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ASSESSMENT OF SPATIAL DISTRIBUTION OF TELECOMMUNICATION BASE STATIONS AND COMPLIANCE LEVEL OF THE OPERATORS TO THE REGULATIONS IN FEDERAL CAPITAL CITY ABUJA, NIGERIA

[1]MUSA DALIL, [2]ABBAS ABDULLAHI YAHAYA, [3]UMAR FARUK YAYA and [4]ADELEYE, BAMIJI MICHAEL
[1,2,4]Department of Urban and Regional Planning
Federal University of Technology, Minna, Nigeria.
[3]Department of Urban and Regional Planning, Ahmadu Bello University Zaria

ABSTRACT

The introduction of Global System for Mobile Communications (GSM) in Nigeria in early 2001, has both its benefits and the attendant consequences. The problems associated with telecommunication base station siting in the Federal Capital City Abuja includes illegal installation, and non- compliance with the provision of the controlling agencies, incompatibility of land use, loss of environmental aesthetic and pollution (Air and Noise). This paper aimed at assessing the spatial distribution of telecommunication base station in Abuja and the level of compliance to the Nigerian Communication Commission (NCC) regulations. Both secondary and primary data were collected from the existing base stations in Abuja. Field survey was employed and spatial analysis through the use of satellite imageries was employed for the study. Analysis of the study indicated that there are 92 base stations in the city with low level of compliance with the NCC regulations (26.1%). The study indicated that 17 base station shows overlapping which can be shut down and will not affect the operation of the operators. It was observed that economic gain was a major propelling factor for the base station sitting rather than standard provided by the NCC.It was recommended that 17 base stations be shut down so as to attain a high level of compliance to NCC directives.

Keywords: Base Stations; Compliance, Telecom Operators; Spatial Distribution and Global System for Mobile Communication (GSM)

INTRODUCTION

Increasing demand for a more convenient communication system has led to the emergence of the Global System for Mobile Communication (GSM). GSM is a sophisticated two-way radio that uses ultra-high frequency (UHF) radio waves to communicate information. GSM base stations are a low powered system that serves only a limited geographic area, varying from a few hundred metres to several kilometres. When a GSM phone connects to the network, it uses radio signals to communicate with the nearest mobile phone site. All of the mobile phone sites in a network are interlinked by cable or microwave beam, enabling phone calls to be passed from one cell to another automatically.

GSM is one of the wildest growing and most demanding telecommunication applications in the world now and Nigeria **(**Shalangwa, Bello 2010**)**. It presents a constantly growing telephone subscription around the globe. Nigeria is one of the major consumers of GSM for communication in Africa, over 60% of the whole populace in Nigeria depend on the GSM as the fastest means of communication (Zain, 2005). There are four GSM providers in Nigeria with a subscription base of over 143.05 million people (National Bureau of Statistics, 2015). Ever since the launch of mobile phone service in Nigeria in the early 2001, it has played a crucial role in the dissemination of information (communication, SMS and Data for internet usage). The sector had recorded an excessive growth from 2.27 million subscribers in 2002, when the first mobile permit was issued, to 143.05 million at the end of the first quarter of 2015 (NBS, 2015).

The base stations (mast) are a free standing structure which supports antennas at a height where they can transmit and get radio waves, a mast is usually 15m high and plays no part in the transmission of radio waves. The base stations are sites that enable mobile phones to work. They can be big or small and have transmitters and receivers in a cabin or cabinet attached to antennas (MOA, 2015). They can be mounted on a substantial pole or tower, an existing building rooftop or street furniture such as street lamps, so without the base station, mobile phone will not work. GSM base stations and cellular telecommunication masts represent part of the infrastructure required for effective communication system. In order to have effective network coverage, several base stations are located close proximity to the target users; the reason telecom operators also place their masts in residential neighbourhoods. The base stations transfer signals between mobile telephones and a network for mobile or normal telephone service through 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, Bentzen & Tennenhouse 1999). The typical Base station 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. A number of environmental issues have attended 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 are scattered around the country. Many of the BTSs are sited within residential, commercial, industrial and transit routes.

The GSM telephone service first became available in Nigeria in 2001 in Lagos and Abuja. By mid-2002 there were approximately 2.27 million subscribers throughout Nigeria and has since rose to over 143.05 million (National Bureau of Statistics, 2015). Base station capacity is a major issue that the telecommunication companies are faced with at present, thereby leading to proliferations of if (NCC, 2014). As the population continues to grow and so does the number of subscribers using GSM phones, more and more base stations are going to be required to meet subscribers demand for reliable coverage.

