# AN INVESTIGATION OF THE USE AND SUSTAINABILITY OF GRID3 INFRASTRUCTURE FOR SOCIAL AND SUSTAINABLE DEVELOPMENT IN NIGERIA

***By***

**TIAMIYU Barakat Bidemi (Student Number: TMYBAR001)**

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**UNIVERSITY OF CAPE TOWN**

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**Professor Nancy Odendaal**

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# ABSTRACT

Geospatial data and technologies are reshaping how the government responds to public issues by delineating and effectively delivering interventions based on data. The Geo-referenced Infrastructure and Demographic Data for Development (GRID3), is one of Nigeria's leading geospatial databases for social development and it is prominently used by government for healthcare service delivery. As GRID3 accelerates the adoption of its expanding geospatial datasets, there is a need to assess the use and sustainability of its infrastructure within the geospatial ecosystem in delivering sectoral development priorities, especially in the area of healthcare service delivery. Therefore, this research investigated the availability and distribution of GRID3 infrastructure and its utilization for sustainable development in Nigeria. It also examined the innovative approaches for enhancing the sustainability of GRID3 tools, services, and technology.

The objectives of the study were achieved by utilising a mixed-method case study approach with both qualitative and quantitative data, collected from GRID3 users, researchers, and service providers in Oyo state, Nigeria. A combination of mean item score and analysis of variance were used for the quantitative data, and grounded theory analytical methods were used for the qualitative data. It emerged from the findings of the study that the GRID3 infrastructure available can be characterised into geospatial tools and technologies, geospatial data, and geospatial services provided. The study revealed that GRID3 enables the verification, implementation, and monitoring of sustainable development goals as per health, wellbeing, water, sanitation, education, food security, and infrastructural development. This creates the hallmark of its contribution in promoting the adoption of geospatial data for strategic national and grassroot development.

Investigation of the level of sustainability of GRID3 infrastructure with respect to its use and sustainability showed two metrics of measurement – the usefulness and satisfaction of users. The usefulness of geospatial data for immunization programs in terms of data accuracy and quality, and spatial analysis functionality, could enhance the sustainability of the geospatial infrastructure. Secondly, end users' satisfaction is dependent on the satisfaction with the geospatial interface and integration. This invariably suggests the alignment of GRID3 infrastructure with the users' specifications and the geospatial ecosystem through learning and application. In addition, it was found that innovative approaches to enhance and sustain GRID3 infrastructure include the improvement of data quality, expansion of coverage and awareness, ensuring user-friendliness for low skilled people, development of a GRID3 app, and investment in capacity building for end-users.

The study concluded that GRID3 will continue to be useful for sustainable development programs and would remain viable if efforts are made to meet the end users' requirements. The study established the innovative approaches and technologies that can help foster wider adoption of the GRID3 infrastructure in Nigeria.

*Keywords*: GRID3; Sustainable Development; Social Development; Healthcare Intervention; Geospatial Infrastructure; Geospatial Tool; Geospatial Data

## DECLARATION STATEMENT

I declare that all the information contained in this thesis has been collected and presented in accordance with ethical rules and academic conducts of the University of Cape Town. I hereby declare that this thesis signifies my own work which has never been submitted either in parts or whole for the award of any degree, diploma or any other qualifications, except where due acknowledgement has been made in the thesis.

TIAMIYU Barakat Bidemi

**Signed:** Signed by candidate

## DEDICATION

This work is dedicated to the Almighty God and my daughter, Aridunu Firewamiri Olugboyega.

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**TABLE OF CONTENTS**

## LISTS OF TABLES

## LIST OF FIGURES

## GLOSSARY OF TERMS AND DEFINITIONS

| | |
|---|---|
| Analysis of Variance (ANOVA) | This is used to check how the different variables respond to each other. |
| Case Study | A case study is a contemporary phenomenon inside its genuine setting, particularly when the limits between a phenomenon and setting are not satisfactory and the researcher has little command over the phenomenon and setting (Yin, 2012:25). |
| Field Experiment | A field experiment is a research approach that happens in real-life settings. It includes the detachment and control of at least one factor to test the impact (Queirós et al., 2017). |
| Geographic Coordinate | A measurement of a location on the earth's surface expressed in degrees of latitude and longitude (https://support.esri.com/en/other-resources/gis-dictionary/term/df46d2ae-cf3c-43ca-8073-ee68617baeeb). |
| Geospatial Information | Geospatial information can be defined, at an abstract level, as any information, data, or document possessing a locational component that can reference it to a location on the Earth (Turskis et al., 2006: 187). |
| Geospatial Information System (GIS) | An integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes. A GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analyzed (http://wiki.gis.com/wiki/index.php/GIS_Glossary). |
| Geospatial Technology | Geospatial technology refers broadly to a range of tools and capabilities contributing to geographic mapping and analysis, such as remote sensing, aerial photography, spectral satellite imagery, geographic information systems, global positioning systems and volunteered geographic information (Convergne and Snyder, 2015: 570). |
| GRID3 | Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) is an organisation that provides geospatial solutions for generating, validating, and using geospatial data on population, settlements, infrastructure, and boundaries (https://support.esri.com/en/other-resources/gis-dictionary/term/metadata). |
| GRID3 Infrastructure | GRID3 infrastructure is a computing and information infrastructure that provides geospatial services, technologies, and data (Gardner et.al, 2015:15; Granell et al., 2013:218). |
| GRID3 Users | These are individuals that utilizes GRID3 infrastructure, services, and tools for their work. |
| GRID3 Service Providers | These are individuals that manage, administer, and produce GRID3 infrastructure at the country level. |
| GRID3 Researchers | These are individuals who utilizes GRID3 tools, services, and infrastructure for academic and research purposes. |
| Grounded Theory | This is a method for extracting concepts from qualitative data and offers a theoretical framework that explains the concepts. |
| Qualitative | Qualitative research is one in which the researcher normally makes |

| | |
|---|---|
| Research | information claims dependent on constructivist points of view (Cresswell, 2003). |
| Quantitative Research | Quantitative research is a research method in which the researcher principally utilises post-positivist cases for creating information, for instance, circumstances and logical results thinking, decreasing to explicit factors and speculations and questions, utilising estimations and perceptions, and testing the hypotheses (Cresswell, 2003). |
| Oyo State | Oyo State is the third most populous city in Nigeria, with a population of about 6 million. The state consists of 33 local government areas and 29 local council development areas (see Table 3.1 for the details of the local government areas). |
| Mean Item Score | This is used to check the underlying variable. |
| Metadata | Information that describes the content, quality, condition, origin, and other characteristics of data or other pieces of information (https://support.esri.com/en/other-resources/gis-dictionary/term/metadata). |
| Social Development | Social development is the process of arranged social change intended to advance the prosperity of the populace in general and is related to a powerful cycle of economic development (Midgley, 1995:28). |
| Survey | Surveys are a research procedure that permits the straightforward collection of information from an individual engaged with the researcher through a bunch of inquiries coordinated around a specific request (Queirós et al., 2017). |
| Sustainable Development Goals (SDG) | These are a set of 17 objectives for achieving sustainable development that were established by worldwide consensus in the 2030 Agenda for Sustainable Development (Venuesa et al., 2020). |
| SDG Indicators | They are the primary metric by which progress in international development initiatives is measured (Karver et al., 2012:3). |

# CHAPTER ONE

# INTRODUCTION

## 1.1 Research Background

The Sustainable Development Goals (often abbreviated as SDGs) are a set of 17 objectives for achieving sustainable development that were established by worldwide consensus in the 2030 Agenda for Sustainable Development (Venuesa et al., 2020). They are intended to influence the trajectory for national action and global cooperation on future development (Sachs, 2012). This framework comprises of 17 goals, targets, and indicators. Some of the SDGs (SDG 3: Good Health and Wellbeing; SDG 4: Quality Education; SDG 5: Gender Equality; SDG 6: Clean Water and Sanitation ) specifically relate to the provision of health services and health-related infrastructures (Asma et al., 2020). However, the implementation and monitoring of these SDGs require geospatial information (Giuliani et al., 2020; Budge et al., 2006). Geospatial information is an important decision-making tool for effective and efficient spatial distribution, tracking, accountability, monitoring and evaluation, and the implementation of any program or interventions.

Geospatial information can be defined, at an abstract level, as any information, data or document possessing a locational component which can reference it to a location on the Earth (Turskis et al., 2006: 187). Geospatial Information has tremendous potential to effectively and efficiently monitor SDG Indicators (SDG indicators measure the level of achievement of SDG goals) (Acharya and Lee, 2019). Since the dawn of human civilization, geographical information tools such as maps and compasses have played a fundamental role in guiding developmental agendas (Paelke and Sester, 2010; Granell et. al., 2014). Given that location plays a critical role in spatial and public infrastructure development planning, maps have played an integral role in territorial planning, cooperation, navigation, and conflict resolution for many centuries. Historically, maps were also used extensively in the discovery of new territories and natural resources. In the 1970s and 180s, the rapid and simultaneous technological developments in computer science, satellite communication, navigation, and earth observation systems widened the scope of the usage of geospatial information in many areas of Sustainable Development (Mhangara et al., 2019). According to Scott and Rajabifard (2017), many issues impacting sustainable development can be analysed, modelled, and mapped within a geographic context, which can provide the integrative framework required for global collaboration, consensus, and evidence-based decision-making.

Also, geospatial information is useful in earth science and other physical sciences to finance and management, evaluate health facilities, doctor-to-patient ratio, and locate health services. (Yauri et al., 2018). Granell et al. (2014) noted that most health-related issues such as public health outbreaks and epidemiological threats are better understood from a spatial–temporal perspective and, clearly demand related geospatial datasets and services so that decision makers may jointly make informed decisions and coordinate response plans. Saran et al., (2020) concurred that during the occurrence of diseases, geospatial technologies and services could help in representing the spatio-temporal information and in analysing the dynamic spread of diseases. Yauri et al., (2018) also maintained that geospatial information reduces the difficulties involved in locating health care facilities and resolving other problems relating to health care and disease prevention, which ranges from soil contamination, air pollution, to disease-carrying vectors.

The above arguments have shown that geospatial information has now become an essential, reliable, and more insightful tool for decision makers in solving many location-specific problems by using its location intelligence to produce a database that can be subjected to spatial queries. In the health sector, it is unarguably clear that infectious disease outbreaks require geospatial datasets and analysis such as locations of infected patients, disease data, and the generation of disease dispersion maps in a city for enhancing informed decision-making processes.

The potential role of geospatial information in assessing the geographic distribution of health services and evaluating the effectiveness of health infrastructures coverage relevant to population density has been a subject of scholarly assertions and investigations. For example, Murad (2011) claimed that geospatial technology offers varied solutions including ones that improve field data collection and reporting and others that support disease surveillance and analysis with online mapping and spatial statistics. Geospatial Technology refers broadly to a range of tools and capabilities contributing to geographic mapping and analysis, such as Remote Sensing, aerial photography, spectral satellite imagery, Geographic Information Systems, Global Positioning Systems and volunteered geographic information (Convergne and Snyder, 2015: 570). According to Murad (2011), health planners can improve the understanding of community health needs and design effective interventions. Mishra et al. (2019) asserted that the huge cost associated with the development of health infrastructure necessitates the development of rational planning models to maximise accessibility to health infrastructures. Murad (2018) contends that the usefulness of geospatial technologies in surveillance of infectious diseases, and mapping and monitoring of the spatial and temporal distributions of vectors of infection, is allowing researchers to study the relationships between spatial and temporal trends, spatial and risks, and between environmental factors and health. Murad (2011) stressed that health care planning requires geospatial technology to analyse the number of people living in an area (demand), the availability of health services in the area (supply), the socio-economic and financial resources available to the population, the population's health status, people's knowledge about health and the health care system, and geographical impedance between population and health services.

Scholarly investigations on the role and effectiveness of geospatial information in assessing the geographic distribution of health services have come from across the globe. Dutta and Das (2019) extracted land use data from the remotely sensed images which show the temporal growth of the urban areas to provide a spatial and temporal understanding of the pattern of land use change, urban growth, and formation of sprawl in the peri-urban region of English Bazar Urban Agglomeration. Tu et al., (2011) examined the spatial patterns of low-birth-weight prevalence, as well as the presence of spatial clusters in the State of Georgia at both the county and census tract levels. The study uncovered trends associated with positive and negative spatial correlations with physical and social variation with respect to its impact. Pina et al., (2020) used geo-spatial analysis to assess the risk of hospital admissions due to community-acquired pneumonia in under-5 children and its association with socially vulnerable areas in Brazil. Murad (2018) used Geographical Information Systems (GIS) for identifying spatial accessibility to health centres in Jeddah City, Saudi Arabia based on the drive-time analysis technique. The study also created a geo-database that includes the location of health centres, population distribution, and road networks.

Kapwata and Manda (2018) spatially evaluated health care access of people diagnosed with cardiovascular disease to health facilities and to evaluate the density of the existing health facility network in South Africa. Mansour (2016) conducted spatial analysis of public health facilities in Riyadh Governorate in Saudi Arabia. Tiwari et al., (2006) investigated the hotspots for the occurrence of tuberculosis in Almora district, India, using GIS and spatial scan statistics. BG and Hiremath (2012) conducted a web based geo-spatial and village level information extraction system using free open-source software. Baig et al., (2016) investigated the planning and data implications of applying geospatial analysis in community needs assessment. The study noted that integrating spatial analysis and community needs assessment enhances planning to improve service accessibility and utilisation in underserved areas. Kazi et al. (2017) piloted the use of geospatial based mobile phones and discussed its potential to improve the efficiency of field-based health providers and health managers for the monitoring of the immunisation program. Kazi et al. (2017) claimed that the system allows routine capture of individual level data through global positioning system (GPS) enabled mobile phones providing actionable information and geospatial maps to local public health managers, policy makers.

Efforts have also been made to evaluate the potential role of geospatial information and tools in health services by Nigerian authors. For example, Yauri et al., (2018) conducted a geospatial documentation and geo-database developments for health facilities in Birnin Kebbi metropolis of Nigeria. Findings from the study revealed a disproportionate distribution of health care facilities in Birnin Kebbi metropolis with the underlying reasons remaining poorly known. The study recommended mapping of healthcare facilities in relation to population distribution to help decision makers plan and take a decision with complete confidence using maps. Lawal and Anyiam (2019) combined open data and geospatial analysis to model geographic accessibility to Primary Health Care Facilities in Akwa Ibom.

From a geospatial perspective, the COVID-19 pandemic once again underpins the role of geospatial information in health services and sustainable development (Müller and Louwsma 2021). In China, Cheng et al., (2020) predicted the COVID-19 epidemic risk of each province based on geospatial data such as geographical proximity information, spatial inverse distance information, economic distance, and Baidu migration index. Mahmood et al., (2020) developed the Flu and Coronavirus Simulator (FACS) for modelling the viral spread of COVID-19 at the sub-national level. The simulator incorporated geospatial data sources to extract buildings and residential areas. Radojević et al., (2020) provides examples of geospatial services based on COVID-19 pandemic-related data, such as algorithms for measuring social distancing through CCTV and proximity contract tracing protocols and applications. Müller and Louwsma (2021) analyse the role of spatio-temporal information in governing the pandemic in the European Union and its member states. Chandir et al., (2020) found that the unprecedented spread of COVID-19 has disrupted the provision of regular health services.

The roles of geospatial information and technologies in response to the COVID-19 pandemic, according to Radojević et al., (2020) include CCTV enabled for face recognition, geospatial machine learning algorithms, thematic geospatial analysis, geospatial data with timestamps, geospatial data tourist information service, and geospatial dashboards. Franch-Pardo et al. (2020) also identified transmission dynamics, spatial correlations, predictive modelling, spatiotemporal dimensions, and spatial analysis of the evolution of the COVID-19 pandemic as some of the roles of geospatial information and technologies in response to the COVID-19 pandemic. Unarguably, the above studies have shown that geospatial information and technologies are valuable tools for identifying infection outbreaks, supporting data sharing and contact tracking, investigating social vulnerabilities and health disparities, and evaluating the validity and effectiveness of specific measures for COVID-19 pandemic. Also, it has become clear that trends in outbreaks over time and space, hotspots of infection, applicable rules and regulations, and available resources for medical treatment of the COVID-19 pandemic can be identified and disseminated to a wider public using geospatial information and technologies. However, the utilisation of geospatial information and technologies in low and middle-income countries, such as Nigeria, the Democratic Republic of Congo, Ethiopia, among others, is currently limited, particularly for immunisation coverage assessments and vaccination campaigns (Kazi et al., 2017). Chandir et al., (2020) noted that the impact of COVID-19 pandemic on routine immunisation will be higher in countries with limited healthcare resources and fragile health systems. Müller and Louwsma (2021) assented that in times of a pandemic such as COVID-19, geospatial information and technologies are needed to take appropriate and coordinated action at all governance levels. Mhangara et al., (2019) identified Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) as a reliable geospatial technology that could provide geospatial information for governments. GRID3 facilitates the production and utilisation of high-resolution population and other geospatial data to support decision making and for assessing the SDG indicators (Qiu et al., 2019).

