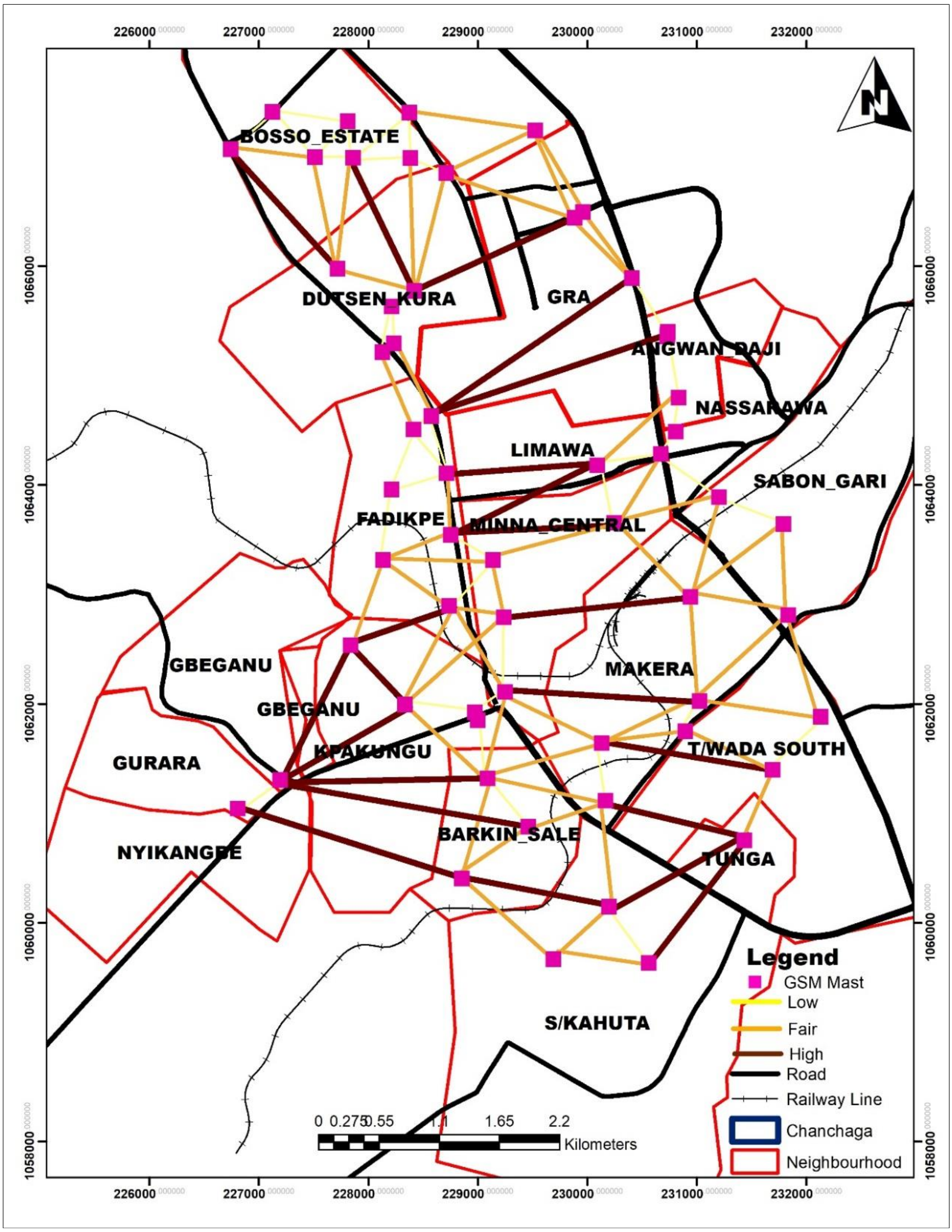

Figure 4.3: Minimum Distance between GSM Mast in Minna

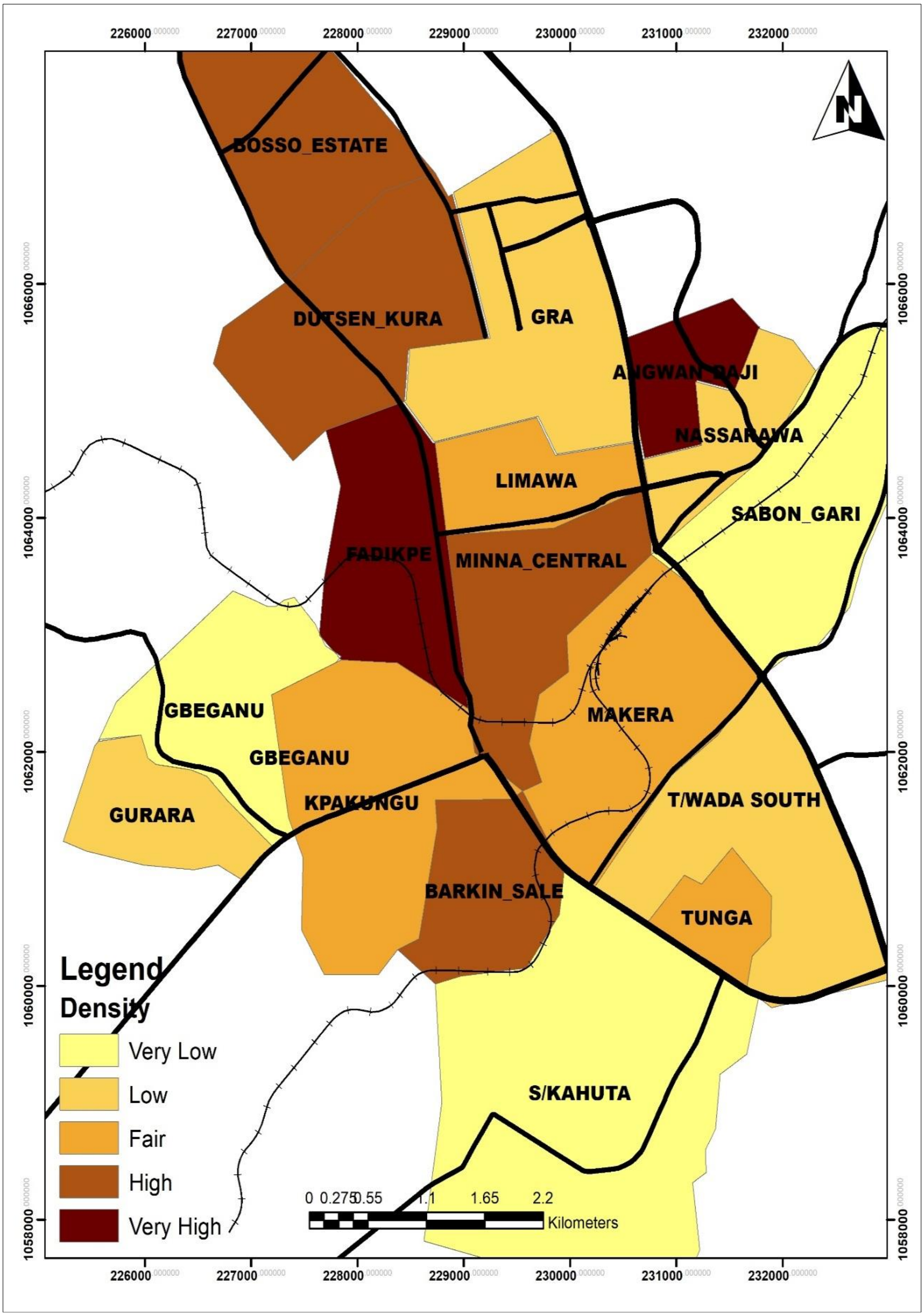

Figure 4.4: Spatial Distribution of Density of GSM Mast in Minna

4.2.3 Spatial distribution pattern of GSM mast in Minna

To determine the spatial distribution pattern of the GSM mast in Minna, the nearest neighbourhood analysis was carried out. The spatial distribution pattern of each GSM operators mast was conducted and the general distribution of all the mast irrespective of the operator was also conducted in ArcGis 10.5 environment. The result and the detail of the analysis is presented in the sections below.

4.2.3.1 Spatial distribution pattern of MTN mast in Minna

The spatial distribution pattern of MTN mast in Minna was carried out and the result is presented in Table 4.7. The analysis recorded observed mean distance of 684.6m, while the expected mean distance is 606.4m. The nearest neighbourhood ratio for the analysis is 1.129, while a z-score of 1.183 and a p-value of 0.237 was recorded. Given a z-score of 1.183 and a p-value of 0.237, it implies that the spatial distribution pattern of MTN mast in Minna is not signofocantly different from a random pattern. Since, the z-score fall within -1.65 and 1.65, it implies that the pattern does not follow any specific pattern (regular or clustered). The graphical representation of the spatial distribution of MTN mast is presented in Figure 4.5. This is an indication that the location of most MTN mast in Minna were not cited with attention to specific criteria such as area of the neighbourhood or population of the neighbourhood.