There are four major GSM providers in Nigeria, namely MTN, Airtel, Globacom and Etisalat. MTN lead the subscriber's preference with 61.21 million subscribers (42.8%), Globacom followed with 21.0%, whilst Airtel has 20.5% and Etisalat has 22.3 million (15.7 percent), (NBS, 2015). **S**ince May of 2014, monthly growth in GSM subscribers has averaged 0.95%, with the greatest increase been recorded in December of 2014 at 1.97% and the lowest in July of the same year at -0.43%. The growth in subscribers was mainly driven by Globacom, which recorded an average rate of 1.45% over the period, followed by Etisalat with 1.37% and Airtel with 1.29%, whilst MTN recorded the lowest average monthly growth in subscribers at 0.44% (NBS, 2015)

According to (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 have been premiered by a myriad of issues that include, exorbitant tariffs, poor audio quality, call interference, non-delivery of short messages (SMS), multiple billing system, poor customer care service, and high call dropout rate. Using the MTN GSM network as a case study, Mughele, Tunde, Longe, & Boateng (2012) studied the network's congestion complaints. The authors attributed the problems to equipment vandalization, 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. Also Adegoke & Babalola (2011) performed an evaluation of the quality of GSM services in Nigeria and concluded that consumers were unsatisfied with the level of services provided in the country.

According to Oyatoye & Okafor (2011) 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. The focus of this paper is the study of the assessment of spatial distribution of telecommunication base stations and the compliance level of the operators to the regulations of the Nigerian Communication Commission (NCC) directives on siting and usage in federal Capital City Abuja, Nigeria. GSM base stations appearing at an alarming rate across the country installed on towers. These towers are occasionally located in close proximity to houses and schools. The study examines location of the telecommunication base stations within the Federal Capital City, assess the spatial and pattern of distribution of it in different neighbourhoods, and evaluate the level of compliance of these operators to the directives of the NCC on the siting of the base stations.

The Study Area

Abuja which is located in Nigeria and as well its capital city of Nigeria with co-ordinates $9^o4^o0^{''}$N and 7^029^00''E covering an area of 713km2, Abuja's geography is define by Aso Rock, a 400- metre monolith left by water erosion. The Federal Capital City (FCC) is a central point in the Nigerian state. The FCC is a major city in FCT, Abuja Nigeria, FCT covers an area of about 8, 000 Km^2. FCC is bounded by Kaduna and Nassarwa State. The FCT which in the national context is placed entirely in the region, which is referred to the middle belt of Nigeria. This belt is the transition between the northern ecological zones dominated by sparse vegetation. The FCT therefore shares some of the attribute of the two zones, thus making it's a fascinating area of urban development. The site for the new capital city has been selected from the north-eastern quadrant of FCT and it occupies about 250 Km^2. Figure 1 shows the FCC in the context of the Nigerian nation. The master plan as prepared and approved by the government put the ultimate population of the city at 3 million people, planned to be developed in four phases as shown in Table 1.