According to Dumitrescu et al. (2005), GRID3 infrastructure is a multi-virtual organisation infrastructure with more than 30 locations and computing resources. Gardner et al. (2015) characterise GRID3 as a shared, persistent, multi-virtual, multi-application grid laboratory capable of providing production-level services for data-intensive science and large-scale computing. Social development has utilised GRID3 infrastructures to distinguish between regular and irregular neighbourhoods, spatially sample household surveys, evaluate accidents, allocate factory sites, manage migrant demand, and analyse poverty. Jochem et al. (2021) utilised building spatial data to classify individual buildings, predict building ages, and automate cartographic generalisations. According to Juergens (2020), the economy and business use GRID3 infrastructures for geospatial analysis of site allocation for new factories, logistic centres, distribution centres, and stores.

In Nigeria, the government is embracing GRID3 as a source of geospatial information and technologies. This could be as a result of the fact that geospatial information and technologies play an essential role in monitoring SDG indicators, evaluating the geographic distribution of health infrastructures, and managing the COVID-19 pandemic. Another reason could be as a result of the claim by GRID3 Nigeria that it supports the government in their efforts to generate, validate, and use geospatial information on population, settlements, infrastructures, and sub-national boundaries for planning and decision-making. So far, there has been little detailed investigation of the utilisation of GRID3 for health-related SDGs planning and decision-making as well as sustainability of GRID3 as a geospatial tool for sustainable development (Utazi et al., 2020). Therefore, it becomes imperative to evaluate utilisation and viability of GRID3 in Nigeria. Consequently, the purpose of this study is to investigate the use and sustainability of GRID3 infrastructures for social and sustainable development in Nigeria, with the hope of discovering methods to improve the sustainability of GRID3 in Nigeria.

## 1.3 Problem Statement

GRID3 infrastructure is highly useful for geospatial data referencing and analysis of spatial characteristics of health infrastructures. However, the application and operational use of GRID3 infrastructure in a bid to ensure improved efficiency and sustainability of the GRID3 infrastructure in achieving evenly distributed health infrastructures as an indicator of SDGs are unknown in developing countries such as Nigeria. Additionally, the COVID-19 pandemic has heightened the complexities surrounding health care delivery.. These have raised concern on the sustainability of GRID3 infrastructure, geographic patterns and accessibility of health infrastructures, and coverage of COVID-19 vaccine distribution in response to the COVID-19 pandemic. Hence, there is a need to investigate the utilisation and sustainability of GRID3 infrastructures for social and sustainable development in Nigeria, towards identifying innovative approaches for enhancing the sustainability of GRID3 infrastructures for sustainable development in Nigeria.

### 1.4 Research Question

The research question that this research will answer is as follows: *To what extent are GRID3 infrastructures employed for healthcare and social development in Nigeria and how sustainable are they?*

*Subsidiary questions:*

- *How long have GRID3 infrastructures been used in Nigeria?*
- *How well is the technology distributed across the country?*
- *How is GRID3 infrastructure managed and governed?*

### 1.5 Research Aim and Objectives

The aim of this research is to explore the sustainability and use of GRID3 infrastructures for social and sustainable development in Nigeria, with a view to exploring approaches for improving the sustainability of GRID3 infrastructure in Nigeria.

The specific objectives of this research are to:

a. Identify the availability and distribution of GRID3 infrastructures in Oyo State, Nigeria;
b. Evaluate the use of GRID3 infrastructures for sustainable development in terms of healthcare delivery in the study area;
c. Assess the level of sustainability of GRID3 infrastructures in the study area; and
d. Investigate innovative approaches for enhancing the sustainability of GRID3 infrastructures for sustainable development in the study area.

### 1.6 Justification for Research

The current COVID-19 pandemic has been declared as the 'worst public health crisis in a generation', with over 12 million confirmed positive cases and 556,342 reported deaths across 213 countries as of July 11, 2020 (Chandir et al., 2020: 7150). Understanding the spatial-temporal dynamics of COVID-19 is critical to its mitigation (Franch-Pardo et al., 2020). This calls for investigations that will analyse and support the use of geospatial tools such as GRID3 in identifying sites suitable for the development of health facilities, attaining spatial efficiency in the distribution of health infrastructures, and allocating resources to the needy areas. Also, the need to explore the utilisation of GRID3 as a geospatial tool in tackling health emergencies and obtaining inputs from the COVID-19 pandemic for future preparedness provides support for this research. The information that will be provided by this research will enable decision-makers, public health teams, healthcare planners and hospital managers to forecast the spread of COVID-19 reliably and reproducibly. This research will also support the government to effectively prepare for the emergency response and mitigate the challenges involved in the front-line defence against the COVID-19 outbreak.

Inequalities in geographic access to health care is one of the primary challenges in achieving the health-related SDG according to Lawal and Anyiam (2019). Tackling this challenge calls for research that will support a better assessment of health-related SDGs and allow improvement in the planning, monitoring and surveillance of public health programs such as COVID-19 vaccination in Nigeria. In addition, the information to be provided by this research regarding the utilisation of GRID3 will be useful to health planners in shifting their policies or health initiatives away from the use of assumptions of spatial homogeneity in health planning. Important and required information regarding the refinement of GRID3 infrastructures and enhancement of their sustainability will also be provided by this research.

### 1.7 Research Scope

The scope of the research will be limited to GRID3 Nigeria and SDGs as measures for social and sustainable development. Only health-related SDGs (SDG 3-6) will be considered in this research. The health-related SDGs to be considered in this research will specifically include immunisation coverage (coverage of vaccine distribution for COVID-19) and spatial distribution of health infrastructures.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 General Introduction

This chapter provides an overview of past studies on the use of geospatial tools and technologies for social and sustainable development. This chapter provides the theoretical background on the connection between social development and the SDGs; the importance of the provision of healthcare and its impact on social development; and the evolution of geospatial tools and technologies. It elucidates the use cases of geospatial tools and technology, with a deep dive into GRID3 infrastructure and its use for social development. Several scholarly works that explore GRID3 and the innovative approaches that were propounded to improve GRID3's data, tools, and technologies were explored.

## 2.1 Social Development and the Sustainable Development Goals (SDGs)

Definitions of social developments are many and varied. Midgley (1995: 28) defined social development as the process of arranged social change intended to advance the prosperity of the populace in general related to a powerful cycle of Economic Development. Cox et al., (1997) defined social development as a participatory cycle of arranged social change intended to advance the prosperity of individuals, and which, in that capacity, offers a successful reaction to the natural necessities and desires of the entire populace for the improvement of their personal satisfaction. Davis (2004) viewed social development as an improvement in the government assistance and personal satisfaction of people; or change in social orders – in their standards and foundations that make advancement fairer and more comprehensive for all individuals from a general public.

According to Browne and Millington (2015), social development alludes to large numbers of the non-economic cycles and results of improvement, including however not restricted to: diminished weakness; incorporation; prosperity; responsibility; individuals focused methodologies; and independence from brutality. Browne and Millington (2015) further noted that social development is essentially concerned about common liberties, formal and casual force relations, imbalance and opportunities for building more prominent correspondence among people and gatherings inside social orders. In the view of ICPD (2017), social development includes a commitment to individual prosperity and volunteerism, and the chance for citizens to decide their own necessities and to impact choices that influence them. According to ICPD (2017), social development fuses public worries in creating social approach and economical drives. The definition by ICPD (2017) characterised social development in the broadest social terms as a vertical directional development of society from lesser to more noteworthy degrees of effectiveness, usefulness, and achievement.

These definitions indicate that social development comprises two interrelated dimensions – learning and application. In social development, society finds better approaches to satisfy its aspirations and create authoritative components to communicate that information to accomplish its social and economic objectives. The above definitions of social development demonstrate that it is an inherent feature of social change and that it provides a good approach for fundamentally understanding and managing social concerns. The definitions also suggest that social development centres around deliberate planning and thinking arising from social concerns with the aim of addressing and resolving them. As a result, the action taken would have an impact on the financial turn of events. It can also be seen in the definitions that social development centres on the reformist changes in using social assets to build individual fulfilment and prosperity; and that social development is a planned complete social change intended to improve individuals' overall welfare. As a final point, the above definitions clarify that social development extends the reach of people and networks; advance harmony and social equity. It also implies access to satisfactory medical care and schooling; combats oppression against women and minorities; and furthermore, makes practical pay and financial constructions.

The summary of the contributions of social development to society can be related to sustainable development. According to Hat et al., (2015), sustainable development and social development are interrelated because sustainable development plays a key role in securing global social development and **s**ocial development is a major dimension of sustainable development. The relationship between sustainable development and social development was extended by Sachs et al., (2019) through the identification of Sustainable Development Goals (SDGs) as a framework for national action and global cooperation on sustainable development. Sachs (2012) noted that the SDGs contribute to a trajectory designed to move the world towards sustainable development and that the notion of the SDGs has gained ground because of the growing necessity of sustainable development for the whole world. Hat et al., (2015) identified SDGs as a universal set of goals, objectives, and indicators that United Nation member states will use to frame their sustainable development agendas and policies over the next 15 years, starting in 2015. SDGs are the new indicators that expand on the Millennium Development Goals (MDGs) – are the primary metric by which progress in international development initiatives is measured (Karver et al., 2012: 3)., which were agreed to by United Nations member states in 2000.

The SDG framework included 17 goals, 169 targets, and 232 indicators. Asma et al., (2019) identified 12 goals, 33 targets, and 57 indicators as health-related SDGs. SDGs 3–6, according to Asma et al., (2020) relate to health services and health outcomes. The number of health-related goals in SDGs led Asma et al., (2020) to the conclusion that the scope of health in the SDGs is much broader than in the MDGs and that the SDG framework includes many indicators that directly measure health outcomes. This indicator include indicator 3.1.1 (maternal mortality ratio), which measures maternal mortality ratio and indicator 6.1.1 (proportion of population using safely managed drinking water services), which measures proportion of population using safely managed drinking water services, among others. Asma et al., (2020) based their conclusion on the fact that the scope of health in the SDGs span from infectious diseases and maternal and child health to risk factors, injuries, non-communicable diseases, and health infrastructures. In line with the conclusion by Asma et al., (2020), Knaul et al., (2018) noted that achieving widespread health coverage, addressing health crises, and promoting healthier people are tactical priorities for attaining SDGs. Studies such as Costanza et al., (2016), Bhutta et al., (2020), Buse and Hawkes (2015), Aftab et al., (2020), and Dora et al., (2015) have also shown the importance of health as a requirement for and an upshot of policies to promote Sustainable Development, with the conclusion that health is central to SDGs.

## 2.2 The Provision of Health Care in relation to Social Development

Based on the above argument, the provision of health services and health-related facilities can be said to be aligned with social development, sustainable development, and the SDGs. Mishra et al., (2019) rightly observed that the provision of proper public health-care infrastructure and quality medical personnel in a nation improves the quality of life of its citizens, enhances their efficiency and productivity, and eventually reduces poverty. The observation by Mishra et al., (2019) suggests that health-care infrastructures entail the number of beds and physicians, road connectivity, number of hospitals, water, and electricity. Lawal and Anyiam (2019) extended this argument by noting that the accessibility to a health care facility is not only governed by the distance to travel but also by the amount of competition for use of such a facility in the area. This is because there is a certain number of bed spaces or range of services that the facility can provide.

This argument pointed to the two critical factors in the provision of proper public health-care infrastructure - physician supply and population demand. Both of these factors are spatially distributed, but it is rare that their distributions perfectly match (Murad 2011). However, matching the distribution of health infrastructures in terms of physician supply and population demand is the core idea of sustainable health delivery. Mansour (2016) maintained that analysing the spatial relationship between locations of health centres and geographic accessibility to those centres towards achieving a balanced distribution of health infrastructures have for a long time been an important consideration for decision-makers, health care managers, and urban planners. Yauri et al., (2018) reported that public infrastructures like health facilities remain inaccessible for the majority of the populace, because the infrastructures are localised in one area and not evenly distributed.

Apart from ensuring evenly distributed health infrastructures or sustainable health delivery, Giuliani et al., (2017) argued that achieving the objective of a sustainable development requires the integration of different data sets on physical, chemical, biological, and socio-economic systems coming from various sources. Likewise, Asma et al., (2019) observed that monitoring the 57 health-related SDG indicators requires data such as nationally representative household surveys, biomarker, civil registration and vital statistics, and verbal autopsy.

The role of geospatial data in the implementation and monitoring of the roadmap for achieving the SDGs was examined by Avtar R. et al., (2020). The study found that the synoptic view and repetitive coverage of the earth's features or phenomena provided by remote sensing data is a powerful and effective technological advancement to implement the SDGs with a multi-disciplinary approach. The role of big data in analysing SDG indicators has been discussed in (MacFeely, 2019). Conventional data sources, such as census data, are a traditional method often adopted by developing countries to implement policies. This census data creates a 5 to 10 years repeat cycle, making it difficult to track, update, and implement. Tatem et al., (2019) have proven that using geospatial data and technologies is the best alternative to updating and filling up big data sets.

Geospatial data plays an important role in information gathering via geospatial technologies, which help in tracking and predicting spatial changes. The need for quality data and information for sustainable development was emphasised at the United Nations Regional Cartographic Conference for Asia and the Pacific (Asia-Pacific, 2015). When geospatial information is integrated into technological tools to analyse disparities, it significantly enhances the effectiveness of the SDG indicators in monitoring and guiding sustainable development on a global to local scale. Geospatial technologies analyse spatial distribution and patterns using geospatial data and statistics (Avtar, R. et al., 2020). This technological tool provides a synoptic view of the impact of social, economic, and climate change at several spatial resolutions to aid decision making.

Budge et al., (2006) concluded that decision making in government establishments has faced a lot of challenges due to the use of inappropriate decision support information, because the decision support systems in use by public officials in many of government parastatals do not utilise the geospatial technologies. Collectively, these arguments describe a diverse amount of information that can be considered to be geospatial information.

### 2.3 Evolution of Geospatial Tools and Technologies

Paper maps are the earliest geospatial technology. As noted by Woldai (2002), paper maps are maps in analogue format used for the supply of geospatial data and information. The formats of presenting and producing paper maps include single sheet paper maps, fold maps for convenient use in the field, pocket size books, booklets and atlases (Fung et al., 2004). Fung et al., (2004) affirmed that paper maps have been used by human beings for centuries for navigation, exploration, codification, planning, indexing and many other purposes. They have been used rigorously to reflect different contexts, cultures, times and places in human history. Paper maps are fail-safe, relatively cheap, offer superior resolution, usable for many tasks, and provide large scale overview (Paelke and Sester, 2010). However, they are non-dynamic, non-interactive, and require learned map skills (Paelke and Sester, 2010).

The need to have maps that can be integrated with media such as video, pictures, sound, and animation has led to development of electronic maps (Fung et al., 2004). Electronic maps are also referred to as digital maps or augmented paper maps. Electronic maps exploit the benefits of electronic devices such as augmented reality by augmenting Paper maps through meaningful integration of additional information, real-time information, user-generated content, and functionality rather than replacing them. In contrast to conventional maps, they can support spatial queries and routing, dynamically provide detail-on-demand, support animation and interaction with the content, and allow for easy update of time critical information. With electronic maps, map information is no longer restricted to a single map sheet. Users can now pull information distributed in different databases, servers and data portals, select each individual map layer, assign graphic symbols and display them at will in their own computers. Electronic maps make the job of mapping far more flexible as compared to the use of paper maps (Fung et al., 2004).

Paelke and Sester (2010) confirmed that electronic maps have high potential for the presentation of up-to-date dynamic content, adapted specifically to the user and his current position, and the task at hand. However, the development of usable geospatial applications for mobile devices is complicated by several factors, including technical ones like the available displays, interaction modalities, resolution, ease of control, and reliability. Conceptual complications of electronic maps include lack of guidelines and tools for the creation of adequate user interfaces and visualisations (Paelke and Sester, 2010). Examples of such electronic maps include MapLens developed by Morrison et al., (2011), NaviCam developed by Rekimoto (1997), PeepHole Pointing developed by Cao et al., (2008), Augmented Maps developed by Bobrich and Otto (2002), Magic Lens introduced by Bier et al. (1993), Marked-up Maps by Reilly et al., (2006), and Sketch layout Model developed by Feng and Lin (1999). MapLens is developed with a system that augments paper maps with digital information registered in 3D and in real-time (Morrison et al., 2011). MapLens is an augmented reality application for camera phones with GPS. The phone camera and the display are used as a viewer in combination with a Paper Map, which is augmented with location-based data. When a Paper Map is viewed through the camera, the system analyses the video frame and determines the GPS coordinates of the visible portion of the Map (Morrison et al., 2011). MapLens uses predetermined Map data files to identify the Paper Map and associates its visible area to geographical coordinates (Morrison et al., 2011).