Table 4.7: Average Nearest Neighbor Summary for MTN Mast in Minna

Statistics	Value
Observed Mean Distance:	684.6 Meters
Expected Mean Distance:	606.4 Meters
Nearest Neighbor Ratio:	1.129
z-score:	1.183
p-value:	0.237

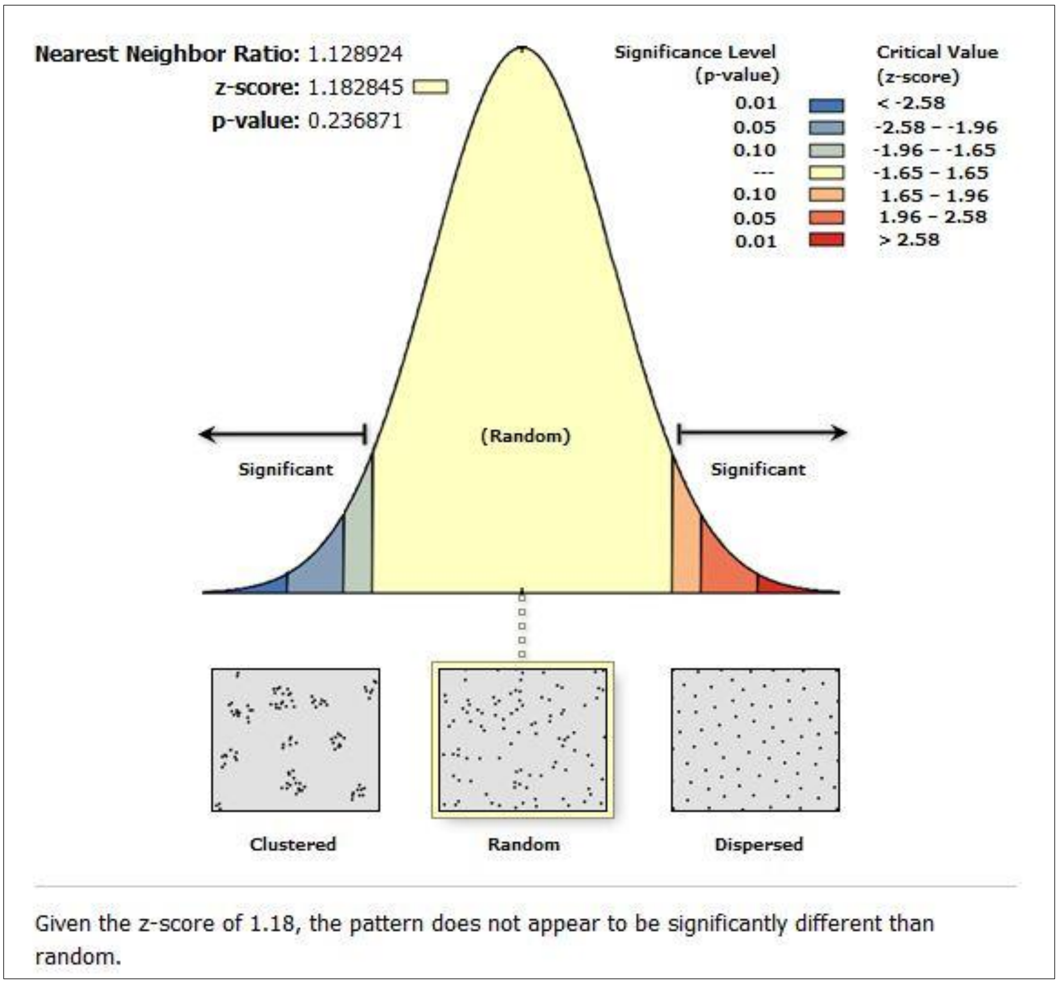

Figure 4.5: Spatial Distribution Pattern of MTN mast in Minna

4.2.3.2 Spatial distribution pattern of Airtel mast in Minna

Table 4.8 shows the result of the nearest neighbourhood analysis for the spatial distribution pattern of Airtel network mast in Minna. The Table shows that an observed mean distance of 807.7 between GSM mast was recorded with an expected mean distance of 8674.1. The analysis also recorded a nearest neighbourhood ratio of 0.093, while a z-score of -8.320 and a p-value of 0.00 was recorded. Therefore, given a z-score of -8.320, it implies that the spatial distribution pattern of Airtel mast is clustered (Figure 4.6). There is less than 1% likelihood that this clustered pattern could be the result of a random chance. This implies that, this pattern must have been informed by a specific criteria which determine s suitable site for the mast. The spatial distribution pattern of globacom mast in Minna is presented in Figure 4.6.