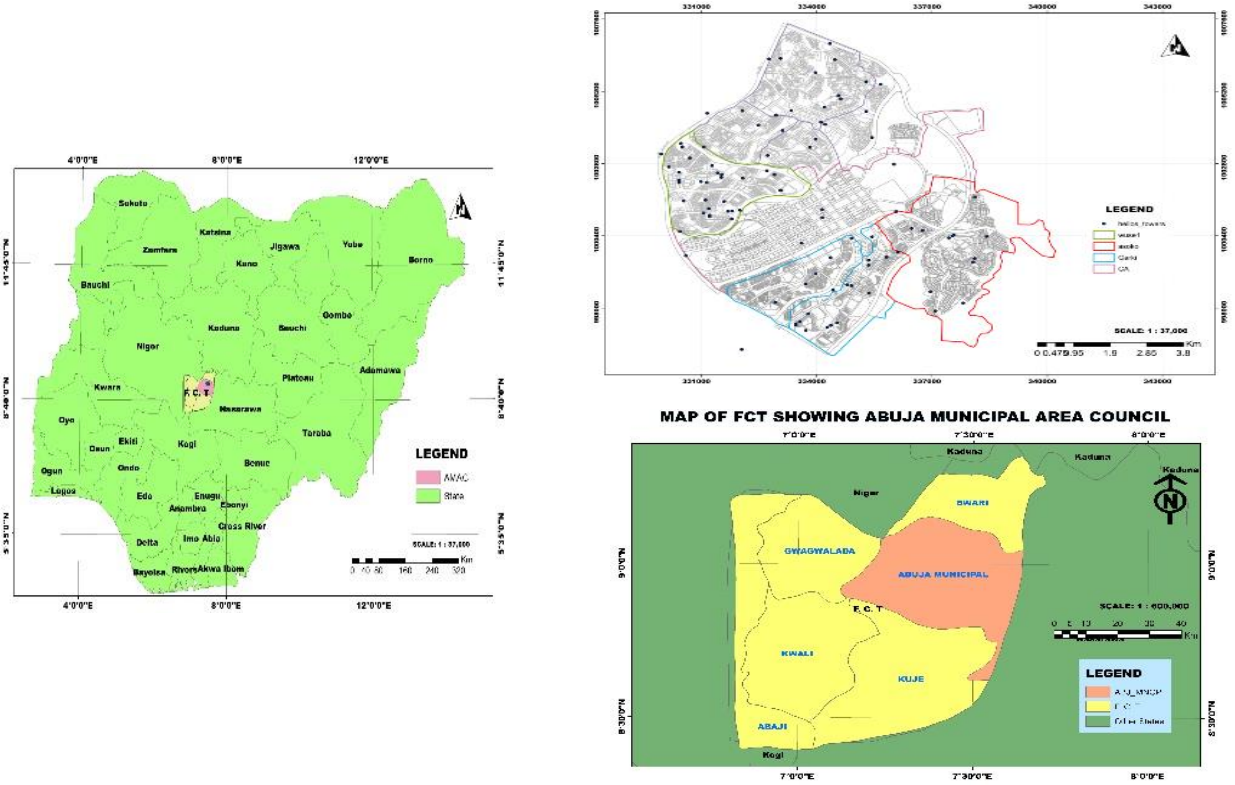

Figure 1.1: **Abuja Municipal Area Council (AMAC) Phase I, FCT, Abuja**

Source: Authors Fieldwork, 2015

Table1: Phases of the FCC and the Target Population

Phases	Projected Target Population
I	20,000
II	585,000
III	640,000
IV	1,700,000
Total	**3,100,000**

Source: AGIS, 2009

The development of FCC as the Federal Capital of Nigeria was phased into four. The first phase, which is the focus of this study has five neighbourhoods of which Central Area is not included in the study, this is because it is not a residential area. The detailed land use planning and site development plan of Phase I of the FCC has been completed and is made up of five (5) district with its population projection shown in Table 2:

Table 2: Districts within the FCC and Planned Population in Phase I.

	District	Land Budget in (Ha)	Planned Population	2015 Projected Population
A	The central Area	1,658	30,000	
B	Garki I and II	865	50,000	62,540
C	Wuse I and II	1,530	69,000	86,305
D	Asokoro	897	30,000	37,524
E	Maitama	1,050	35,000	43,778
	Total	**214,000**		**267,671**

Source: AGIS, 2009 and Authors' Computation, 2016

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

The healthy City Concept

The health city concept serves as a basis for this study. The healthy city concept aims to place health high on the agendas of decision makers and to promote comprehensive local strategies for health protection and sustainable development (WHO, 2016). The concept of health city originated in 1842 and had growing awareness in 1984 after the " Beyond Health Care" conference in Toronto Canada (WHO, 2007).

A healthy city concept is " that city which continually creates and improve those physical and social environments and also strengthen those community resources which enable people to mutually support each other in performing all the functions of life and achieving their maximum potential" (Hancock, 1993).

The Effect of Telecommunication Masts

Mobile phone base stations and telecommunications masts emit radio frequencies, which is a form of electromagnetic radiation, which covers up to a distance of 322 metres (Ogboru, 2015). Ogboru (2015) opined that these radio frequency waves are essential for effective mobile phone connectivity. Several Scholars have linked radio frequencies from base stations and telecommunication mast to various health issues. According to Abdel et al (2006) as cited by Olukolayo et al. (2013) problems associated with telecommunication mast range from changes in cognitive performance, sleep disturbances and higher cancer rates. In a study carried out on telecommunication mast and base station in the united Kingdom reveals that cancer and other serious illnesses were discovered in neighbourhoods where telecommunication masts were sited (Santini et al., 2002 as cited by Odunola, 2015). In the same vein residents of Dunanon Local Government District in Northern Ireland, were of the view that, residents that live between 1-5km from masts have several cancer cases which range from lings, prostate, breast cancer, lung cancer, leukaemia, lymphoma and haematopoietic cancer (Abdel et al 2006).

Onifade, Ikotun, Opejin and Ibraheem (2011) also shared the same opinion that indiscriminate location of masts is associated with lots of health issues. Onifade et al (2011) relates noise pollution from the mast and fumes from generators to causes of leukaemia and other ailments. Though several authors have associated indiscriminate location of telecommunication masts and its radio frequency waves to health issues in neighbourhoods where they are sited, the World Health Organisation (2006) tends not to share this opinion. The World Health Organisation (2006) affirmed that the levels of exposure to radio frequency from Base Stations and wireless networks are so low and insignificant that the temperature increases do not effect on human health.

MATERIAL AND METHOD

Both primary and secondary data were employed in the study. The first step in data acquisition included satellite imageries of the study area, photographs, maps, planning schemes. An observational checklist was designed in order to draw a comparison between the various telecommunication masts that are being proposed, completed, or abandoned.