Efforts to resolve the challenges of electronic maps ushered in the development of internet-based maps such as google maps and Geographic Object-Based Image Analysis (GEOBIA). GEOBIA is an example of internet-based maps that represents the most innovative new trend for processing remote sensing images. GEOBIA is devoted to developing automated methods to partition remote sensing imagery into meaningful image objects and assessing their characteristics through spatial, spectral and temporal scales, thus generating new geographic information in a GIS-ready format (Arvor et al., 2013). GEOBIA functions as a link between the pixel world and the vector world and thus has been considered as a sub-discipline of GIS (Arvor et al., 2013). The main applications of ontologies in GEOBIA are especially for data discovery, automatic image interpretation, data interoperability, workflow management and data publication. However, its application is mainly based on expert knowledge, but it is gaining widespread traction given the advances in the use of artificial intelligence (Ma et al., 2021).

Geospatial infrastructures are networks of geospatial information, tools and technologies representing an improvement on internet-based maps, and a combination of many nodes and decentralised data and services. Geospatial technologies are sets of geospatial technologies or geospatial infrastructure networks that evolved based on recent advancements in GIS, information technology, computer networks, sensor networks, web computing, and cyber infrastructures (Yang et al., 2010; De Smith et al., 2007). These data infrastructures were created for better utilisation of geospatial data and for decision support through scientific research and experimental model simulations (Yang et al., 2011). The infrastructures adopt intrinsic geospatial principles for large amounts of geospatial data processing such as geospatial analysis, feature relationship calculations, geospatial modelling, geo-visualisation, and geospatial decision support (Kralidis, 2005). Geospatial infrastructures encompass the networked geospatial databases and handling complex organisational, technical, human and economic issues which interact with one another. They underpin the design, implementation and maintenance mechanisms that facilitate the standardisation, sharing, access to and responsible use of geospatial data at affordable costs for a specific application domain or enterprise (Woldai, 2002).

Geospatial infrastructures reduce the requirements for multiple standards for visualising, accessing, analysing, modelling, and discovering geospatial information by establishing unified standards for data and content. Geospatial infrastructures provide significant improvements to how the sciences that need geospatial information will advance and seek to support sharing of data via standards, such as national spatial reference systems, templates (Kralidis, 2005). The evolution of geospatial infrastructures produces platforms for geospatial science domains and communities to better conduct research and development and to better collect data, access data, analyse data, model and simulate phenomena, visualise data and information, and produce knowledge (De Man, 2004). Examples of geospatial infrastructures include Spatial Data Infrastructure (Li et al., 2011), Geospatial Cyberinfrastructure (Yang et al., 2010), Spatial On-Line Analytical Processing (SOLAP) technology (Rivest et al., 2005), Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) infrastructure (Gardner et al., 2015), GeoGratis and GeoConnections (Kralidis, 2005), and Geographic Information Grid System (GIGS) (Singh and Bawa, 2012).

Yang et al., (2010) explained Geospatial Cyber infrastructure as a combination of data resources, network protocols, computing platforms, and computational services that brings people, information, and computational tools together to perform science or other data-rich applications in this information-driven world. Rivest et al., (2005) reported that SOLAP technology allows rapid and easy navigation within spatial databases and offers many levels of information granularity, many themes, many epochs and many display modes synchronised with maps, tables, and diagrams (Rivest et al., 2003). SOLAP was developed to fully exploit the powerful concepts brought by the multidimensional database structure, and to add spatial extensions that provide highly interactive map visualisation and data exploration. SOLAP technology cannot support decisional applications nor support highly interactive navigation through spatial data at different levels of aggregation and through different epochs (Rivest et al., 2001).

Recently, Big Data have been integrated into geospatial tools to develop geospatial big data technology. An example of this geospatial technology is spatial big data generated through smart phones with embedded GPS receivers by Thatcher (2014) and Choi (2020). Although geospatial big data provides unprecedented opportunities for data gathering and we have to admit that geospatial big data also brings challenges for privacy, data quality, reproducibility, and proper application (McCoy, 2017; Zhen et al., 2016).

Different types of geospatial technologies come with their advantages and disadvantages. Paper maps are cheap but not interactive, electronic maps are interactive but not always reliable and not always accessible. Internet-based maps such as Google maps and GEOBIA, resolved all the disadvantages of both paper and electronic maps, but they require expert knowledge to utilise them. Geospatial infrastructures and geospatial big data have privacy issues, but they have significantly reduced the shortcomings of all the other geospatial technologies.

## 2.4 Examples of the Use of Geospatial Tools and Technologies

There are many case studies of the application of geospatial tools globally. In Egypt, Emam and Soliman (2020) conducted a case study of the application of geospatial technology in quantifying spatiotemporal shoreline dynamics along Marina El-Alamein Resort. The objective of the study was to couple geospatial technology with the Digital Shoreline Analysis System (DSAS) tool in monitoring, analysing, and quantifying the impacts of anthropogenic activities on the spatiotemporal shoreline dynamics at Marina El-Alamein resort. Arnous and Sultan (2013) applied the geospatial technology to demonstrate the capability of the geospatial technology, such as remote sensing to estimate the combined influence of lithology and structure studies, and to create lithological and structural maps of Feiran–Solaf metamorphic complex, South Sinai. Detailed structural analysis was carried out to reveal the different ductile and brittle deformational events and proposed the tectonic evolutionary model for the study area.

In India, towards coastal conservation and management, Sahana et al., (2019) employed geospatial tools to assess coastal island vulnerability in the Sundarban Biosphere Reserve. In a case study of the Chennai coast, Dar and Dar (2009) used geospatial technology to predict future recession of the coast. In an effort to develop Smart and Precision Agriculture, Bhanumathi and Kalaivanan (2019) combined the geospatial technology with Internet of Things for precision is to monitor and predict the critical parameters such as water quality, soil condition, ambient temperature and moisture, irrigation, and fertiliser for improving the crop production. Prajapati et al., (2018) conducted a case study of the applicability of multi-temporal and multi-sensor data set for geomorphological mapping and surveying.  Using geospatial technology, Prabhakaran and Raj (2018) mapped tectonic lineaments of Pachamalai hills in Tamil Nadu.

In Nigeria. Bashir et al., (2019) conducted a case study of the potentiality of remote sensing and GIS in detecting Land Used and Land Cover (LULC) changes in Minna between 1976 and 2016 (50 years period of time). Ekeu-wei and Blackburn (2020) explored an integrated approach for flood modelling and mapping by combining available segmented hydrographic, topographic, floodplain roughness, calibration, and validation datasets using a 2D Caesar-Lisflood hydrodynamic model to quantify and recreate the extent and impact of the historic 2012 flood in Nigeria. This study demonstrated how the complementary strengths of open, readily available Geospatial Datasets and tools can be leveraged to model and map flooding within acceptable levels of uncertainty for flood risk management.

In Kuantan district of Malaysia, Hashim et al., (2012) modelled the sprawl of unauthorised development using geospatial technology. The study concluded that the GIS-cellular automata model can lead to new levels of understanding of how urban areas grow and change as in view of digital earth aspiration. Safaei et al., (2010) applied geospatial technology to landslide susceptibility assessment. Saran et al., (2020) reviewed geospatial technology for infectious disease surveillance and performed case studies of COVID-19 geo-surveillance. Sunar et al., (2005) employed satellite image maps for urban planning in Turkey. Jung et al., (2020) investigated sustainable applications of remote sensing and GIS to Earth Observations in South Korea. All these case studies in different countries are dealing with geospatial, however, the issue of sustainability of geospatial tools remains unaddressed.

The above examples of the use of geospatial tools and technologies shows that geospatial technologies have wide applications, they are flexible, and have great utility in monitoring and predicting sustainable development. They also show that geospatial technologies are useful for modelling and mapping changes in land use resources and understanding of urban growth. In spite of all the benefits and utilities of geospatial technologies as revealed by the case studies, issues surrounding the sustainability of geospatial technologies and how it can be sustained have not been widely explored.

## 2.5 Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) Infrastructure

The GRID3 initiative was launched at the Columbia University in March 2008 with the purpose of facilitating the production and utilisation of high-resolution population and other geospatial data, towards supporting government decision-making, and the assessment of Sustainable Development Goals (Qiu et al., 2019). Dumitrescu et al., (2005) describe GRID3 infrastructure as a multi-virtual organisation infrastructure that is composed of more than 30 participating sites and computing resources (computers, storage, and networks). Van Den Hoek et al., (2021) explain GRID3 as a human-validated, open-source geospatial dataset in which settlement boundaries are generated by clustering individual buildings detected in very high-resolution Maxar satellite imagery. Gardner et al., (2015) define GRID3 as a shared, persistent, multi-virtual organisation, and multi-application grid laboratory, capable of providing production level services for data-intensive science applications and large-scale computation. The illustration of GRID3 architecture as produced by Gardner et al., (2015) is shown in Figure 2.1. The definitions of GRID3 as given by Dumitrescu et al., (2005), Van Den Hoek et al., (2021), and Gardner et al. (2015) suggest that GRID3 infrastructures is a computing and information infrastructures that provides geospatial services, technologies, and data (Gardner et., 2015: 15; Granell et al., 2013:218).

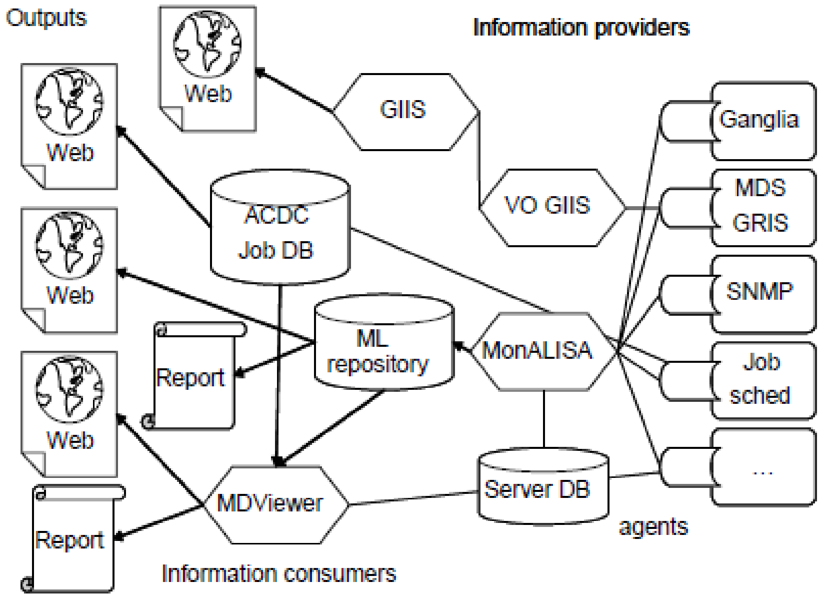


**Figure 2.1: GRID3 architecture (source: Gardner et al., 2015:19)**

The link between geospatial services and data was highlighted by Granell et al., (2013) through a definition of geospatial services as the discovery, accessing, processing, visualisation, and managing of geospatial datasets. Figure 2.2 presents a spectrum of geospatial datasets and services as described by Granell et al., (2013). According to Giuliani et al., (2010), a service is simply a collection of operations that a user can discover and invoke. In the case of the geospatial domain, an operation can be a simple request to create a map or a complicated geoprocessing routine applied to a remote sensing image. These services are defined in a standard manner by ISO 19119 (Geographic Information—Services), have a published interface, and can communicate with other services to achieve a specific process or task (Giuliani et al., 2010). Figure 2.3 shows the geospatial services as illustrated by Giuliani et al., (2010).

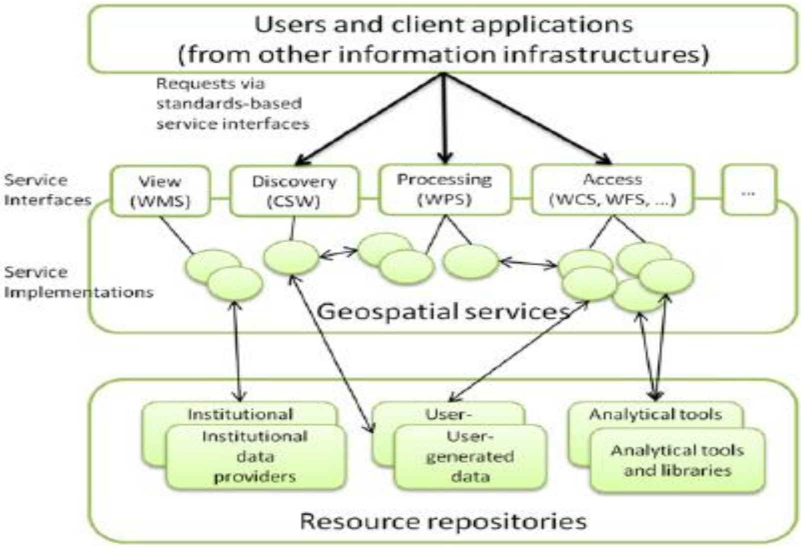


**Figure 2.2: Spectrum of geospatial datasets and services (Source: Granell et al., 2013:5)**

Kodge and Hiremath (2012) indicated that geospatial data include data that identify a specific location on the Earth, linked to geographic locations or have a geospatial component such as socio-economic data, land records, land surveys, homeland security information, and environmental analyses. As stated by Giuliani et al., (2010), geospatial data typically describe geographical locations giving through various attributes knowledge about their spatial and/or temporal extents. These definitions suggest that geospatial data are extremely valuable as users can build spatial relationships between features and data.

Ocansey (2019) listed mobility data, population data, settlement mapping, infrastructure mapping, and sub-national boundaries as examples of geospatial data. These datasets are important inputs for a range of different analyses, such as understanding the development of cities, mapping the distribution of populations, and identifying areas at risk of disasters (Jochem and Tatem, 2021). Likewise, Ocansey (2019) estimated that as many as 20% of the SDGs indicators can be measured using geospatial data – either alone or integrated with statistical data. Also, Jhamba et al., (2020) explained that a population and housing census is an enumeration of the total population of a country, which provides data on numbers of people, their spatial distribution, sex and age structure, their living conditions and key socioeconomic characteristics. Such data, according to Jhamba et al., (2020) are critical to national and sub-national development planning, tracking progress towards the SDGs, the needed distribution of infrastructure and social welfare investments, market analysis, and election planning.