Table 4.8: Average Nearest Neighbor Summary for Airtel Mast in Minna

Statistics	**Value**
Observed Mean Distance:	807.7 Meters
Expected Mean Distance:	8674.1 Meters
Nearest Neighbor Ratio:	0.093
z-score:	-8.320
p-value:	0.000

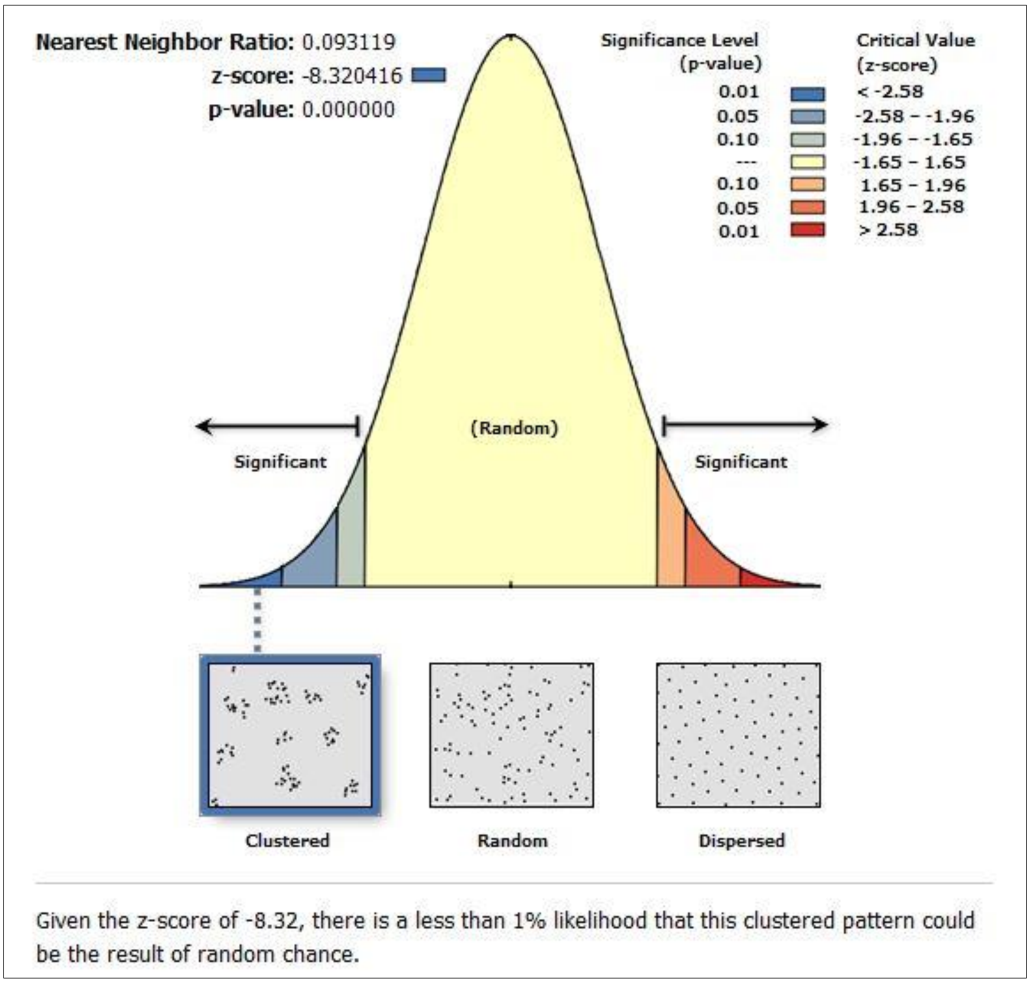

Figure 4.6 Spatial Distribution Pattern of Airtel Mast in Minna

4.2.3.3 Spatial distribution pattern of Globacom mast in Minna

The spatial distribution pattern of Globacom GSM mast is presented in Table 4.9. The nearest neighbourhood summary for the analysis as depicted in Table 4.9 shows that an observed mean distance of 669.6m and expected mean distance of 978,530.4m was recorded. The analysis also recorded a nearest neighbourhood ratio of 0.000684, while a z-score of -9.168 and p-value of 0.00. Having recorded a z-score of -9.17, the spatial distribution pattern of Globacom GSM mast in Minna can be described as clustered. Given a p-value of 0.00, it implies that there is less than 1% likelihood that this clustered pattern could be the result of a random chance. This is an indication that there is a conscious attempt and criteria for the citing of Globacom GSM mast in

Minna. The spatial distribution pattern of Globacom GSM mast in Minna is depicted in Figure 4.7 Table 4.9:Average Nearest Neighbor Summary for Globacom Mast in Minna.

Table 4.9:AverageNearest Neighbor Summary for Globacom Mast in Minna

Statistics	Value
Observed Mean Distance:	669.6 Meters
Expected Mean Distance:	978530.4 Meters
Nearest Neighbor Ratio:	0.000684
z-score:	-9.168484
p-value:	0.000