Instrument of data collection includes: Satellite image of the study area, Land use map of the study area (FCDA, AGIS), Data on telecommunication masts location points (NCC, Development Control, Helios Towers Nigeria limited, and other various Telecommunication networks providers), Records from relevant literatures, Questionnaires (Questionnaires were administered to the various stakeholders involved in the siting of telecommunication masts in the study area), Newspapers, Handheld Global Positioning System (GPS) and Camera.

The questionnaire that was administered was coded in numbers and entered into the IBM Statistical Package for Social Sciences (SPSS) spread sheet. Statistical analysis carried out included interpretation of the readings from the handheld GPS, also ArcGIS 10.2.2, AutoCAD map 2014 was used in capturing and analysis of data on the spatial distribution of the Base Stations. Secondary data from NCC was used to determine the level of compliance by the telecom operators in terms of location, distance between siting of masts and other regulations. The result was displayed in the form of maps, tables, graphs and charts. The Nearest Neighbour Analysis technique using the ArcMap 10.2 was employed to determine the level of compliance in the study area.

RESULT AND FINDINGS

Telecommunication Base Stations within the Federal Capital City, Abuja

This study consider the number of telecommunication mast in the Federal Capital City, Abuja; the spatial location of telecommunication masts and telecommunication service operators.

Types of Telecommunication Masts of each Operators in Federal Capital City, Abuja

There are basically two types of telecommunication masts used by service operators in the Federal Capital City, Abuja which are the Single and multiple telecommunication masts. The single telecom base station users include MTN, Globaocm, Airtel and Etisalat while the multiple service operators are, Visafone and Multilink.

Number of Telecommunication Masts per Operators in the Federal Capital City, Abuja

There are a total of 35 base stations are being used by MTN in the FCC; 29 by Glo; Etisalat has 5 base stations; 15 by Airtel, while the multiple operators has 8 base stations. The breakdown of the locations of the base stations across the four neighbourhoods shows that Wuse I and II has 41 base stations, 22 base stations are present in Garki I and II, Maitama has 15 and Asokoro has 14 base stations as shown in Table 3.

Table 3: Summary of Telecommunication Service Operators

District(s)	Telecom Service Providers				
	Single Base Station Operators				Multiple Base Station Operators
	MTN	Glo	Etisalat	Airtel	
Wuse I and II	**14**	**13**	**3**	**7**	**4**
Garki I and II	**8**	**8**	**1**	**3**	**2**
Maitama	**5**	**5**	**1**	**2**	**2**
Asokoro	**8**	**3**	**-**	**3**	**-**
Total	**35**	**29**	**5**	**15**	**8**

Source: Authors Fieldwork, 2016

Spatial Distribution Pattern of Telecommunication Masts in Federal Capital City Abuja.

Each district was divided into cadastral zones and the number of the telecommunication base stations as shown in Table 4. In overall, the Federal Capital City, Abuja which has a total number of 92 telecommunication masts. Wuse I and II districts has 41 base stations, Garki I and II has 22 base stations, Maitama 15 stations, while Asokoro has 14 base stations.

Table 4: Inventory of Telecom Masts per Operators in Federal Capital City

District(s)	Cad. Zone					Multiple	Grand Total
		MTN	Glo	Etisalat	Airtel	Operators	
Wuse	AO2	10	8	3	6	4	31
	A07	2	2	-	1	-	5
	A08	2	3	-	-	-	5
Garki	A01	7	5	1	2	-	15
	A03	1	3	-	1	2	7
Maitama	A05/06	5	5	1	2	2	15
Asokoro	A04	8	3	-	3	-	14
	Total	**36**	**30**	**7**	**15**	**8**	**92**

Source: Authors Fieldwork, 2016

Telecommunication Masts Location in Federal Capital City, Abuja

As earlier stated, there are four GSM operators within the study area, which is shown in Table 4, the composite map showing the total base station in the study area and spatial distribution of the base stations in the neighbourhoods (district) is shown in Figure 2.