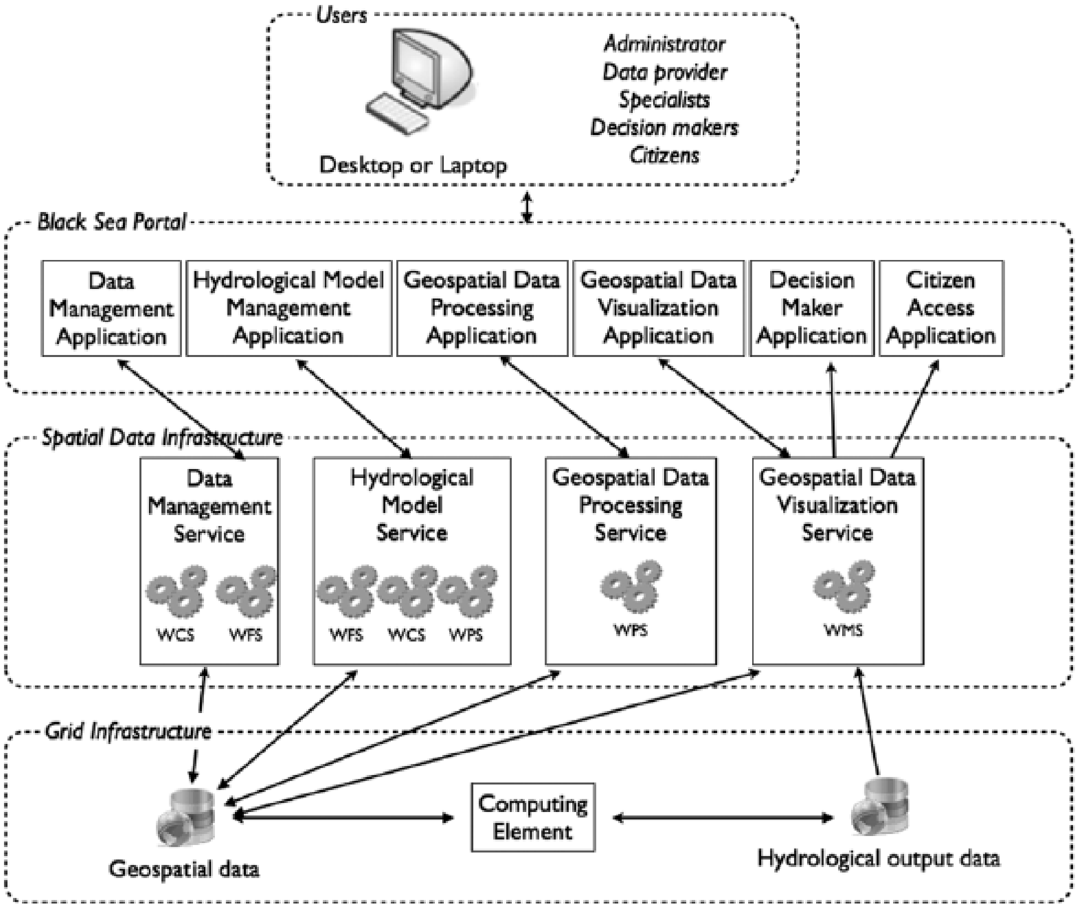


Figure 2.3: Geospatial services (Source: Giuliani et al., 2010: 11)

## 2.6 Use of GRID3 Infrastructures for Social Development

Generally, GRID3 infrastructures have been used in social development for classifying regular and irregular neighbourhood types, spatial sampling in household surveys, accident analysis, site allocation for new factories, managing travellers' demand, and spatial analysis of poverty. This can be seen in a study by Jochem et al., (2021) that used the spatial data of buildings to classify regular and irregular neighbourhood types or more nuanced functional areas, to classify individual buildings, predict buildings' ages, and as part of automated cartographic generalisations. Boo et al., (2020) proposed a grid-based sample design framework for spatial sampling in household surveys. The framework defined a sampling frame based on gridded population estimates and formalised as a bi-dimensional random field. The framework was also characterised by spatial trends, spatial autocorrelation, and stratification.

Gaikwad et al., (2014) proposed accident analysis system by integration of spatial data mining with GIS web services. The system creates a SMS alert system for government authorities to know that an accident has happened and locate the spot for further investigation. The system also provides information on optimised routes to nearby healthcare facilities from current location. Juergens (2020) reported that GRID3 infrastructures have application in the field of economy and business which include the geospatial analysis of site allocation for new factories, logistic hubs, and distribution centres or shops. Singh and Singh (2014) developed a geospatial database for managing travellers' demand. Holt (2007) described a spatial analysis of poverty in the United States using county-level data from the community health status indicators project.

The availability of geospatial data for public health reflects both the health outcomes and the health-shaping environments in which people live and work. This is further shaped by increasing coverage of high-resolution geospatial datasets and the need to disaggregate statistics for initiatives such as the SDGs (Thomson et al., 2019). The availability and high-resolution of geospatial datasets have prompted the use of GRID3 infrastructures for health care delivery. An example of this is the study carried out by Utazi et al., (2020) in which an analysis of the geospatial variation in measles vaccine coverage through routine and campaign strategies was carried out in Nigeria. The study reported that coverage during the campaign was generally higher and more homogeneous than routine immunisation coverage. The study identified the geospatial differences in the campaigns reach of previously unvaccinated children and recommended the need for improved routine immunisation performance in the persistent areas of low coverage.

Using immunisation target population estimates, Ghiselli et al., (2019) conducted a micro-census in Magarya ward, Wurno Local Government Area of Sokoto State to obtain an accurate count of the total population living in the ward, and to compare these results with other sources of denominator data. The study employed a precise micro-plan using satellite imagery and navigation tool EpiSample version 1 in the field to guide teams to each building, without duplications or omissions. The study concluded that micro-census results can better define the target population for routine immunisation services and estimate the number of children still unprotected from vaccine-preventable diseases. Granell et al., (2013) illustrated how geospatial services and health information infrastructures are related (see Figure 2.4). The illustration provided by Granell et al., (2013) explained how health services such as outbreak control require geospatial capabilities that can be supplied by specialized geospatial services from geographic information infrastructures.

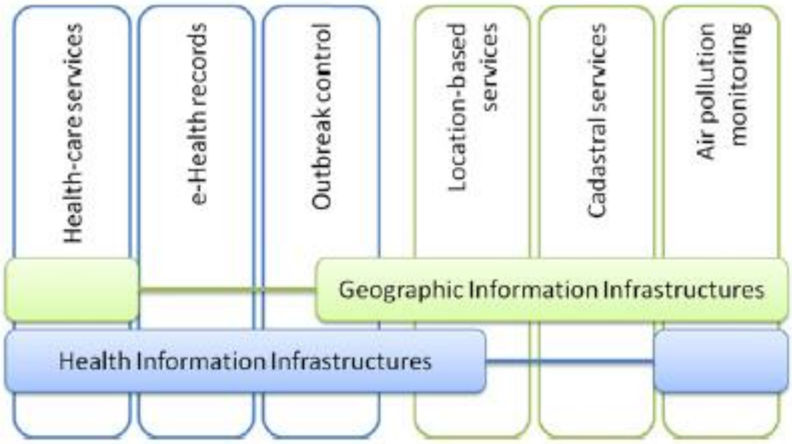


**Figure 2.4: Interlink between geospatial and health services (Source: Granell et al., 2013:3)**

Song et al., (2019) used remote sensing and geospatial big data to assess the health risk of particulate matter with aerodynamic diameters less than 2.5 mm ($PM_{2.5}$). The study collected location-based service (LBS) data from social media and satellite-derived high-quality $PM_{2.5}$ concentrations were collected to perform highly spatiotemporal exposure assessments for thirteen cities in the Beijing-Tianjin-Hebei (BTH) region in China. The study concluded that dynamic population distribution showed great influence on environmental exposure and health assessments. Mishra et al., (2019) proposed a methodology that uses GIS and multi-criteria decision-making techniques for development of health care units (HCUs), to attain spatial efficiency in the distribution of facilities. The methodology assigns spatial weightage to the suitability index of the candidate locations in the objective function of maximising coverage location-allocation problem embedded in ArcGIS software. In the methodology, habitations unserved by the existing HCUs are considered as candidate locations. The methodology considers the following five criteria for determining the suitability index of a location are: access distance to nearest existing HCU (C1), accessibility index of habitations to existing HCUs based on service to population ratio (C2), connectivity to all weather roads (C3), population of neighbourhood (C4), and health care requirement of a zone (C5). The study claimed that the proposed methodology enables maximisation of coverage, minimization of needless competition within community health centres, and satisfaction of the zonal requirement for health. Simarro et al., (2014) mapped the capacities of fixed health facilities to cover people at risk of gambiense human African trypanosomiasis (HAT). The study revealed the existence of 632 fixed health facilities that are active in the control and surveillance of Gambiense HAT in endemic countries. The study concluded that future updates of the database will regularly provide evidence to inform and monitor a rational deployment of control and surveillance efforts.

With the declaration of the novel coronavirus (COVID-19) as a global pandemic, the use of GRID3 infrastructures have become particularly relevant (Franch-Pardo et al., 2020). Mostly, studies have investigated the use of geographical and geospatial analysis in understanding locations and the distribution patterns of COVID-19. For example, Rahman et al., (2020) geospatially modelled the spread and dynamics of the 154-day outbreak of COVID-19 pandemic in Bangladesh. Brito et al., (2020) discussed and conceptualised how the Earth observation (EO)-based datasets can potentially support a risk assessment of COVID-19 from the spatial dimension (see Figure 2.5). As claimed by Brito et al., (2020), EO-based data have the potential to add an important component to understand the health risks of COVID-19 in slums, in addition to information on demographic, social, and economic conditions. Brito et al., (2020) further claimed that EO has proved to be efficient in deriving timely spatial information and bridging spatial data gaps.

Altogether, these studies showed that GRID3 infrastructures are useful for improving the accuracy of social development, health metrics assessments, and optimising health interventions.

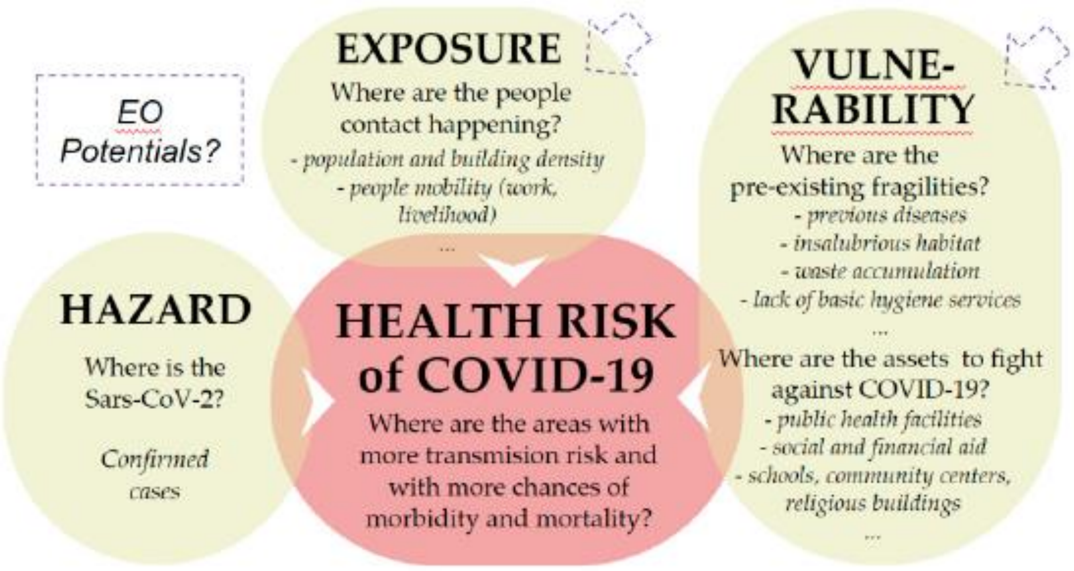


**Figure 2.5: Conceptualization of COVID-19 risks and the role of Earth observation (EO)-based data (Source: Brito et al., 2020:3)**

### 2.7 Levels of Sustainability of GRID3 Infrastructures

Mentis et al., (2016) observed that GRID3 infrastructures are sustainable for as long as they are relevant to achieving the SDGs. This argument hinges on the fact that GRID3 infrastructures play a significant role in achieving the SDGs since they are capable of providing the data needed in the decision-making process. This finds support in Avtar et al., (2019) which indicated that the scientific results provided through the use of geospatial technologies can provide a strong basis for policymaking to promote sustainable development in communities at local and regional levels. Similarly, Li et al., (2020) noted that the SDGs constitute a vast system that is complicated, diverse, dynamic, and interconnected, where success in achieving one goal is often linked to solving issues associated with other goals. This necessitates the need for infrastructures such as GRID3 in resolving the lack of accurate and timely data, lag in developing proper methodologies to process the data, and implementation bottleneck of the 2030 SDGs (Li et al., 2020).

SDGs as formulated by the United Nations highlight that urban areas in lower income settings each have unique development needs associated with human health, livelihoods, changes in family patterns, and the local environment (Lloyd et al., 2020). Avtar et al., (2019) claimed that the 17 SDGs (presented in Figure 2.6) have been set for improvement of human well-being, protecting natural resources, and mitigating the impact of human activities on the planet for future generations. It is clear that the SDGs seek to leave no one behind while creating inclusive, safe, environmentally sustainable, and healthy cities. However, the SDGs highlight that urban areas are not homogenous in their development needs, and they require more detailed, disaggregated data to monitor these issues (Jochem et al., 2021).


**Figure 2.2: The 17 United Nations Sustainable Development Goals (SDGs) adopted in 2015 as part of the United Nations 2030 Agenda for Sustainable Development (source: Van Den Hoek et al., 2021:2).**

Avtar et al., 2019 argued that GRID3 is relevant in the implementation of SDGs and monitoring of their progress because of its usefulness in measuring the SDGs targets. They maintained that the recent GIS technologies utilising spatial statistics for analysing spatial distributions and patterns can be used for controlling diseases by monitoring water quality and sanitation for different areas (SDG 3, SDG 6, and SDG 14). Qiu et al., (2019) also made a case for GRID3 infrastructures as facilitating the production and use of high-resolution population and other reference data, providing support for government decision-making, and useful for the assessment of SDGs. Li et al., (2020) claimed that the UN suggested that geospatial data should be utilised to mitigate the shortage of in-situ data availability, support and track the progress in fulfilling SDGs, provide the social and economic statistical data required for calculating SDG indicators, and detect social and economic inequalities at both national and local levels. Bernard and Ostländer (2007) contended that GRID3 infrastructures have become widely accepted and used as tools to pre-process the input and analyse the output of the various simulation models used to forecast and assess environmental change and its impacts. Avtar et al., (2019) asserted that GRID3 infrastructures are key to achieving SDG 1, SDG 4, SDG 11, SDG 12, and SDG 16 within the stipulated time frame because of their usefulness in visualising spatiotemporal changes in poverty, schools, literacy, green space in cities, usage of natural resources, greenhouse gases emissions over product life cycle, and cases registered against violence.

The usefulness of GRID3 infrastructures in achieving SDGs have been demonstrated by Bernard and Ostländer (2007) which presented the application of GRID3 Infrastructures to climate change assessment by implementing a generic methodology for the quantification of vulnerability to climate change. Mhangara et al., (2019) concluded that the usage of GRID3 infrastructures as a monitoring and evaluation tool for African Union's Agenda 2063 has gained traction in the last few decades due to its ability to support the collection, integration, storage, analysis, output, and distribution of location-based data. Chen et al., (2020) presented the methodology and results of a pioneer project which measured the progress toward SDGs at a local level in China by integrating statistical and geospatial information. Shamsudduha et al., (2019) developed a geospatial hazard map in Bangladesh. The map was overlaid with hydrological indicators for water quality and quantity, as well as access to drinking, irrigation water supplies, and social vulnerability. The study claimed that the maps can potentially guide policy makers in prioritising mitigation and adaptation measures towards achieving the United Nations' SDGs.

Towards the actualisation of SGD 2 (Zero Hunger), Ujoh et al., (2019) employed geospatial data to map the suitability of rice cultivation in Benue State, Nigeria. The results of the study revealed that the Normalised Difference Vegetation Index (NDVI) in highly suitable rice planting regions is higher than marginally suitable regions except in the months of October and November, which shows that the highly suitable regions will yield better than the marginally suitable regions during the dry season. Giuliani et al., (2020) proposed knowledge generation using satellite earth observations to support SDGs. Korkovelos et al., (2020) provided an overview of open access geospatial data and GIS based electrification models aiming to support SDG7. Geospatial data was used by Korkovelos et al., (2020) to develop a least cost electrification model in support of electrification policy in fragile states in Afghanistan. Ajisegiri et al., (2019) presented a geospatial model of access to water and sanitation in Nigeria. Van Den Hoek et al., (2021) examined the potential of OpenStreetMap (OSM) data for monitoring SDG progress in refugee settlements. The study created a novel

SDG-OSM data model, measured the spatial and temporal coverages of SDG relevant OSM data across refugee settlements, and compared these results to non-refugee settlements.

In spite of the usefulness of GRID3 Infrastructures in achieving SDGs, the sustainability of GRID3 Infrastructures have been questioned by scholars. For instance, Korkovelos et al., (2019) observed that geospatial data are usually incomplete, of uncertain quality, and with varied accuracies. Mhangara et al., (2019) claimed that in some cases, GRID3 Infrastructures lack the basic analytical capability and spatial analysis functionality. According to Li et al., (2018) geospatial data is increasingly becoming massive and complex. This finds support in Gao et al., (2008) which claimed that the dynamic characteristic of GRID3 brings complexity to spatial query optimization because spatial operations are data intensive.

In an effort to characterise data ecosystems to support official statistics with open mapping data for reporting on SDGs, Van den Homberg and Susha (2018) noted that there is a large variety of geospatial data sharing platforms and online accessible information management systems with however a low adoption due to limited internet connectivity and low data literacy. Cader et al., (2018) noted that the quality of geospatial data is sufficient but the data are not readily available. The scarcity of geospatial data, according to Cader et al., (2018) is affecting the achievement of SDGs in Tanzania. Ali et al., (2020) analysed the cost-effectiveness of traditional and geographic information system (GIS)-supported micro planning approaches for routine immunisation program management in northern Nigeria. The analysis covered the use of GIS microplanning, which estimate target populations using satellite imagery and calculate distances using spatial analyses. The analysis revealed that GIS-based microplanning incurs higher costs than traditional microplanning, due mainly to the additional vaccinations required for populations previously unreached by traditional microplanning.