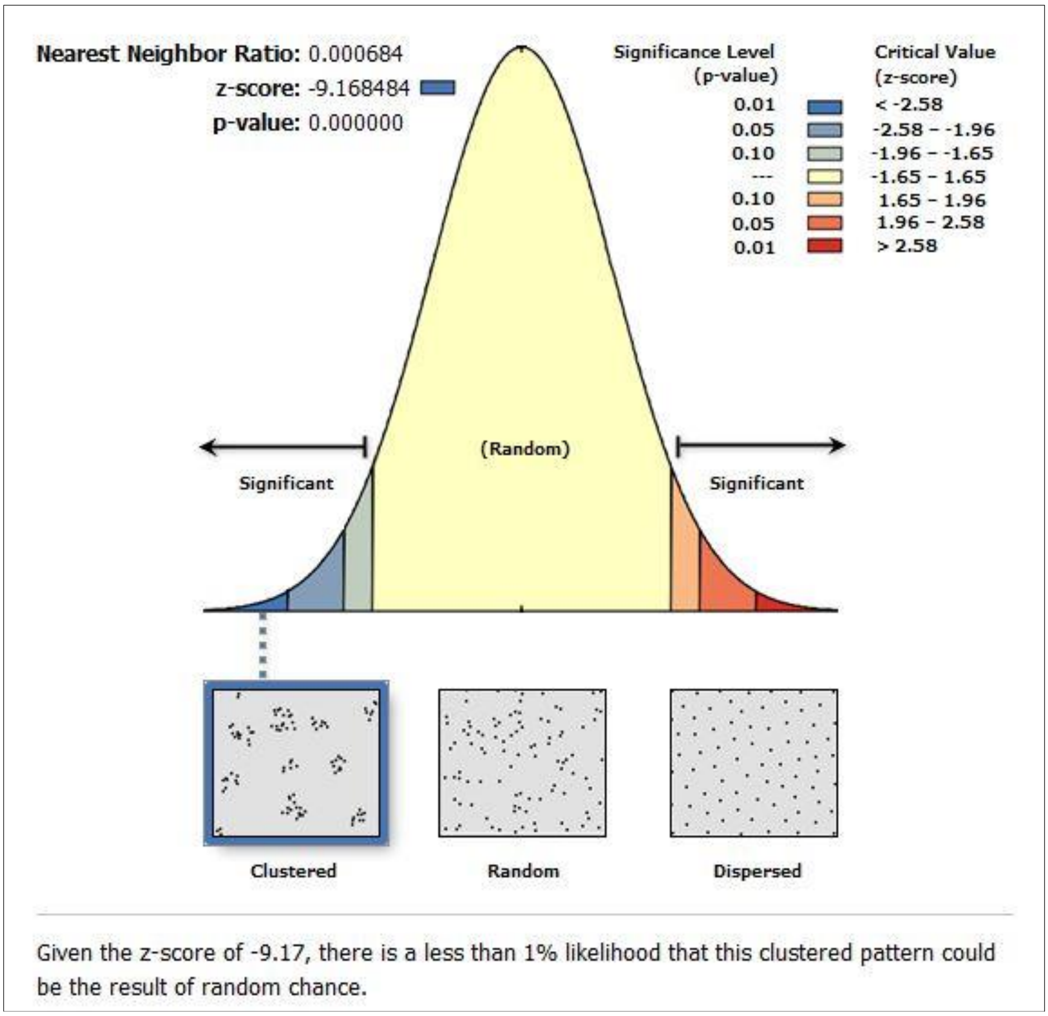

Figure 4.7 Spatial Distribution Pattern of Globacom Mast in Minna

4.2.3.4 Spatial distribution pattern of 9Mobile mast in Minna

Table 4.10 shows the average nearest neighbor summary for 9Mobile GSM mast in Minna. The nearest neighbourhood 9mobile as depicted in Table 4.10 shows that an observed mean distance of 659.2m and expected mean distance of 8674.1m was recorded for the analysis. The analysis recorded a nearest neighbourhood ratio of 0.076, while z-score and p-value of -8.477 and 0.000 was recorded respectively. Given a z-score of -8.477, the spatial distribution pattern of 9Mobile can be described as clustered (Figure 8). The chances that this pattern is due to random chance is less than 1% having recorded a p-value of 0.00.

Table 4.10: Average Nearest Neighbor Summary for 9Mobile Mast in Minna

Statistics	Value
Observed Mean Distance:	659.2 Meters
Expected Mean Distance:	8674.1 Meters
Nearest Neighbor Ratio:	0.075999
z-score:	-8.477491
p-value:	0.000

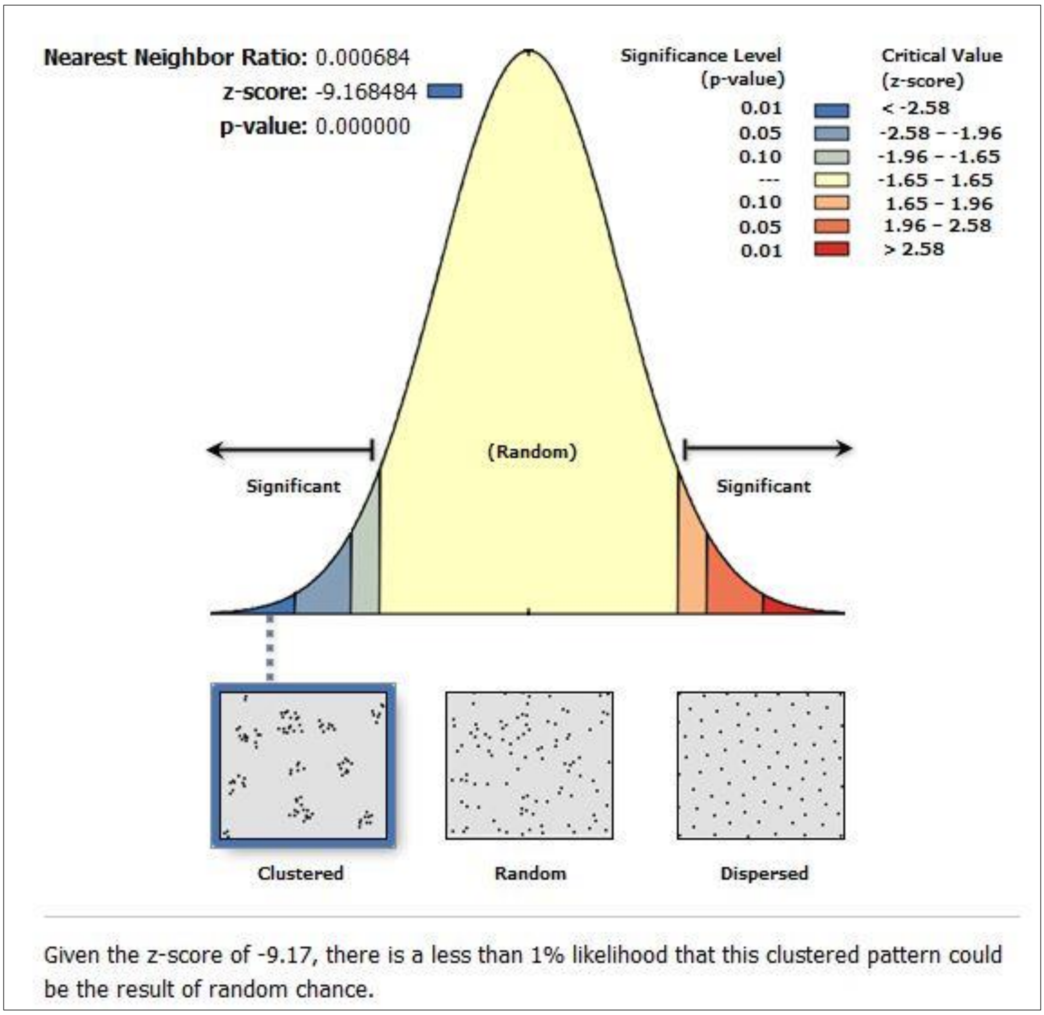

Figure 4.8 Spatial Distribution Pattern of Globacom Mast in Minna

4.3 Level of Compliance of Network Providers to NCC and NESREA Standard

4.3.1 Level of compliance of network providers to NCC standard 5 metres setback from residential buildings

The study assessed the compliance level of the network providers to National Communication Commsission (NCC) guideline on setback between GSM mast and residential building. Table 4.11 shows the level of compliance of network providers in Minna. The result shows out of the 23 MTN GSM mast with MTN mast on it, six (6) of them where within a distance of less than 5 metres from residential landuse, with a non-compliance level of 0.26 on a scale of 1. Globacom mobile has 3 out of 18 GSM mast within the 5m setback, while Airtel mobile has 5 out of 19 GSM mast within the 5m setback stipulated by NCC. Table 4.11 also shows that 5 out of 15

GSM mast of 9mobile do not conform with the NCC standard of 5m setback, while it recorded a non-compliance index of 0.33.