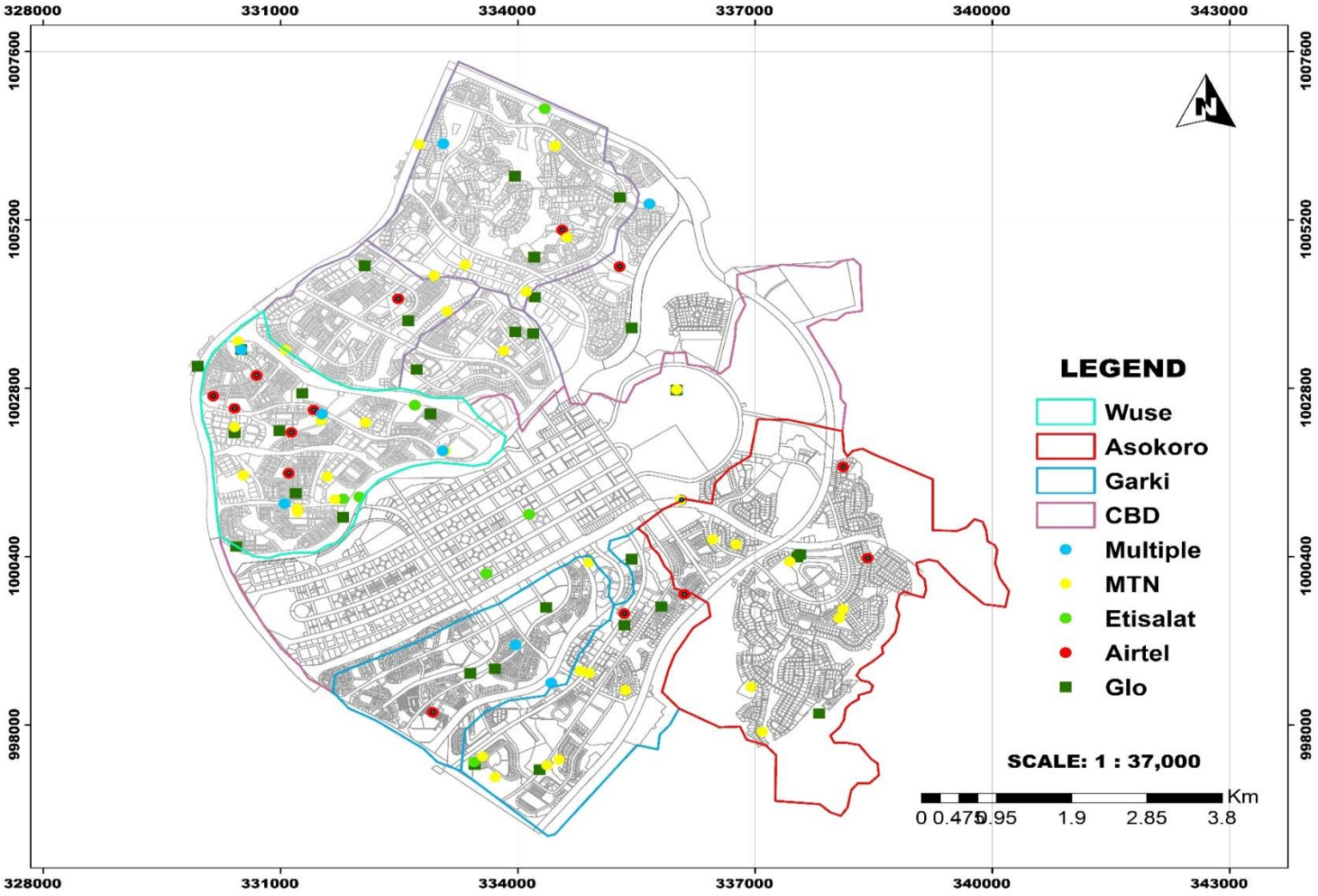

Figure 2: Composite of Spatial Distribution of Base Stations in F.C.C, Abuja

Source: Authors Fieldwork, 2016

Near Neighbourhood Analysis of Telecommunication Masts in Federal Capital City, Abuja

The spatial distribution pattern analysis of telecommunication masts in the Federal Capital City, Abuja was found that the best model to use is the Average Nearest Neighbourhood Analysis which is shown in Figure 3.