Based on the findings of the above studies, it becomes important to further investigate the level of sustainability of GRID3 infrastructures in Nigeria, owing to the usefulness of GRID3 infrastructures in achieving SDGs.

## 2.8 Innovative Approaches for Enhancing the Sustainability of GRID3 Infrastructures for Social Development

The sustainability of GRID3 infrastructures for social development depends heavily on having access to accurate, timely, and compatible spatial data (Murad 2018). This view is shared by Qiu et al., (2019), Giuliani et al., (2010), and Goodman et al., (2019). According to Qiu et al., (2019), a uniform, truly distributed, and fine-scale population data are necessary to comprehensively achieve the 17 SDGs. Giuliani et al., (2010) argued that the limited analytical capabilities of geospatial data limit the types of analyses that can be conducted on them in the process of turning the data into understandable information. In terms of data interoperability, Giuliani et al., (2010) noted that efforts are needed to organise and standardise the format and quality spatial data to improve its interoperability. Regarding the standards and effective use of geospatial data, Giuliani et al., (2010) observed that the provisions such as identification, spatial and temporal extent, quality, distribution rights, and spatial reference system should be used for describing geospatial data and services. Also, Giuliani et al., (2010) observed that due to lack of awareness of their availability, poor documentation, and numerous data inconsistencies, the vast majority of geospatial data are not being used as effectively as they should. Goodman et al., (2019) noted that computational skill sets required for geospatial data has increased the same way the quantity and resolution of geospatial data has increased.

A considerable amount of literature has been published on innovative approaches for enhancing the sustainability of GRID3 infrastructures for social development. For example, Qiu et al., (2019) presented a geospatial disaggregation method of population data for supporting SDG assessments based on a case study of Deqing County in China. In the case study, Deqing County was divided into residential areas and non-residential areas according to the idea of dasymetric mapping. Then, the town administrative areas were taken as control units, building area and number of floors were used as weighting factors to establish the disaggregation model, and population data with a resolution of 30 m in Deqing County in 2016 were obtained. After analysing the statistical population of 160 villages and the disaggregation results, the study found that the global average accuracy was 87.08%. The disaggregation population data was used to conduct an accessibility analysis and a buffer analysis in a quantitative assessment of the SDGs. The study claimed that the SDG measurement and assessment results based on the disaggregated population data were more accurate and effective than the results obtained using the traditional method.

Giuliani et al. (2012) developed an approach to process geospatial data on different computing back-ends. Woldai (2002) identified consistency, integrated baseline, multiple use and re-use of data, mapping standards, data security, accountability and transparency, and cost-effectiveness of databases as criteria for sustainable geospatial infrastructures. Yue et al., (2010) proposed augmenting geospatial data provenance through metadata tracking in geospatial service chaining. Yang et al., (2017) utilised cloud computing to address big geospatial data challenges. Llyod et al., (2020) proposed an ensemble machine learning building classification model that was developed from the combination of GIS and Machine Learning. The study claimed that the model is useful for classifying residential status of urban buildings in low and middle-income settings. The study concludes that the classification outputs from the proposed model are valuable in the modelling of human population distributions, as well as urban planning, resource allocation, and service delivery.

These previous studies have shown that enhancing the sustainability of GRID3 infrastructures will enable the GRID3 infrastructure to provide high processing and storage capabilities, improve output data resolution, improve model complexity, widen the covered area and from local to national and global scales. The previous studies have also shown that innovative approaches will enable the GRID3 infrastructure to improve the time-of response (from hours to minutes), integrate new and heterogeneous input data, integrate outputs in a higher-level application chain, facilitate the data's interoperability and composition, and facilitate interoperability with other standard based infrastructures such as Global Earth Observation System of Systems (GEOSS). Thus, it becomes important to extensively investigate innovative approaches for enhancing the sustainability of GRID3 infrastructures for social development.

## 2.9 Summary of the Chapter

The preceding sections in this chapter have presented the interconnection between social development and achieving the SGDs. It explores the dimensions of social development approaches that have led to the conscious efforts of social interventions for human development. The chapter argues that the provision of health services and health related facilities is an important social and sustainable development strategy. The chapter also explores the evolution of geospatial to the present times and how geospatial technologies and tools are used to solve complex social issues with a wide application spectrum of events. An example of geospatial tools and technology—GRID3—was investigated, and its use and application for social development was further highlighted. The chapter also investigates the relevance and level of sustainability using specific variables as highlighted by scholars. Other innovative approaches or improvements from scholarly publications that can be applied to the GRID3 platform were discussed in order to identify potential areas for GRID3's sustainability.

The next chapter presents the methodology and case study approach used for this research thesis. It also provides information on the study areas, the social and economic characteristics of the study area, and the case study design for the research.

# CHAPTER 3

# RESEARCH METHODOLOGY

## 3.1 Introduction

This chapter examines the procedures followed during the research for the study. The chapter commences with a discussion of qualitative and quantitative research approaches used in the study, questionnaire design, interview protocols, and data collection generally. The subtleties of grounded theory research including theoretical sampling, and data analysis as embraced in this study was discussed. The chapter finishes up the conversation of the applicable ethical contemplations as viewed in this study.

## 3.2 Case Study

Case study as a contextual investigation does not fit a single and direct definition. This is because it accompanies various affiliations, ones which are regularly held certainly by researchers and thought to be shared by scholars. Yin (2012:25) characterises a case study as a contemporary phenomenon inside its genuine setting, particularly when the limits between a phenomenon and setting are not satisfactory and the researcher has little command over the phenomenon and setting. Yin (2012:25) also explains that case study analysis is an experimental request that researches the case or cases adjusting to the previously mentioned definition by tending to the "how" or "why" questions concerning the phenomenon of interest. Creswell (2003:6) characterises case study as a process where researchers investigate a phenomenon in-depth, an occasion, a movement, a cycle, or at least one individual. Leedy and Ormrod (2001) state that case study endeavours to learn more with regards to a generally secret or inadequately obtained circumstance. Leedy and Ormrod (2001) further require a case study to make some characterised memories outline. Also, Creswell (1998:11) recommends that the design of a case study ought to be the issue, the specific situation, the issues, and the illustrations learned.

The data collected for case study is broad and draws from numerous sources, for example, direct or member perceptions, interviews, authentic records or reports, actual ancient rarities, and varying media materials. In case study, the researcher should invest energy on location collaborating with individuals considered. The report would incorporate illustrations learned or designs found that associate with the hypotheses. In a case study, the researcher investigates a solitary substance or phenomenon ('the case') limited by time and action (e.g., a program, occasion, organization, or gathering of people) and gathers definite data throughout a supported timeframe. Case study, as a research procedure, gives an illustrative record of a singular's encounters and additional practises kept by an external onlooker. It is useful for exploring complex circumstances with various factors under investigation. Case studies are especially engaging for propelling a field's information base. It offers a decent chance for development and challenges current hypothetical presumptions. They can likewise be a decent other option or supplement to the focus group strategy (Leedy and Ormrod, 2001).

Nonetheless, it very well may be hard to set up a cause and impact association and it can be difficult to arrive at resolutions. It also tends to be difficult to generalise, especially when a modest number or contextual analyses are thought of (Queirós et al., 2017). There are four sorts of case study analysis configuration; these incorporate single holistic design, single embedded design, multiple holistic design, and multiple embedded design (Yin, 2002).

### 3.3 Case Study Data Collection Methods

Research originates with at least one question about one phenomenon of interest (Queirós et al., 2017). The three common approaches to conducting research comprise quantitative, qualitative, and mixed methods. Qualitative and quantitative research are different in terms of goals, applications, sampling procedures, types of data, and data analysis. Qualitative research is interpretive research while quantitative research is inferential research (Creswell, 2003). According to Winter (2000), quantitative research is even handed, utilises deductive thinking, examines research question(s), makes inductions, discovers connections among factors, makes forecasts, discovers causation, tests hypotheses, and sums up outcomes. Quantitative research endeavours to section and delimit phenomena into quantifiable or 'normal' classifications that can be applied to the subjects in general or more extensive and comparative circumstances.

Quantitative research, while ready to guarantee legitimacy for more extensive populaces and not simply only examples, is confined to estimating those components that, by definition and contortion, are normal to all (Winter, 2000). Cresswell (2003) characterises quantitative research as a research method in which the researcher principally utilises post positivist cases for creating information, for instance; circumstances and logical results thinking, decrease to explicit factors and speculations and questions, utilisation of estimations and perceptions, and the test of the hypotheses. This means that quantitative research can be utilised because of social inquiries of factors inside the examination. Quantitative researchers look for clarifications and expectations that will generate different people and places. The goal is to build up, affirm, or approve connections and to foster speculations that add to hypothesis.

Quantitative strategies and systems permit the researchers to get expansive and generalisable discoveries and present them concisely and close-fistedly. Quantitative research strategies are fitting when 'authentic' information are needed to respond to the research question; when general or likelihood data is looked for on sentiments, perspectives, convictions or inclinations; when factors can be disconnected and characterised; when factors can be connected to frame speculations before information assortment; and when the inquiry or issue is known, clear and unambiguous (Hammarberg et al., 2016). Quantitative research starts with an issue proclamation and includes the arrangement of a speculation, a literature survey, and a quantitative data investigation.

Creswell (2003) states that quantitative research utilises systems of request, for example, test and reviews, and gather information on foreordained instruments that yield measurable information. The discoveries from quantitative research can be prescient, illustrative, and affirming. Quantitative research includes the assortment of information so data can be measured and exposed to factual treatment to help or disprove substitute information claims (Creswell, 2003). In the opinion of Williams (2007), quantitative research centres on objectivity and is particularly fitting when there is the chance of gathering quantifiable proportions of factors and inductions from tests of a populace. Quantitative research embraces organised methodology and formal instruments for information assortment. The information are gathered dispassionately and deliberately. Ordinarily utilising deductive rationale, quantitative strategies look for consistencies in human subjects, by isolating the social world into experimental parts called factors which can be addressed mathematically as frequencies or rate, whose relationship with one another can be investigated by factual methods, and accessed through methodical estimation (Rahman 2020).

There are limitations associated with quantitative research. For instance, the quantitative research method restricts itself to what exactly can be estimated or measured. The method endeavours to get the bits of the unquantifiable, individual, top to bottom, enlightening and social parts of the world (Winter, 2000). Yimaz (2013) noted that on the grounds that quantitative research requires a deductive methodology and foreordained arrangements of normalised reactions dependent on hypothesis, they neglect to give understanding into the participants' experiences. The method does not allow the participants to depict their sentiments, musings, casings of reference, and encounters with their own words. According to Hopkins (2008), quantitative research is also limited because it utilises less heterogeneous participants by working out their attributes and investigating them.

Conclusively, quantitative research is an investigation into a distinguished phenomenon, in view of testing a hypothesis, estimated with numbers, and analysed using statistical procedures. The method normally selects the quantitative way to deal with questions requiring numerical information.

Unlike quantitative research methods, qualitative research is one in which the researcher normally makes information claims dependent on constructivist points of view (Cresswell, 2003). Likewise, qualitative research has been portrayed as a viable model that happens in a natural setting that empowers the researcher to develop a degree of detail from being profoundly engaged with the genuine encounters (Schwandt, 2001). Different terms have been applied to connote qualitative methods, like social examinations, constructivist worldview, natural inquiry, phenomenological examination, postmodernism, post-positivism mentality, and post-structuralism. The qualitative research is useful for rearranging and overseeing information without obliterating intricacy and setting. It is profoundly fitting for questions where pre-emptive reduction of the information will forestall discovery. On the off chance that the reason for existing is to gain from the participants in a setting or an interaction the manner in which they experience it, the implications they put on it, and how they decipher what they experience, the researcher needs strategies that will take into consideration disclosure and do justice to their insights and the intricacy of their understandings.

Qualitative research shares practically the objective of producing better approaches for seeing existing information. On the off chance that the reason for existing is to develop a hypothesis or a hypothetical structure that reflects reality instead of the analyst's viewpoint or earlier examination results, one might require techniques that help the revelation of hypotheses in data. The point of qualitative investigation is a complete, nitty gritty depiction. No endeavour is made to allocate frequencies to the semantic provisions which are recognized in the information, and uncommon phenomena get similar measure of consideration as more common phenomena. Qualitative research considers fine distinctions to be drawn on the grounds that it is not important to shoehorn the data into a limited number of categories. Qualitative research is utilised to respond to inquiries concerning experience, meaning and viewpoint, regularly from the stance of the participants. Qualitative research procedures incorporate small group conversations, semi-structured meetings, in-depth interviews, and examination of texts and records (Hammarberg et al., 2016).

The characteristics of qualitative research entails the utilisation of inductive thinking, investigation of a topic, gaining a comprehension of what/who is being considered, clarifying phenomena, and developing hypotheses (Winter, 2000). Qualitative research, emerging out of the post-positivist dismissal of a solitary, static or target truth, has fretted about the implications and individual experience of people, groups and sub-societies (Winter, 2000). Qualitative research method typically stresses words as opposed to evaluation in the collection and investigation of information (Bahari, 2010). The research method is an all-encompassing methodology that includes discovery. One identifier of qualitative research is the social phenomenon being explored from the participant's perspective and it is led inside a poststructuralist worldview.

There are five areas of qualitative research: contextual investigation, ethnography study, phenomenological study, grounded theory study, and content examination. These five areas are illustrative of exploration that is based upon inductive thinking and related philosophies. This indicates that the method is concerned about measure, setting, translation, meaning or comprehension through inductive thinking. The point is to portray and comprehend the phenomenon studied by catching and imparting participants' encounters as would be natural for them by means of perception and experience. What is accentuated is the assessment of the setting that impacts participants' activities or co-operations and the importance that participants credit to their encounters (Hafiz, 2008). Participants can clarify how they figure out their general surroundings and their encounters through interviews with open-ended inquiries. That is the reason qualitative research requires a top to bottom investigation of participants' lives or the issues in their regular settings without falling back on predetermined classes of investigation. Open-ended responses let the researcher comprehend and present the world as it is seen and experienced by the participants without foreordaining those stances. Direct quotations report the participants' profundity of sentiments, encounters, musings concerning what's going on, and meaning at an individual level. Consequently, qualitative discoveries are far longer, more definite and variable in content than quantitative ones (Yilmaz, 2013).

Every one of the qualitative methodologies have two things in common. In the first place, the accentuation of phenomena that occur in regular settings-that in reality. Another is the study of those phenomena for all their difficulties (Yilmaz, 2013). However, these realities are the other way around in quantitative methodology (Leedy and Ormrod, 2010). What constitutes qualitative research includes deliberate use for depicting, clarifying, and deciphering gathered information. Leedy and Ormrod (2001) affirmed that qualitative research is less organised in description since it details and fabricates new hypotheses. The limitation of this method is also revealed in the fact that it fabricates its premises on inductive, instead of deductive thinking. It is from the observational components that suggest questions that the researcher endeavours to clarify. The solid relationship between the researcher and the information is a stamped distinction from quantitative research, where the researcher is totally outside of the phenomena being researched (Williams, 2007).

Other limitations of qualitative research methods include ambiguities, which are innate in human language that can be perceived in any given analysis. The fundamental impediment of qualitative approaches to deal with corpus investigation is that their discoveries can not be reached out to more extensive populaces with the very level of assurance that quantitative examinations can. This is on the grounds that the discoveries of the examination are not focused onwhether they are statistically significant or because of probability (Ochieng, 2009). Equivalent to quantitative research, qualitative exploration is requesting, restrained, precise, and it often conveys a useful elective way to deal with quantitative examination strategies (Zangeneh, 2010).

In summary, a qualitative course of inquiry has the objective of understanding a social or human issue according to different viewpoints. Qualitative examination is led in a characteristic setting and includes a course of building an intricate and comprehensive image of the phenomenon of interest.

Qualitative and quantitative methods can likewise be integral to each other. This strategy is known as mixed methods. Mixed methods examination can be seen as a methodology which draws upon the qualities and points of view of every strategy, perceiving the presence and significance of the physical, normal world just as the significance of the real world and impact of human experience (Ostlund et al., 2011:372). Mixed methods research is an examination technique where the researcher gathers and investigates information, coordinates the discoveries and draws inductions utilising both subjective and quantitative methodologies. Mixed methods research offers a more extensive scope of points of view that can do equity to the intricacy of the phenomena considered. By consolidating subjective and quantitative discoveries, an in general or arranged record of the discoveries can be produced in mixed methods. Mixed methods can likewise assist with featuring the likenesses and contrasts between specific parts of a phenomenon. The mixed methods approach gives researchers the capacity to plan a solitary exploration concentrating on answering inquiries concerning both the perplexing idea of phenomenon according to the participants' perspective and the connection between quantifiable factors (Williams, 2007).