Table 4. 11. Non-Compliance Level of Network Providers to NCC 5m Setback

Neighbourhood	MTN	GLO	AIRTEL	9MOBILE
GURARA	0 (0)	0 (0)	1 (0)	0 (0)
GBEGANU	1 (0)	0 (0)	0 (0)	0 (0)
S/KAHUTA	1 (0)	0 (0)	1 (1)	2 (1)
BOSSO_ESTATE	3 (1)	3 (1)	2 (0)	3 (1)
DUTSEN_KURA	3 (1)	1 (0)	2 (1)	1 (0)
GRA	1 (0)	3 (0)	2 (0)	0 (0)
FADIKPE	4 (2)	1 (0)	1 (0)	2 (1)
LIMAWA	1 (1)	0 (0)	2 (0)	1 (0)
ANGWAN_DAJI	1 (0)	0 (0)	1 (1)	1 (0)
NASSARAWA	1 (0)	0 (0)	0 (0)	0 (0)
MINNA_CENTRAL	1 (1)	2 (0)	1 (0)	1 (0)
SABON_GARI	1 (0)	1 (0)	1 (0)	1 (0)
KPAKUNGU	2 (0)	2 (1)	0 (0)	1 (1)
BARKIN_SALE	1 (0)	1 (0)	2 (1)	0 (0)
MAKERA	1 (0)	3 (1)	1 (0)	0 (0)
T/WADA SOUTH	1 (0)	1 (0)	2 (1)	1 (1)
TUNGA	0 (0)	0 (0)	0 (0)	1 (0)
Total	**23 (6)**	**18 (3)**	**19 (5)**	**15 (5)**
Compliance Index	**0.26**	**0.17**	**0.26**	**0.33**

4.3.2 Level of compliance of network providers to NESREA standard 10metres setback from residential buildings

The Study also examined the compliance of the network providers to National Environmental Standards and Regulations and Enforcement Agency (NESREA) setback of 10m as stated in NESREA 2011 guidelines of GSM installation. The result of the analysis is presented in Table 4.12. The result shows that MTN has 15 GSM mast that do not conform with the 10m setback stipulated by NESREA, Globacom had 12, Airtel had 13, and 9mobile had 9. The study shows that Airtel has the highest non-compliance index of 0.68, followed by Globacom 0.67, and

MTN 0.65, while 9mobile had the least non-compliance index of 0.60.The high non-compliance index recorded by the network providers may be as a result of the fact that most of the GSM have been constructed before the NESREA guideline on GSM mast distribution was enacted.

Table 4.12: Non-Compliance Level of Network Providers to NCC 5m Setback

Neighbourhood	MTN	GLO	AIRTEL	9MOBILE
GURARA	0 (0)	0 (0)	1 (1)	0 (0)
GBEGANU	1 (0)	0 (0)	0 (0)	0 (0)
S/KAHUTA	1 (0)	0 (0)	1 (1)	2 (1)
BOSSO_ESTATE	3 (2)	3 (2)	2 (2)	3 (1)
DUTSEN_KURA	3 (3)	1 (1)	2 (1)	1 (0)
GRA	1 (0)	3 (2)	2 (0)	0 (0)
FADIKPE	4 (3)	1 (0)	1 (0)	2 (2)
LIMAWA	1 (1)	0 (0)	2 (1)	1 (1)
ANGWAN_DAJI	1 (1)	0 (0)	1 (1)	1 (1)
NASSARAWA	1 (0)	0 (0)	0 (0)	0 (0)
MINNA_CENTRAL	1 (1)	2 (2)	1 (1)	1 (1)
SABON_GARI	1 (0)	1 (1)	1 (0)	1 (0)
KPAKUNGU	2 (1)	2 (1)	0 (0)	1 (1)
BARKIN_SALE	1 (1)	1 (1)	2 (2)	0 (0)
MAKERA	1 (1)	3 (2)	1 (1)	0 (0)
T/WADA SOUTH	1 (1)	1 (0)	2 (2)	1 (1)
TUNGA	0 (0)	0 (0)	0 (0)	1 (0)
Total	**23 (15)**	**18 (12)**	**19 (13)**	**15 (9)**
Compliance Index	**0.65**	**0.67**	**0.68**	**0.60**

4.3.3 Telecommunication service operators compliance to NCC regulation of 1km tower to-tower

The telecommunication service operators as regards to NCC regulation of 1km (1000m) radius to tower to tower spacing for siting of telecommunication masts is assessed and the result is presented in Table 4.13. The result shows that only 5 of MTN mast conforms to the 1000m tower to tower setback guideline by the NCC. Globacom had six in conformity with the standard of 1000m tower to tower distance, Airtel had 9, and 9mobile had 8. Table 4.13 also shows that 9Mobolie had the the highest compliance index of 0.53 to rank first, while Airtel had 0.47 (2^{nd}), while Globacom (0.33) and MTN (0.22) ranked 3^{rd} and 4^{th} respectively. The distribution of the mast based on 1000m tower to tower setback is depicted in Figure 4.9-4.12 for MTN, GLO, AIRTEl and 9Mobile respectively.

Table 4.13: Compliance to NCC 1000m Tower to Tower Setback

Network	**Below 1000m**	**Above 1000m**	**Compliance Index**	**Rank**
MTN	18	5	0.22	4^{th}
GLO	12	6	0.33	3^{rd}
AIRTEL	10	9	0.47	2^{nd}
9MOBILE	7	8	0.53	1^{st}