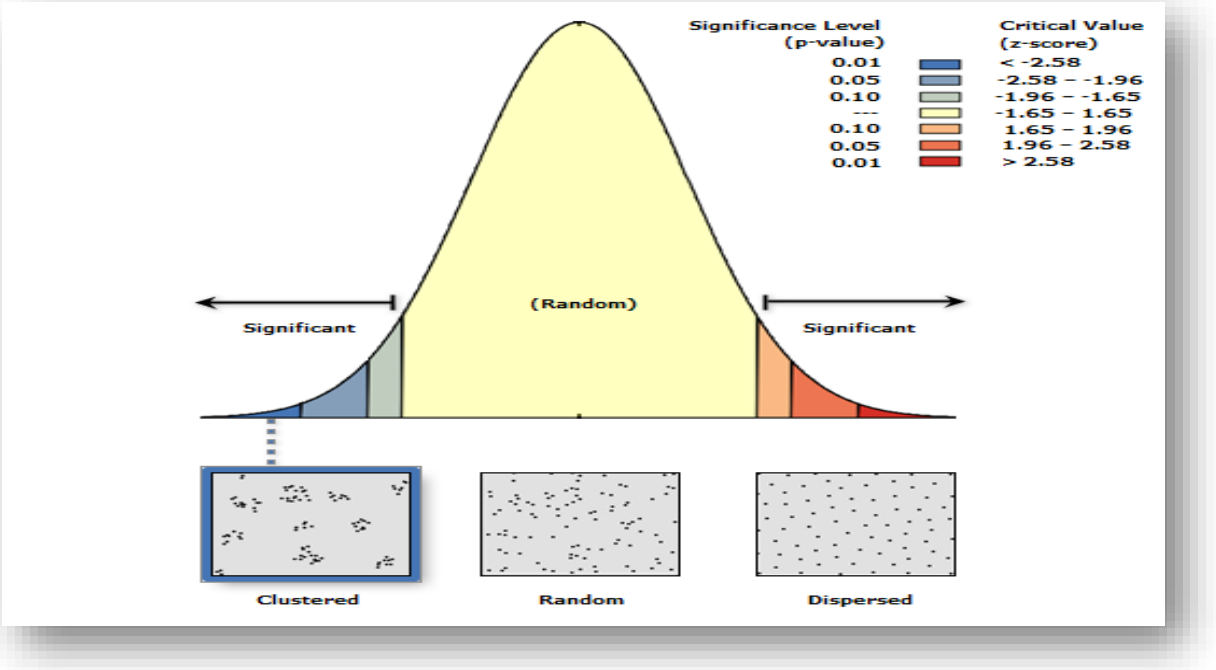

Figure 3: Average Nearest Neighbourhood Analysis carried out on the Telecommunication Masts in the Federal Capital City, Abuja.

Source: Author's Fieldwork, 2016.

The Nearest Neighbour Analysis on the distribution of Telecommunication Masts in the Federal Capital City, Abuja. Indicates that Rn = 0.01 with a critical value of <-2.58, N = 92, study area of 9539.0678 metres, average nearest neighbour ratio = 0.413662, and test significant: P – value = 0.000000, Z – score = -12.740124. The result of the breakdown therefore indicates that the pattern of spatial distribution of telecommunication mast in the federal capital city, Abuja are clustered.

Patterns and compliance of Telecommunication mast to planning regulations in the Federal Capital City, Abuja

NCC Regulations on location of Telecommunication Base Station

According to Nigeria Communication Commission Act of 2009 on the siting of telecommunications towers and masts are stated as follows:

i. The siting of masts and towers shall take cognizance of the provision of the Act and be guided by the provision of the collocation and infrastructure sharing in such a way to minimize their number, protect and promote public safety, and mitigate visual impact on the community.
ii. Telecommunication towers above 25 metres in height would not be permitted within districts delineated as residential.

iii. Where towers in excess of 25 metres in heights are permitted, they should be placed at a minimum setback of 5 metres distance to the nearest demised property, excluding the fence.

iv. The minimum spacing between two or more towers in excess of 55 metres in heights shall be 1 (one) kilometre.

Level of Compliance to NCC Regulation on Siting of Telecommunication Masts

The level and percentage of compliance by telecommunication service operators is shown in Figure 4. There are the sum total of 92 base stations found in the city and only 24 operators comply with regulation of siting of telecommunication masts. Result showed that 8.3% compliance by MTN, 23.3% from Glo, 71.4% compliance from Etisalat while 40.0% from Airtel.