The mixed methods research is an addition, not a replacement, for the quantitative and qualitative approach to research, as these methods will continue to be useful and significant (Johnson and Onwuegbuzie, 2004). The objective for researchers utilising the mixed methods research is to draw from the qualities and limit the shortcomings of the quantitative and qualitative exploration methods (Johnson and Onwuegbuzie, 2004). Obviously, the qualities and shortcomings related with the different research approaches are not outright but instead comparative with the specific situation and the way in which researchers seek to address the phenomenon under study. For instance, if the researcher implies to give inside and out knowledge into a phenomenon, the researcher may decide to choose a small yet instructive sample, which is regular of qualitative exploration. The researcher may utilise inferential measurements to evaluate the outcomes, which is ordinary of quantitative examination, as qualities deserving of consolidating into a solitary exploration study (Williams, 2007). The major argument is that the mixed methods approach is suitable for research questions requiring both numerical and textural data.

The data collection methods for the case study approach used in this research are discussed below. This provides an overview of the data collection techniques employed to conduct the research and present the data collected.

### 3.3.1 Data Collection: Field Experiment

Field experiment is one of the research approaches that can be adopted in the research methods. It is a research approach that happens in real-life settings. It includes the detachment and control of at least one factor to test the impact (Queirós et al., 2017). It permits the researcher to notice more regular conduct, however the researcher will have much more factors to consider. This methodology is likewise normal in sociology and applied science like bio-engineering and health sciences. Field experiment offer critical qualities when contrasted with lab tests. It offers a characteristic setting as opposed to a fake lab setting (Queirós et al., 2017).

Field experiment is genuine tests and are portrayed by irregular tasks of subjects to test conditions and the utilisation of test controls. Field experiment is a method of data collection that plans to decide whether a particular treatment impacts a result (Zou et al., 2014:320). An experiment commonly includes giving a particular treatment to one gathering and denying it of another. In an experimental setting, the presentation of each group according to a foreordained arrangement of results is then looked at and investigated (Zou et al., 2014).

### 3.3.2 Survey

Surveys are a research procedure that permits the assortment of information straightforwardly from an individual engaged with the researcher through a bunch of inquiries coordinated in a specific request (Queirós et al., 2017). It is quite possibly the most utilised quantitative technique, since it permits acquiring data about a given phenomenon, through the plan of inquiries that mirror the suppositions, insights and practises of a group of people. Surveys incorporate cross-sectional and longitudinal investigations utilising interviews or questionnaires for data collection with the plan of assessing the qualities of an enormous populace of premium dependence on a more modest sample from that populace. As a research approach, survey gives a numeric portrayal of patterns, perspectives, or assessments of a populace by concentrating on a sample of that populace. Regularly, information is gathered utilising surveys, organised interviews, or organised perceptions with the aim to sum up from a sample of a populace (Zou et al., 2014).

Surveys offer a few advantages. Two of those most significant advantages incorporate the high representativeness of the whole populace and the minimal expense of the strategy when contrasted with different other options. On the opposite side, the dependability of survey data is extremely reliant upon the study structure and the exactness of answers given by the respondents (Queirós et al., 2017).

### 3.3.3 Interview/focus group

Interviews can be in-depth, unstructured, structured, or semi-organized(Hanson and Grimmer, 2007). Structured interviews are an evaluation technique configured to get and analyse reactions from every one of the interviewees. The interviewees are asked about past encounters and additionally proposed speculative circumstances. The cycle is standard for all individuals interviewed. Structured interviews ordinarily offer a high reaction rate and the interviewer is available to disclose the inquiry to keep away from distortion from respondents. Be that as it may, setting up a structured interview can likewise be tedious (Queirós et al., 2017)

In-depth interviews are a sort of unstructured, direct, and individual meeting with every respondent. In this interaction, the researcher commonly starts with a conventional inquiry, and afterward urges the respondent to talk openly about the theme. There is likewise a variation that thinks about the presence of semi-organized interviews, where there are a bunch of pre-characterized questions, yet in which opportunity is given to investigate one of the inquiries in more prominent profundity. In-depth interviews give exceptionally rich data and the chance to ask follow-up inquiries, test extra data, legitimise past replies, and build up an association between a few subjects. It likewise offers an agreeable climate where individuals might feel better to build up a discussion. Nonetheless, there are a few impediments and entanglements, since it is time-concentrated and it is not generalizable.

Focus groups are an extremely well known and helpful strategy to explore complex conduct, where the exploration can collaborate with the participants. The data is normally given more rapidly than if individuals were met independently. Two principal attributes that separate centre gatherings from different procedures are, the data source is a gathering; and the heuristic worth of this method lies in the sort of communication that arises during the discussion (Acocella, 2012). Focus groups can give a more extensive scope of data and they offer the chance to look for explanations, in case there are subjects that need further explanation. Be that as it may, focus groups can be difficult to control and oversee. Also, it may be difficult to encourage individuals to participate and, consequently, they may not be the required representation and participation may be low.

### 3.3.4 Observation

Observation is a methodical course of gathering data, where researchers notice a given phenomenon right in its natural setting (Zou et al., 2014:321). This technique is particularly demonstrated when a given subject is moderately neglected and it becomes critical to comprehend exhaustively a given phenomenon, while keeping up with the natural conditions where it happens.

Observation is a decent method of gathering information at the same time with the event, without meddling with the event (Zou et al., 2014:320). It is a subtle and truly adaptable technique, situated to the disclosure of information. In some circumstances, like the examination of the conduct of individuals and creatures, is the best way to acquire information in a dependable manner. On the opposite side, it is an extremely tedious strategy, which needs earlier readiness and the accessibility of the researcher to visit where the event happens. Besides, the strategy is very delicate to the freedom of the researcher's examination, since the translation of the information is done solely by the researcher (Queirós et al., 2017).

## 3.4 Study Area

Oyo, a pre-colonial empire in present-day Southwestern Nigeria, was founded in the 1300s. Established by Oranmiyan of the Yoruba people of West Africa, Oyo quickly grew to become one of the most powerful states in the Yoruba-speaking region. Oyo was ruled by an *alafin* (king) who shared power with the Oyo Mesi (aristocratic leaders from each of Oyo city's seven wards) (Adeyeri, 2019). The empire was the largest and best-known of the Yoruba kingdoms. The power and influence of the Oyo Empire serve as the most significant features of Yorubaland. The role and depth of Oyo's influence in nurturing a Yoruba identity and consciousness among the Yoruba has continued to resonate across generations and boundaries. The Yoruba who today are found in the Southwestern part of Nigeria, the Republics of Benin and Togo, Brazil, Cuba, Trinidad and other places in the Caribbean have continued to imagine the glory and renown of the empire and the consciousness created by the Oyo empire. The dominance and commercial links of the Oyo Empire with different parts of the world provided the basis for stability that protected Yorubaland from aggression or untoward experiences. Even, the name Yoruba was initially used for the Oyo speaking people, their empire and dialect until the 19th century when European explorers applied the name widely to other Yoruba sub-groups. Oyo Empire also became the basis for a global understanding of the capacity of the black race to construct an enduring political and social arrangement (Edo, 2010).

Oyo Empire did not only give a major identity and dominant political power to Yorubaland; the name for Oyo state was derived from Oyo Empire. Oyo state was one of the three States carved out of the former Western State of Nigeria in 1976. Oyo State is homogenous, mainly inhabited by the Yoruba ethnic group who are primarily agrarian but have a predilection for living in high density urban centres (Mayowa, 2014). The indigenes mainly comprise the Oyos, the Ogbomosos, the Oke-Oguns, the Ibadans and the Ibarapas, all belonging to the Yoruba family and indigenous city in Africa, south of the Sahara. Notable cities and towns in Oyo State include Oyo, Ibadan (centre of administration/capital city), Ogbomoso, Iseyin, Kisi, Okeho, Saki, Eruwa, Lanlate, Sepeteri, Ilora, Awe, Ilero, Igbeti, Igboho and Igbo-Ora (Ejiogu, 2015).

Oyo State covers approximately an area of 28,454 square kilometres and is ranked 14th by size, it is bordered in the south by Ogun State, in the north by Kwara State, in the west, it is partly bordered by Ogun State and partly by the Republic of Benin, while in the East by Osun State (see Figure 3.1). Oyo State contains a number of natural features including the Old Oyo National Park. This location was the early habitat of the endangered African Wild Dog; Lycaon pictus. However, this canid is thought to have been locally extirpated at present. The Climate is equatorial, with dry and wet seasons and with a notably relatively high humidity. The dry season lasts from November to March while the wet season starts from April and ends in October. The average daily temperature ranges between 25 °C (77.0 °F) and 35 °C (95.0 °F), almost throughout the year. The topography of the State is of gentle rolling low land in the south, rising to a plateau of about 40metres. The State is well drained with rivers flowing from the upland in the north-south direction. The vegetation pattern of Oyo State is that of rain forest in the south and guinea savannah in the north. Thick forest in the south gives way to grassland interspersed with trees in the north. The climate in the State favours the cultivation of crops like Maize, Yam, Cassava, Millet, Rice, Plantain, Cocoa tree, Palm tree and Cashew (Oladele et al., 2020; Bamigboye, 2020).

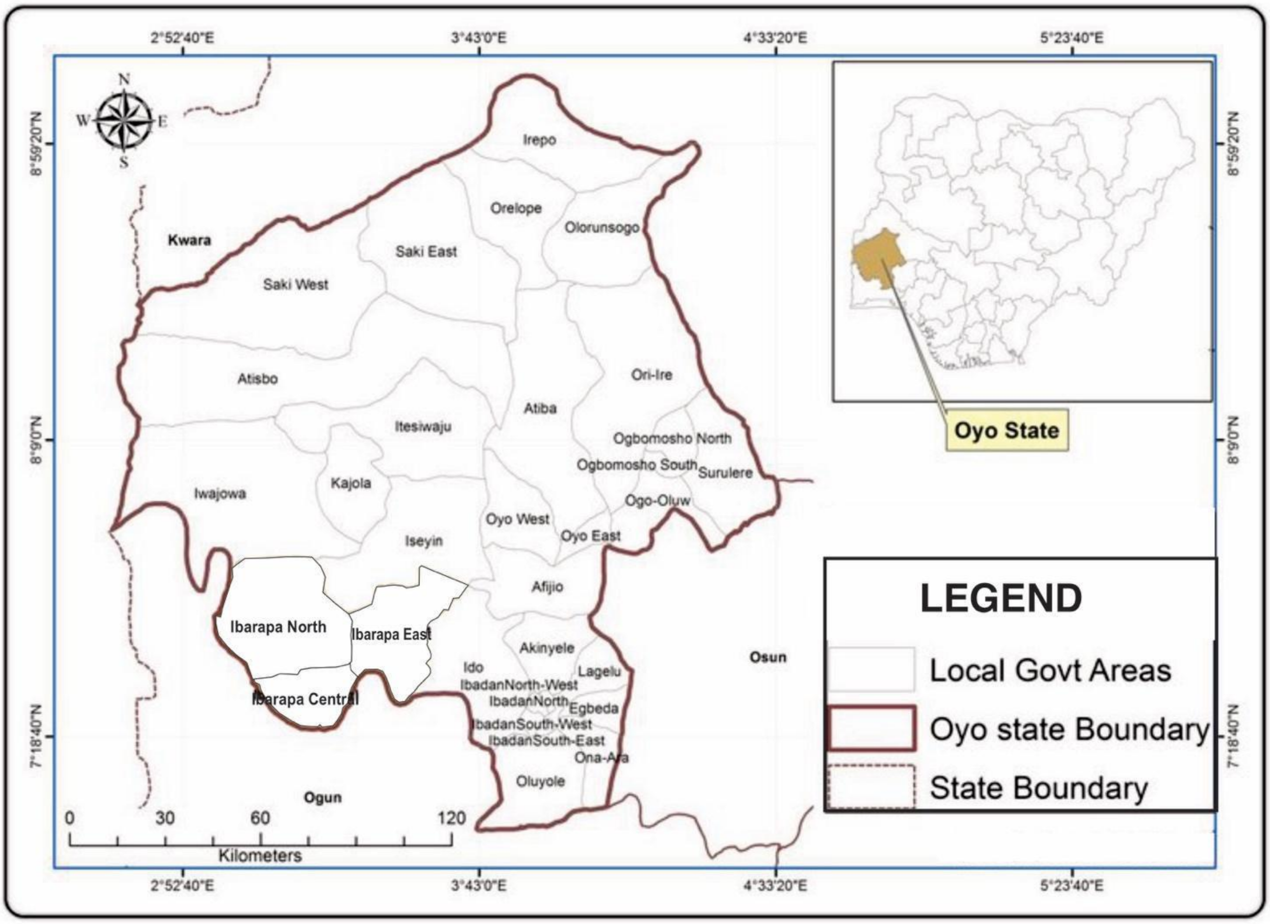


**Figure 3.1: Geographical Location of Oyo State within Nigeria**

Oyo state is the third most populous city in the country with a population of about 6million. The State consists of 33 Local Government Areas and 29 Local Council Development Areas (see Table 3.1 for the details of the Local Government Areas). Oyo State is crucial to the progress and development of Nigeria. The state hosts the first university in Nigeria (the University of Ibadan, established as a college of the University of London when it was founded in 1948, and later converted into an Autonomous university in 1962) and the first teaching hospital in Nigeria (the University College Hospital). Other Universities in the State are: Ladoke Akintola University of Technology, First Technical University Ibadan, Ajayi Crowther University, Lead City University, Kola Daisi University Ibadan, Dominican University Ibadan, Precious Cornerstone University, Atiba University, and Dominion University Ibadan. Another prominent landmark in Oyo State is the Cocoa House (the first skyscraper built in Africa), the National Television Authority in Ibadan (the first television station in Africa), and Liberty Stadium (the first stadium built in Africa).

Oyo State was selected as the study area for this research owing to its importance as the third most populous and largest city in Nigeria. Also, the history of geospatial analysis of Oyo state qualifies it as a study area for this research. Ojiako et al., (2021), designed and created the Automated Topographic Information System of Emmanuel Alayande College of Education in Oyo State. Fajuyigbe et al., (2007) developed a web-based GIS for tourism in Oyo state. Idhoko et al., (2015) developed a Geographic Information Systems road network database for emergency response in Oyo State. Igbokwe et al., (2016) created Cadastral Information System for Part of Oluyole LGA in Oyo State.

**Table 3.1: Local Governments Areas in Oyo State**

**(Source:https://oyostate.gov.ng/about-oyo-3/)**

| S/No | Local Government | Headquarters | Date of Creation | Landmass ($km^2$) |
|---|---|---|---|---|
| 1 | Afijio | Jobele | 1989 | 800 |
| 2 | Akinyele | Moniya | 1976 | 575 |
| 3 | Atiba | Ofa-Meta | 1996 | 219.753 |
| 4 | Atisbo | Tede | 1996 | 315.23 |
| 5 | Egbeda | Egbeda | 1989 | 410 |
| 6 | Ibadan north | Agodi-Gate | 1991 | 420 |
| 7 | Ibadan north east | Iwo-Road | 1991 | 125 |
| 8 | Ibadan north west | Onireke | 1991 | 238 |
| 9 | Ibadan south east | Mapo | 1991 | 805.37 |
| 10 | Ibadan south west | Ring-Road | 1991 | 244.55 |
| 11 | Ibarapa central | Igbo-Ora | 1996 | 480.424 |
| 12 | Ibarapa east | Eruwa | 1989 | 705.78 |
| 13 | Ibarapa north | Ayete | 1999 | 427.857 |
| 14 | Ido | Ido | 1989 | 1010.954 |
| 15 | Irepo | Kisi | 1976 | 972.316 |
| 16 | Iseyin | Iseyin | 1976 | 988.54 |

| | | | | |
|---|---|---|---|---|
| 17 | Itesiwaju | Out | 1996 | 1543.193 |
| 18 | Iwajowa | Iwere-Ile | 1996 | 147.677 |
| 19 | Kajola | Okeho | 1976 | 4329 |
| 20 | Lagelu | Iyana-Ofa | 1976 | 416 |
| 21 | Ogo oluwa | Kinnira | 1991 | 2466.42 |
| 22 | Ogbomoso north | Arowomole | 1991 | 15 |
| 23 | Ogbomoso south | Ajaawa | 1989 | 4159.51 |
| 24 | Olorunsogo | Igbeti | 1996 | 1070.216 |
| 25 | Oluyole | Idi-Ayunre | 1976 | 4000 |
| 26 | Oorelope | Akanran | 1989 | 424.544 |
| 27 | Ona ara | Igboho | 1989 | 893.082 |
| 28 | Orire | Ikoyi-Ile | 1989 | 2040 |
| 29 | Oyo east | Kosobo | 1996 | 365.50 |
| 30 | Oyo west | Ojongbodu | 1996 | 5193.77 |
| 31 | Saki east | Ago-Amodu | 1996 | 2000 |
| 32 | Saki west | Saki | 1996 | 300 |
| 33 | Surulere | Iresa-Adu | 1989 | 975 |

### 3.5 Social Economic Characteristic in the Study Area

Several studies have established the relationship that exists between the socio-economic characteristics of respondents and their level of proficiency in the use of geospatial data, tools, and technology (Yenenesh, Abreham, & Terefe, 2022; Wekasa, Steyn, & Otieno, 2011). The socio-economic characteristics of respondents play an important role in determining the level of impact of GRID3 infrastructure as a development tool in the health sector. Some examples of socio-economic characteristics of research participants as it relates to this study were examined, such as educational qualification, occupation, years of experience, language proficiency, and role in their organization. These socio-economic variables was collected and analysed in the next chapter to provide additional context on the maturity level of the people receiving the GRID3 infrastructural intervention, who are administering or utilising it, as well as the population's ability to translate it into an impact for healthcare service delivery.