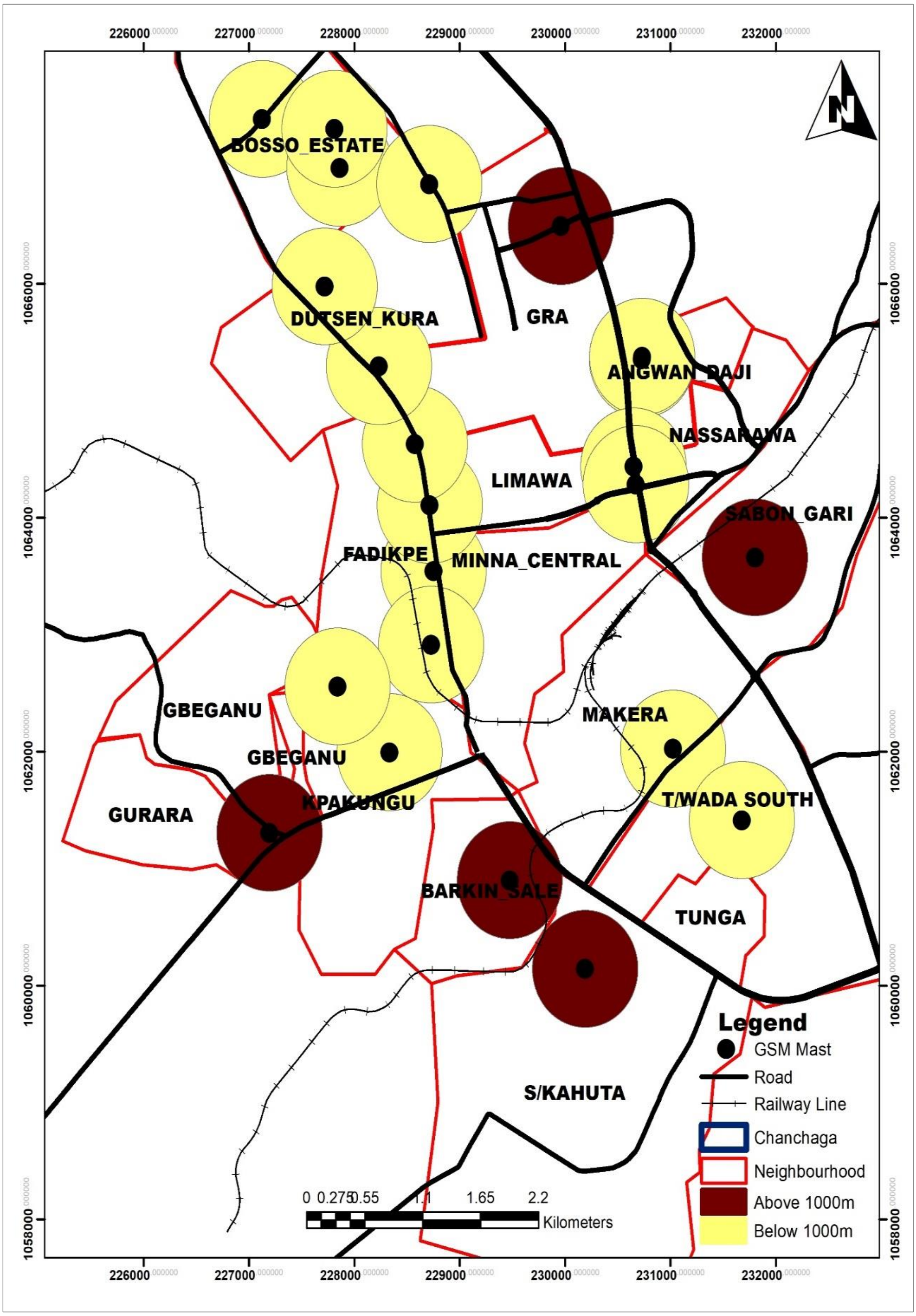

Figure 4.9: 1000m Buffer Analysis of MTN Mast in Minna

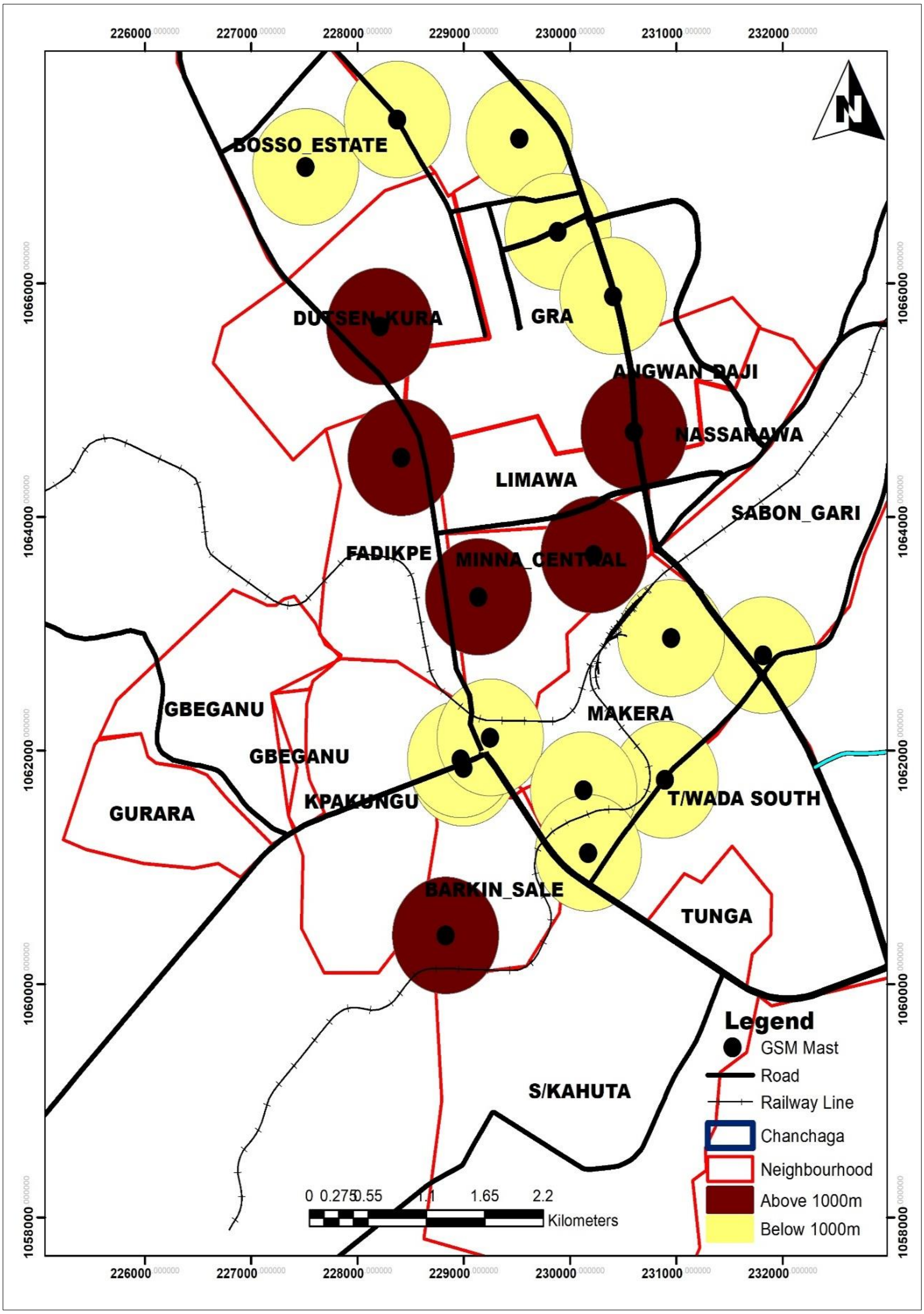

Figure 4.10: 1000m Buffer Analysis of Globacom Mast in Minna

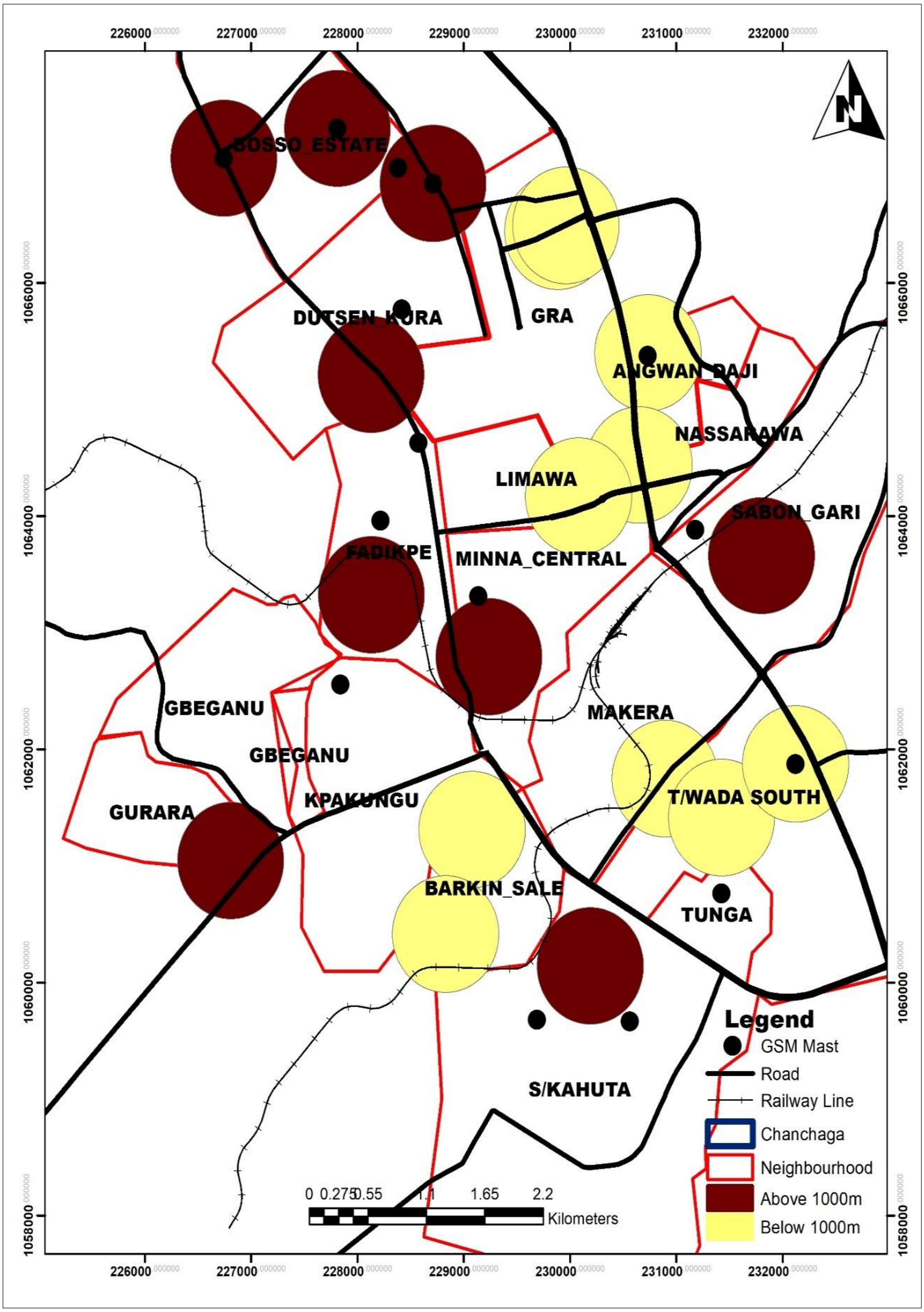

Figure 4.11: 1000m Buffer Analysis of Airtel Mast in Minna

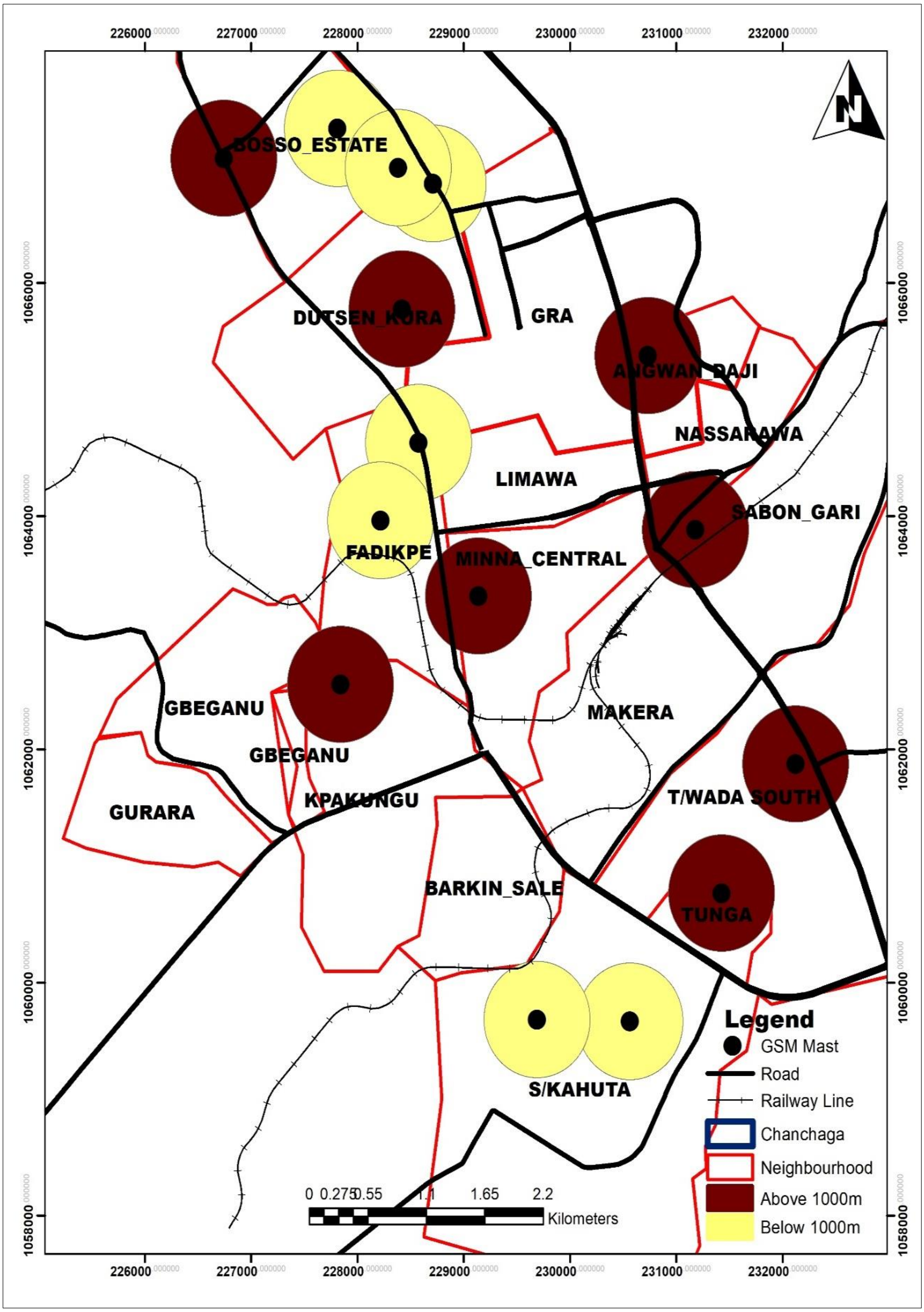

Figure 4.12: 1000m Buffer Analysis of 9Mobile Mast in Minna

4.4 Health Implication of the Spatial Distribution of GSM Masts in Minna

4.4.1 Environmental problems associated with telecommunication mast

The environmental problems associated with the siting of base stations on the environment in the study area, ranges from gases and noise emission level on the environment. The ambient air quality, noise level measurements was carried out around the sample one randomly selected base station for each of the four network operators in Minna, and compared with Federal Ministry of Environment in Nigeria (FMENV) stipulated limits as shown in Table 4.14.