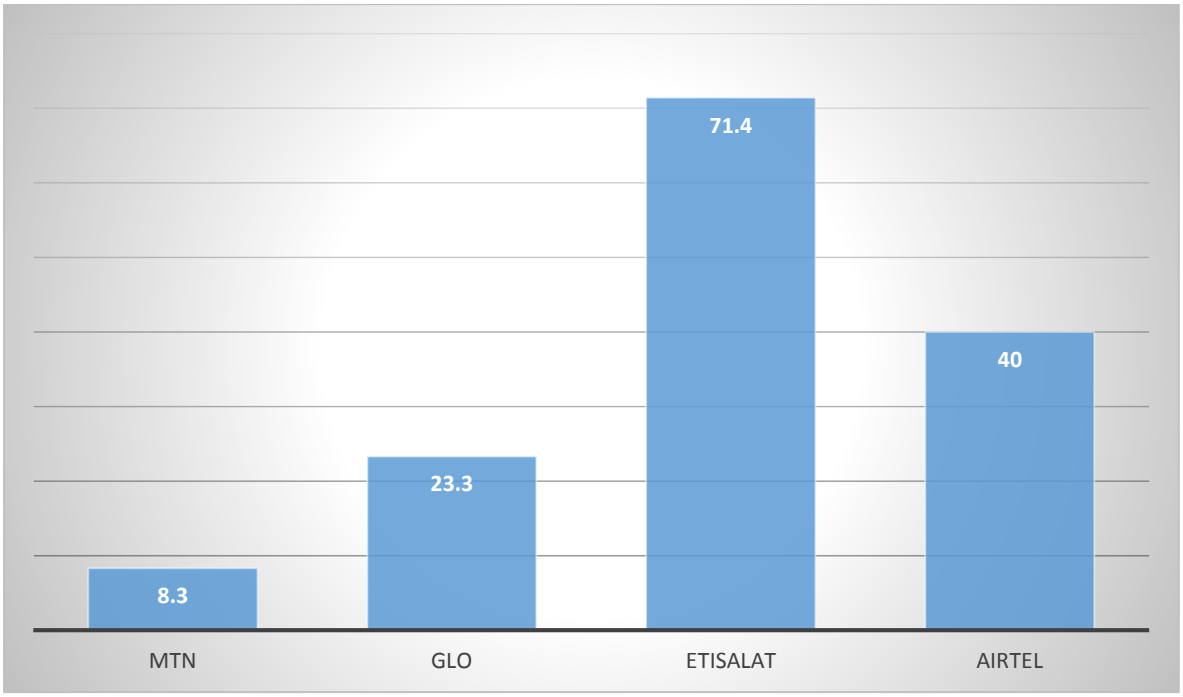

Figure 4: Percentage of Compliance by Service Operators

Source: Authors Fieldwork, 2016

Telecommunication Service Operators Compliance to NCC Regulations in Federal Capital City, Abuja.

The NCC regulation and town planning regulation indicated that the minimum distance between two base stations should be 1 km apart. The 1 Km radius of tower to tower spacing for siting of telecommunication base station in the Federal Capital City, Abuja was considered and the extent of compliance to this directives was looked into and the result is presented in Table 4. Figure 5, 6, 7 and 8 shows the base station coverage for each of the telecommunication service operators in various neighbourhoods (districts) in the Federal Capital City, Abuja. The level of compliance as stipulated by NCC was not complied with by the operators due to some reason, such as the number of subscriber in the neighbourhoods and the altitude of the neighbourhoods.

Table 4: Level of Compliance per Service Operators in Each District of the City

Districts											
		Wuse		**Garki**		**Asokoro**		**Maitama**		**Total**	
NCC Rules	Operators	No. of Masts	% Compliance	No. of masts	% Compliance	No. of masts	% compliance	No. of masts	% Compliance	No of masts	% Compliance
1000 m	MTN	14	7.1	8	0.0	8	37.5	5	40.0	35	17.1
1000 m	Glo	13	7.7	5	60.0	3	33.3	5	60.0	29	27.6
1000 m	Etisalat	3	0.0	1	100	-	-	1	100	5	40.0
1000 m	Airtel	7	14.3	3	33.3	3	33.3	2	0.0	15	20.0
1000 m	Multiple	4	75.0	2	0.0	-	-	2	100	8	62.5
Total		**41**	**14.6**	**22**	**22.7**	**14**	**35.7**	**15**	**53.3**	**92**	**26.1**

Source: Authors Fieldwork, 2016

The analysis as shown in Table 4 shows that multiple operators have the highest level of compliance to NCC regulations. The least operator to complied with NCC regulation is MTN. This has shown that the number of the base station has direct relationship to the level of compliance. MTN with large number of base stations proved to be a violator of the NCC regulations. The analysis also further shows that Wuse with the highest population and highest number of base stations is has least compliance level. Maitama with least population and lowest base stations has highest compliance level. On the average, it could be established that there is a low level of compliance with NCC directives by the telecom operators in FCC.

The implication of this analysis is that population pressure and interconnectivity of the subscriber determines the siting of the telecom base station rather than the distance as speculated by the NCC regulation. MTN with highest subscriber base has the highest level of violation of the NCC regulations because economic gain is placed as premium rather than the distance between the base stations. Because of the large number of subscribers using the base stations, there is always drop calls when the base station is congested, this proved to be the reason why more and more base stations overlap.