### 3.6 Concept and Case Study Design for the Research

To explore the use and the sustainability of GRID3 infrastructures for social and sustainable development in Nigeria, this study developed a conceptual framework explaining the links between the tools, infrastructure, and service variables. Figure 3.2 illustrates the conceptual framework developed for this study. The framework describes the connection between GRID3 infrastructures, social development, sustainable development goals, and health infrastructures. As explained in the framework, GRID3 infrastructures include geospatial services, data, and tools. These infrastructures are useful for implementing and monitoring SDGs. Despite its usefulness, there is a question of the sustainability and the need to enhance the sustainability of the infrastructures. Further, the framework posits that geospatial services, data, and tools that are available on GRID3 infrastructures are useful for social and sustainable development. It was also argued in the framework that all the 17 SDGs can be monitored and implemented with a sustainable and enhanced GRID3 infrastructures. Lastly, the framework posits that social development is a component of sustainable development and that both address health infrastructures. The health infrastructures that should be found in GRID3 include the number of health facilities, number of beds, number of physicians, road connectivity, water availability, and availability of electricity.

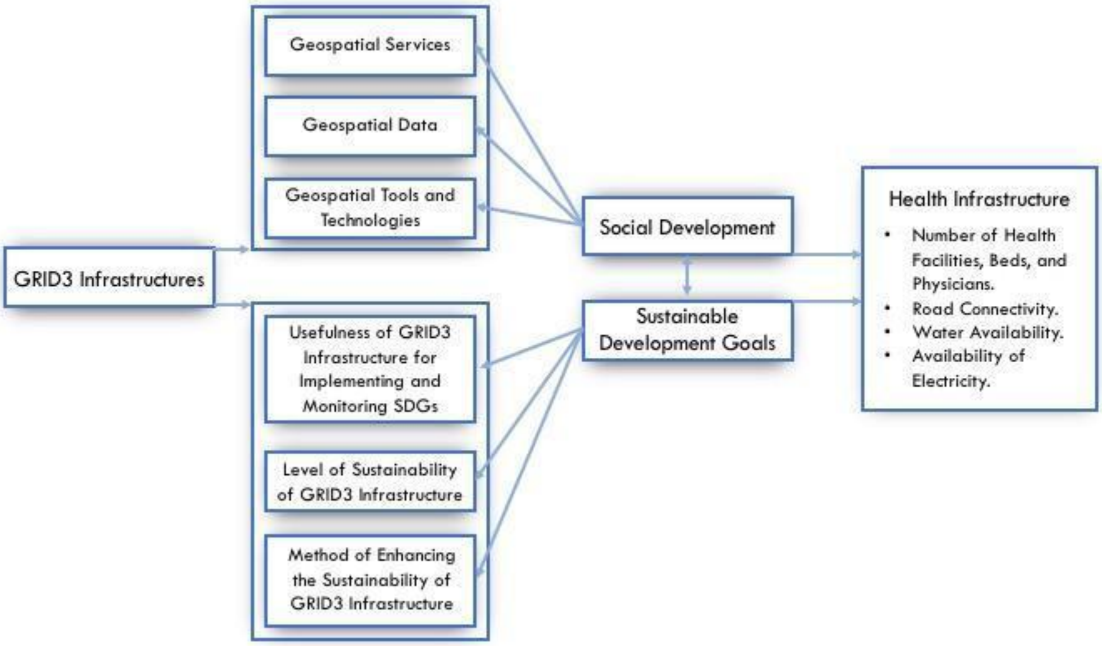


**Figure 3.2: Conceptual framework for the research (Source: Author)**

GRID3 infrastructures was the case study for this research. The infrastructures were considered as a single embedded case design. The components of the case study include the research question, unit of analysis, data gathering tools, qualitative evidence, and quantitative evidence. Figure 3.3 presents the case study design for this research. As shown in Figure 3.3, the context of the study was Oyo State, Nigeria. The case under consideration was the use and the sustainability of GRID3 infrastructures for social and sustainable development. The unit of analysis included GRID3 users, researchers, and service providers. These are the active users of the GRID3 infrastructure and are in the best place to speak on its utility for work and education, the use cases for programmes and projects, as well as integrating with existing tools. Data collection for the case study entailed qualitative data (questionnaire survey) and interviewees (qualitative data). The use of both qualitative and quantitative data collection methods is to provide pragmatic insights as required and ensure specific questions were answered using the survey. For qualitative, interviews were mostly conducted with GRID3 users, who are health care officers who conduct microplanning activities at the local level and are more actively engaged with the application of geospatial data and technology in the delivery of healthcare services. On the other hand, researchers and service providers are participants with more comprehensive understanding of how GRID3 is being utilised in the study area and in Nigeria as a whole. The data collected were analysed using mean item score, analysis of variance (ANOVA), and Grounded Theory.

The use of the case study method was considered suitable for this study because of the lack of rigorous and contextualised application of geospatial technologies in Nigeria. Also, the effectiveness and availability of geospatial infrastructures have not been largely documented in Nigeria (Utazi et.. al., 2020). Previous studies such as Idhoko et al. (2015), Gamazo (2016), Labus et al. (2012), Qiao et al. (2020), Corchado et al., (2021), Zhou et al., (2017), Yi et al., (2017), Zhuang and Li (2017), Jayantha and Yung (2018), Zhong and Leung (2019), Sabatini-Marques et al., (2020), and Zhuang et al., (2020) have successfully adopted the use of case study to investigate the contextual application of geospatial technologies. These studies have carried out a case study of urban renewal and urban rehabilitation in Madrid (Gamazo, 2016), case study of concepts of urban renewal in an aging society in the XXI century in Poland (Labus, 2012), case study of South African area-based urban renewal programme (Donaldson et al., 2013), case study of the impact of urban renewal on land surface temperature changes (Qiao et al., 2020), case study of rapid deployment platform for smart territories (Corchado et al., 2021), case study of strategic approaches to sustainable urban renewal in developing countries (Yi et al., 2017), and case study of participatory micro-regeneration as sustainable renewal of built heritage community (Zhong and Leung, 2019). A similar study by Idhoko et al., (2015) conducted a case study of Geographic Information Systems road network database for emergencies in Oyo-Town, Oyo State, Nigeria.

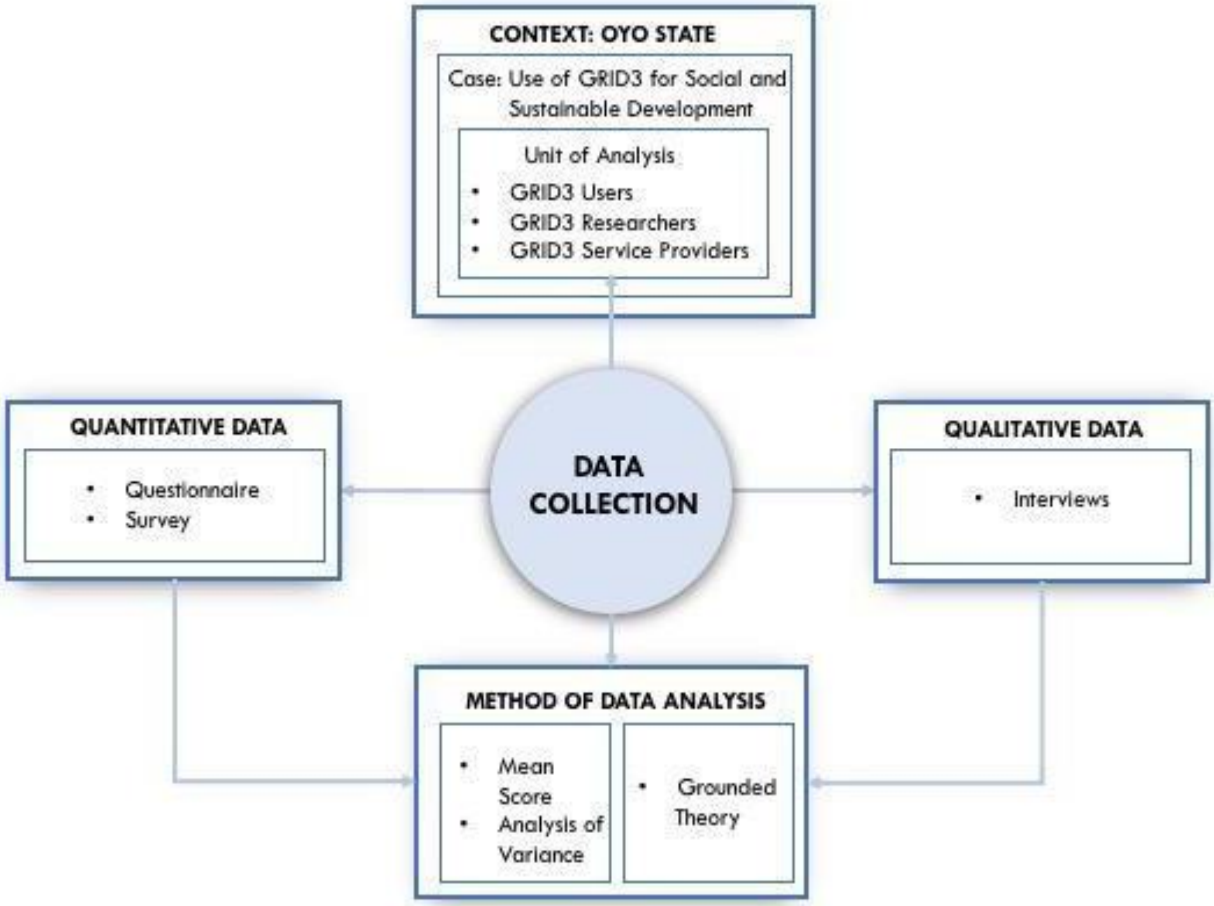


**Figure 3.3: Single embedded case study design for this research (Source: Author)**

## 3.7 Case Selection for the Research

### 3.7.1 Geo-Referenced Infrastructure and Demographic Data for Development (GRID3)

GRID3 supports the Nigerian government and other private and non-profit stakeholders in their efforts to generate, validate and use geospatial data on population, settlements, infrastructure, and subnational boundaries for planning and decision making. GRID3 is a Geospatial Data Program with prominent use cases in Health, particularly Routine and Non-Routine Immunisation and Primary Healthcare coverage, and it is being used for data referencing and analysis of health facilities receiving and distributing the COVID-19 vaccine. The GRID3 portal combines the highest-resolution population estimates and other key data layers that are optimised with dynamic modelling and the newest scientific methods to ensure sustainable use of geospatial data in Nigeria.

GRID3 Nigeria is working to expand the knowledge and use of geospatial data within Nigeria, by creating a feedback mechanism that enables knowledge transfer, the sharing of use cases, and the sustainability of GRID3 (GRID3, Nigeria). Hence, the investigation of the use of GRID3 for social and sustainable development will further ensure validity and use of GRID3. This investigation into how GRID3 is used is critical to improving the on-going COVID-19 Vaccine Global Access and other vaccine distribution in Nigeria.The subject of the case study will include GRID3 users in the health sector and GRID3 service providers.

### 3.7.2 Target Population, Sampling Process, and Selection Techniques

The targeted population for this research consists of GRID3 users in the health sector (public health agencies, health facilities administrators, and vaccination officers), GRID3 service providers, and GRID3 researchers. This population was targeted because of their experience and familiarity with GRID3. The process for sampling and selecting the target population was purposive, so as to identify the individual best suited to answer the questionand random sampling was used for the questionnaire survey to reduce bias and get a better representation of the population. Participants for the interview were sampled and selected using theoretical sampling in order to provide a framework for data collection and data analysis. Theoretical sampling consists of choosing the group to be studied as long as it is creating new categories and until new cases stop to give new data—or all in all, until theoretical saturation is reached (Charmaz, 2006). Theoretical sampling, along these lines, does not rely upon choosing a sample a priori, yet rather runs corresponding with data analysis, as long as it gives categories to propel the theory.

A list of potential participants was generated from the information obtained from the national coordinator for GRID3 and national immunisation officer in Nigeria. From the list a total of 16 participants were targeted for questionnaire survey and interview, which include GRD3 users, researchers, and service providers. Only 15 participants fully filled the questionnaire; while 12 participated in the interviews. This gives a response rate of 93.75% for the questionnaire survey.

## 3.8 Data Requirements and Collection Methods

Data requirements for this study comprised of geospatial services, geospatial data, geospatial tools, and technologies that are available on GRID3, information on the use of GRID3 infrastructure for social development in terms of health care delivery, the level of sustainability of GRID3 infrastructures, the usefulness of GRID3 infrastructure in the implementation, and monitoring of SDGs, level of sustainability of GRID3 infrastructure in terms of data accuracy and quality, analytical capability, spatial analysis functionality, data availability, cost effectiveness, data literacy, and internet connectivity. Also, this study required information on the innovative approach for enhancing the sustainability of GRID3 infrastructures for social development.

For data collection methods**,** observation of GRID3 infrastructures and in-depth literature review were conducted to generate a questionnaire that will seek responses on the following: population mapping for the study area and mapping of health facilities in Oyo State. The mapping covered health care requirements of the neighbourhood, walking distance to the health facilities, driving distance to the health facilities, population mapping of the neighbourhood, and spatial accessibility of health facilities based on service to population ratio. Questions on health infrastructures such as, number of beds, number of physicians, road connectivity, water availability, and availability of electricity were posed to the research participants. Interview and survey procedures were designed and employed to investigate the following: use of GRID3 infrastructure to support health-related policies and planning decisions, building of local capacity (training and support) to use GRID3 infrastructure in making data-driven decisions for health, role of GRID3 infrastructures in decision-making, challenges faced in using GRID3 infrastructures for planning and decision-making, ways of improving the sustainability of GRID3 infrastructures, and geospatial data availability gaps. The details of the questionnaire and interview guide for this study are presented in APPENDIX A and B.

### 3.9 Methods of Data Analysis

Table 3.2 presents the methods of data analysis that were adopted in this research. As explained in the table, quantitative data were analysed using mean item score to check the underlying variable and analysis of variance (ANOVA) to check how the different variables respond to each other. For instance, how GRID3 impacts service and technology, or how their level of education influences how they utilise GRID3 infrastructure. Mean item score is a subjective scoring system that quantifies how much the respondents agree with the point of view in the Likert scale item (Othman et al., 2012).

**Table 3.2: Methods of data analysis (Source: Author)**

| S/No | Objectives | Methods of Analysis |
|---|---|---|
| 1 | Identify the GRID3 infrastructures | Mean item score, ANOVA, Grounded Theory |
| 2 | Evaluate the use of GRID3 infrastructures for social development in terms of health care delivery | Mean item score, ANOVA, Grounded Theory |
| 3 | Assess the level of sustainability of GRID3 infrastructures | Mean item score, ANOVA, Grounded Theory |
| 4 | Investigate innovative approach for enhancing the sustainability of GRID3 infrastructures for social development | Mean item score, ANOVA, Grounded Theory |

Analysis of variance (ANOVA) checks out contrasts between groups. It estimates two sources of variety in the data and analyses their relative sizes (Sawyer, 2009). These incorporate variation BETWEEN groups (the distinction between its group mean and the general mean) and variation WITHIN groups (the contrast between that worth and the mean of its group). ANOVA is a measurable test for recognizing contrasts in group means when there is one parametric dependent variable and at least one independent variable. Assumptions underlying ANOVA incorporate parametric data measures, normally distributed data, similar group variances, and freedom of subjects. Be that as it may, normality and variance presumptions can frequently be disregarded without any potential repercussions if sample sizes are adequately enormous and there are equivalent quantities of subjects in each group (Sawyer, 2009).