4.4.2 Effect of telecommunication mast on the environment

Table 4.14 shows the environmental pollution indices of the network operators in Minna. The result shows that 9mobile base station in Fadikpe contravene the 90(dB) noise level limit stipulated by FMENV for noise at 10m setback from the base station. At 10m distance the noise level of the base station is 92.3(dB). This shows that the noise generated from the base station can be harmful to human health within 10m radius of the base station. Similarly, the Total Hydrcarbon (THC) readings recorded within 10m radius of the GSM mast exceeded the 10ppm limit stipulated by FMENV. The THC recorded within 10m distance from the base station is 11.2ppm as against the acceptable limit of 10ppm. 9mobile base station also exceeded the acceptable limit of 0.04-0.06 for Nitrogen oxide (NO) at 10m (2.00), 20m (0.09), and 30m (0.06). Exceeding the acceptable limit for these gases has significant implication on the health of residents within this area. The study revealed that environmental indices observed in Bosso Estate for Globacom network falls within the FMENV limit for noise and all other gases examined in the study.

The study further revealed that the MTN base station observed in Kpakungu exceeded the acceptable noise limit of 90(dB) within 10 and 20 metres radius from the base station. The noise level recorded within 10m radius of the mast is 91.6(dB) and 90.1(dB) at 20m radius. The MTN mast also exceeded the FMENV limit for Nitrogen dioxide and Sulphur dioxide with a value of 0.08ppm and 0.3ppm respectively at 10m radius. All other observation were within the acceptable limit of the FMENV.

Furthermore, Table 4.14 also shows that the Airtel base station observed in Dutsen Kura exceeded the noise level limit with 10m radius. The noise level at the base station within 10m radius is 90.8(dB). In addition, Nitrogen dioxide (NO_2) limit of 0.04-0.06 was also exceeded at the base station within 10m (0.4), 20m (0.29), and 30m (0.12). The Table also shows that the Airtel base station exceeded the THC limit of 10ppm as prescribed by FMENV. The THC recorded within 10m radius is 16.0 and 13.4 at 20m radius. Having exceeded the acceptable limit as prescribed by FMENV, it can be inferred that this situation will impact negatively on the environment and residents within close proximity with the base station

Table 4.14: Ambient Air Quality and Noise level measured at selected Base Stations in Minna

s/no	Site id	Coordinates (m)		sampled location	operator	Distance (m)	Noise level (dB)	C0 (ppm)	N0 (ppm)	$N0_2$ (ppm)	$S0_2$ (ppm)	H_2S (ppm)	THC (ppm)
		Eastings	Northings										
						10 m	**92.3**	0.0	**2.0**	0.03	0.0	0.003	**11.02**
1.	BTSs 01	332701.5	1002560.7	Fadikpe	9Mobile	20 m	57.9	0.0	**0.09**	0.02	0.0	0.02	9.6
						30 m	56.6	0.0	**0.06**	0.0	0.0	0.0	8.2
						10 m	46.2	2.0	0.01	0.003	0.001	0..1	3.01
2.	BTSs 02	332900	1002435	Bosso Estate	Globacom	20 m	52.8	1.07	0.0	0.0	0.0	0.0	2.06
						30 m	51.3	1.0	0.0	0.0	0.0	0.0	1.03
						10 m	**91.6**	2.01	0.0	**0.08**	**0.3**	0.03	6.4
3.	BTSs 03	333825.3	1003336.3	Kpakungu	MTN	20 m	**90.1**	1.05	0.0	0.03	0.01	0.0	4.6
						30 m	65.5	0.04	0.0	0.0	0.0	0.0	3.04
						10 m	**90.8**	4.0	0.0	**0.4**	0.0	0.006	**16.0**
4.	BTS 04			Dutsen Kura	Airtel	20 m	60.6	3.01	0.00	**0.29**	0.00	0.003	**13.4**
						30 m	49.4	2.05	0.00	**0.12**	0.00	0.00	8.8
				FMENV Limits			**90**	**10**	**0.04-0.06**	**0.04-0.06**	**0.1**	**0.02**	**10**

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study showed that there are high level of non- compliance from the telecommunication service providers in locating their base stations within the city. In order for physical planning to continue to impact on the physical environment and achieve sustainability in the Minna, Niger State, Nigeria, there is the need to review all development planning permit and approval processes that often create hindrances for telecommunication service operators. Such encumbrances cause unnecessary delays in granting approvals which in turn aid corrupt practices that often force service operators into commencing development without due approvals. This would encourage residents and service operators to adhere to supervisory agencies guidelines in other to minimize the impact of the mast on the people.

However the sitting of telecommunication masts without due compliance to the set guidelines is disturbing as such may affect the safety, convenience, comfort and aesthetic of the built environment. Therefore the multiplicity of tower sites in the study area by the various service providers without a particular trend and degree of densification is an indication that there is no comprehensive database and graphical representation telecommunication facilities of existing tower sites in terms of their spatial and attribute characteristics. Therefore the provision of modern and efficient telecommunication facilities can act as a means for effective telecommunication service delivery.

5.2 Recommendations

Based on the findings of this research, recommendations were made that will help sanitise the distribution of GSM mast in Minna. The present setback of at least 10 meter to any demise property defective owing to the fact that height of the mast in most residential areas should be more than 36 meters. This is because, in the event of collapse, lives and property within the height coverage would be threatened. The researcher, advice that the setback be increased to at least 20 meters in place of the 10 meters.

Also the Nigeria communication commission should encourage operators to subscribe to co-location allows operators to jointly install their base receiver stations in one telecommunication tower thereby reducing the number of masts and as well the reducing the cost of siting of telecommunication base stations. Technical and structural requirement for installation and construction of masts must conform to the stipulated guidelines to avoid collapse, the ministry of environment and the Nigeria Communication Commission should collaborate in order to enact planning law bidding on all the service operators in carrying out effective environmental impact assessment before and after the erection of the telecommunication tower.

Telecommunication masts that are poorly erected should be urgently be removed and co-locate with those fairly located to attend to the immediate problems resulting from the poor location. It is recommended that the telecommunication service operators should adopt eco-friendly methods; by the use of sound proof and less vibrating generating sets, the use of solar power in powering the telecommunication facilities rather than dependent on fossil fuel in running daily activities which release polluted gases into with atmosphere which contribute to the depletion of the ozone layer. The next revised master plan for Minna should make provision for telecommunication infrastructure service plots in order to accommodate telecommunication facilities to avoid land use conflicts Therefore, physical planning and urban development in Minna can achieve more through improvedcontinuouseducation and capacity building for professional planners and service operators on global best practices in participatory planning and environmental sustainability. All these will help residents, who are at the receiving end of all physical development activities, to feel the sense of ownership and be ready to judiciously use the urban development and urban functions in such a manner that it becomes sustainable and healthy for the generation unborn.

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APPENDIX A