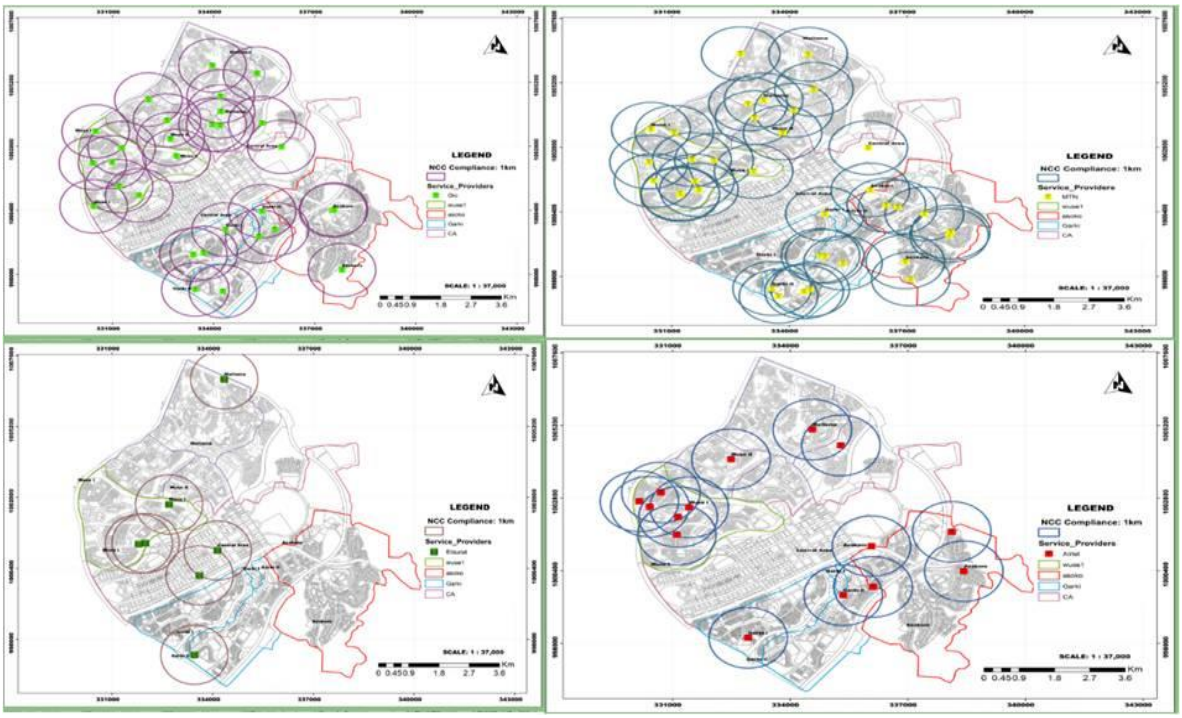

Figure 8: Telecom Operators Violation to NCC regulations

Source: Authors Fieldwork, 2016

DISCUSSIONS

From the study carried out in the Federal Capital City, Abuja which has a total number of 92 telecommunication masts, Wuse I and II districts have 41 base stations, Garki I and II have 22 base stations, Maitama has15 stations, Central Business District (4)stations while Asokoro (14) base stations. The spatial distribution pattern of the telecommunication masts within the Federal Capital City, Abuja is an uneven pattern that is that is clustered. There is a total number of 92 telecommunication masts in the city. If the NCC regulations are followed, 17 of those base stations need to be shut down. The study has revealed that economic gain and drop calls have been the driving force for base station sitting, rather than the regulations of the regulators. Other factors are accessibility, land value, population, proximity to other base stations, topography, availability of power/electricity, security, network quality/coverage, where their masts are located. The catchment analysis, which is 1 Km radius reveals that there is an overlapping of various telecommunication base stations amongst each network and high level of overlap across all the service providers. The result presented in Table 4 reveals that 26.1% of the base stations complied with the NCC directives in the study area. MTN is the least operator to comply with these directives because of their proliferations of the base stations to serve their subscribers. It has 17.1% compliance across all the neighbourhoods. Further analysis shows that Wuse district with the highest population in Abuja has the least level of compliance (14.6%), while Maitama which housed the government official quarters and embassies office has lowest population and highest level of compliance by all the service providers (53.3%). This reiterate the fact that siting of base station is a function of population of such localities.

Most of the location of the base stations are close to residential areas, also, there are situation where two or more base stations are sited side by side at a close range in a particular location especially in Wuse, Garki and Maitama districts.

RECOMMENDATIONS

The analysis on the level of compliance in sitting base stations shows that 17 have to be shutdown, when applying the compliance level of NCC regulations. In that order, MTN has to shut down 9 base stations (4 in Wuse District, 3 in Garki District and 2 in Asokoro District). Globacom has to shut down 5 base stations (2 in Wuse District, 2 in Garki District and 1 in Asokoro District). Airtel has to shut down 2 base stations in Wuse District and Etisalat has to shut down 1 base station in Wuse District. This recommendation is to enable the operators to comply with the NCC regulations and to avoid land use conflict and to restore orderliness in the physical planning development of the city by the concerned authorities.

There should be the use of a super structure base station that can hoist mast of multiple service providers to transmit and receive signals by GSM telephone, rather than proliferation of the base stations within the city.

CONCLUSION

The study shows that there is high level of non- compliance from the telecommunication service providers in locating their base stations in Federal Capital City, Abuja. The sitting of telecommunication base stations without due compliance to the set guidelines is alarming and disturbing, as such trends may affect the safety, convenience, comfort and aesthetic of the built environment of the capital city of the nation. The multiplicity of base station 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 of telecommunication facilities in Abuja, Nigeria. The spatial distribution and attribute characteristics of the service providers indicated that economic gain is placed in the fore front in the process of sitting base stations. Therefore, the provision of modern and efficient telecommunication facilities can act as a means for effective telecommunication service delivery.

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ABOUT THE AUTHORS:

Dr. Musa Dalil : Adeleye Bamiji Michael is an Assistant Lecturer in the Department of Urban and Regional Planning, Federal University of Technology Minna. He holds a Masters degree in Urban and Regional Planning from the University of Ibadan, Nigeria.

Abbas, Abdullahi Yahaya is a town planner and holds a Master of Technology degree in Environmental Impact Assessment from the Federal University of Technology, Minna.