Grounded Theory (GT) was employed for qualitative data analysis. GT is an overall philosophy for creating hypotheses that are grounded in data efficiently assembled and investigated (Pulla, 2016; Noble and Mitchell, 2016). As a progression of organised yet adaptable standards for doing inductive-subjective examination into creating theories (Charmaz, 2006). GT unites components of numerous subjective exploration techniques to make a methodical guide whereby data can be all the while, as opposed to consecutively, handled during both collection and analysis stages, fully intent on inferring an inductive theory about a specific phenomenon (Hussein et al., 2020).

GT has consequently become viewed as a valuable instrument for specialists looking to conceptualise social and human-focused phenomena in imaginative ways (Compton and

Barrett 2016). Within disciplines as architecture, landscape architecture, urban planning, design, and management, GT has been minimal utilised, generally on the grounds that urban research has customarily centred around the complicated and dynamic genuineness of urban environments and has prioritised practice over theory (Allen and Davey 2018). In this unique circumstance, GT can be viewed as the ideal vehicle for urban research in light of its perspective on dismissing the thought of development (that researchers can enter their investigations uninfluenced by prior investigations and their own experiences and interests) and objectivity (that research is without esteem), which helps in eliminating the restricted methodologies that rise up out of standard planning views. Moreover, it is of worth to researchers who are zeroing in on how the most common way of thinking about how abstract/immaterial encounters can frame hypothetical insights in regards to aggregate understandings or connections among actors.

GT preferably educates urban research since all human scaled encounters and reactions are contextualised inside a spot or an urban setting. At last, it empowers researchers to build and foster solid hypotheses where key examination ideas do not exist or might be muddled or significantly under-investigated (Hussein et al., 2020). Charmaz (2006) set up the following as the characterising parts of GT:

- Concurrent collection and analysis of data
- Building scientific codes and categories from data, not from biased sensibly derived hypotheses
- Utilising the constant comparative technique, which includes making comparisons during each phase of the analysis
- Propelling theory advancement during each progression of data collection and analysis
- Memo writing to characterise and expound categories, determine their properties, and characterise connections among categories and recognize gaps
- Sampling pointed toward theory development, not to be illustrative of the populace
- Conducting a literature review subsequent to fostering a free examination.

## 3.10 Ethical Considerations

Ethical issues are foremost significant issues specifically in primary research, yet additionally even as far as utilising secondary data on the grounds that there are ethical issues identifying with reasonable and fair determination of sources and examination (MacKinnon and Fiala, 2014). Connelly (2014) stressed that it merits remaining back briefly and taking into account what impact your research activities may have on others as the outcome can be very harmful to yourself. Hammersley and Traianou (2012) brought up five ordinarily perceived standards: limiting damage, respecting independence, ensuring security, offering correspondence, treating individuals fairly.

Myriad issues such as informed consents, confidentiality, and anonymity are involved in ethical considerations. For this research, the "informed consent" of the participants was sought by informing them about the research in which they are involved, about the researcher, and about the expected outcomes. The confidentiality of the results and anonymity of the participants were maintained. At the University of Cape Town, there is a system of ethical review of all research with human subjects. As a result, an ethical application was made to the Ethic Committee of the University of Cape Town. The ethic application and approval for this research is presented in APPENDIX C.

The researcher does not have any personal relationship with the research participants nor works directly with GRID3. The contact of participant was obtained from GRID3 Nigeria office and the contact referred other users of GRID3 within the study area. The users of GRID3 in the study area and primary health care centres were introduced by the state focal persons of the immunisation program that received GRID3 maps and support.

### 3.11 Summary of the Chapter

This chapter reports on the methodology of the research and discusses in detail how the data collection techniques were deployed, including information on respondents and a deeper examination of the case study. It also presents an overview of the study area and its socio-economic characteristics. The chapter concludes with a description of the method of data analysis employed for the research and specifies the ethical considerations and modalities for conducting the research. In the next chapter, a detailed discussion of the results of the data analysis was provided to build understanding of findings and gaps, as well as provide statistical data for reference.

# CHAPTER FOUR

# DATA ANALYSIS, RESULTS AND DISCUSSION

## 4.1 Introduction

This chapter presents the analysis of the qualitative and quantitative data that were collected to achieve the objectives of this study. The qualitative data was analysed using the Grounded Theory Analytical method. The method enabled the extraction of concepts from the responses of the interviewees. The extracted concepts were formed into categories and theories which were further developed into theoretical frameworks. The quantitative data were analysed using mean item score and Analysis of Variance. The characteristics of the survey participants were analysed using frequency distribution and presented using graphical methods.

## 4.2 Characteristics of Respondents

This section presents the analysis of the profile of the participants for questionnaire survey and interview sections.

Respondents were geographic and technical professionals that currently use GRID infrastructure and techniques in their day to day work.

### 4.2.1 Social Economic Characteristics of Participants for Questionnaire Survey

The background details of the participants are provided in Figures 4.1 – 4.4. The Figures show that the participants are geo-spatial and GIS experts based on their roles. Their roles include GIS analyst (7%), GIS consultants (7%), GIS researchers (7%), Monitoring and Evaluation officers (7%), and Town planning officers (7%). This means that the participants have the required reputation and will give legitimate information. All the participants are educated with degrees in relevant fields such as BSc (33.3%), MSc degree holders (33.3%), and MSc in education (13.3%). To further confirm the legitimacy of the information elicited from the participants; they were requested to indicate their years of experience. As shown in Figure 4.3, all the participants have gathered experience for 6-10 years (40%), 5 years (33.3%), and 6 – 20 years (13.3%). This indicates that the participants will give accurate, real-life, and first-hand information on the use of GRID3 infrastructures. The work experience of the participants covers geo-spatial technologists (46.7%) and geo-spatial researchers (6.7%). Others are public health practitioners, health facility administrators, healthcare monitoring and evaluation officers, livelihood specialists, and urban planners. This indicates that the participants are connected to the area of this study and will give practical information that will aid the answering of the research question.

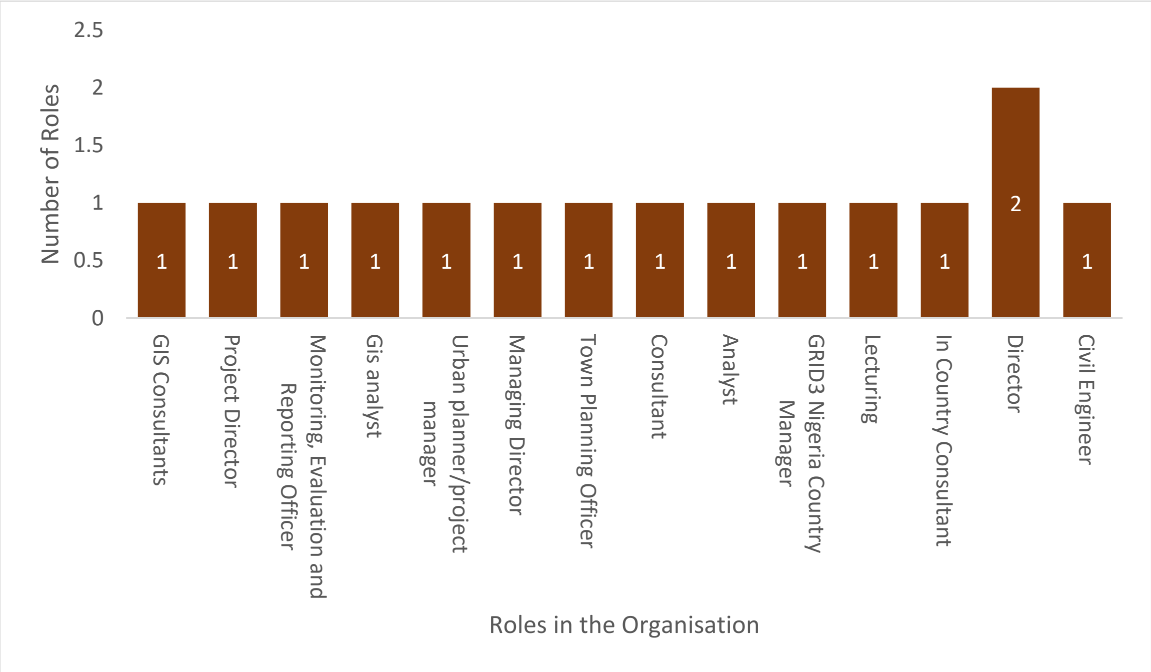


**Figure 4.1: Role of the respondents in their organisations (Source: Author)**

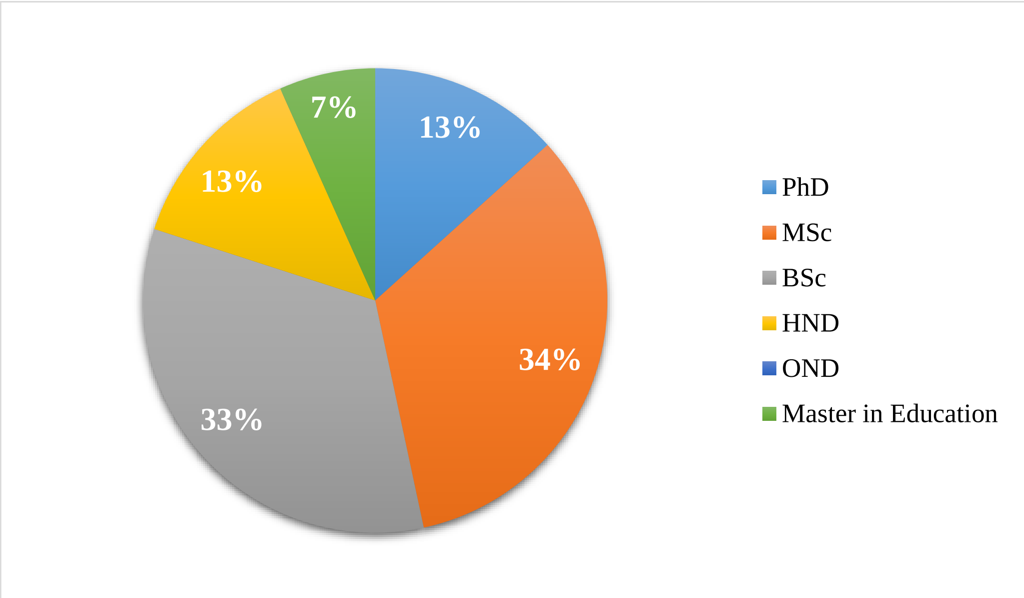


**Figure 4.2: Educational background of the respondents (Source: Author)**

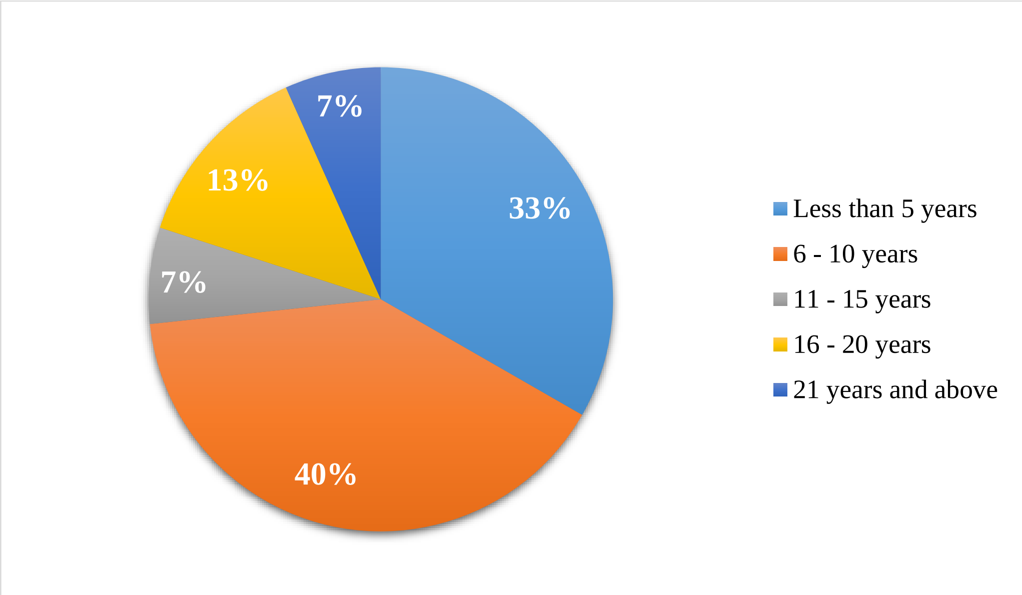


**Figure 4.3: Years of experience of the respondents (Source: Author)**

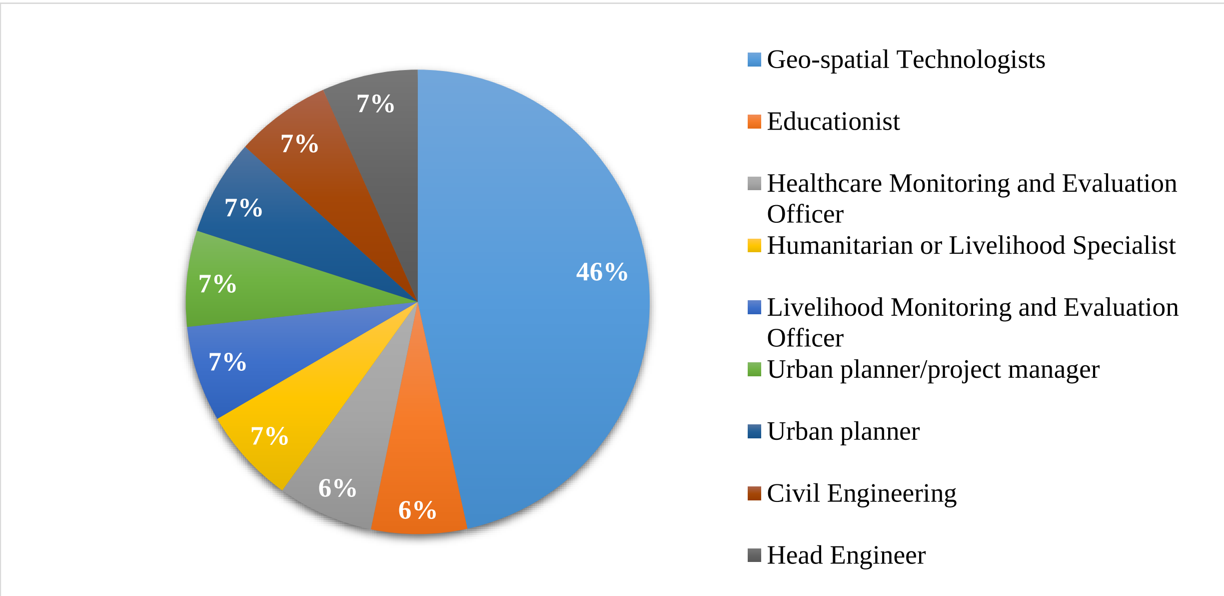


**Figure 4.4: Occupation of the respondents (Source: Author)**

### 4.2.2 Social Economic Characteristics of Participants for Interview

Twelve users and GRID experts were invited by letter to participate in the interview for this study. The participants for the interview were required to have used GRID3 for at least three years. This was revealed by the number of years that the interviewees have served in their positions (see Table 4.1). As shown in Table 4.1, none of the interviewees has less than three years of experience. The roles of the interviewees included Monitoring and Evaluation Officer (M&E), GIS analyst, Local Government Immunisation Officer (LIO), and country program assistant for GRID3. Many of the interviewees work with the primary healthcare department and are in charge of immunisation services. The profile of the interviewees suggests that they have the knowledge and skills they need to understand the interview questions.

**Table 4.1: Profile of respondents for qualitative data (Source: Author)**

| **Interviewees** | **Roles** | **Department** | **Years served in position** | **Immunisation services in charge of** |
|---|---|---|---|---|
| *Interviewee 1* | M&E Officer | M&E Unit | 21 years | All the immunisations, either radioimmunoassay (RIA), campaign, or activities |
| *Interviewee 2* | LIO | Primary health care centre | 3 years | Bacille calmette-guerin (BCG), poliomyelitis, penta-hepatitis, and tetanus toxoid vaccine. |
| *Interviewee 3* | LIO | Primary health care centre | 30 years | Poliovirus vaccine (IPV) and COVID-19 virus, and pneumococcal conjugate vaccine (PCV). |
| *Interviewee 4* | Monitoring and evaluation officers, entering data into the DHIS2, collect the report about the health facilities | Primary healthcare department | 15 years | All the immunisation services and programmes |
| *Interviewee 5* | Local cold chain officer | Primary healthcare department | 18 years | Routine immunisation, polio campaigns, and COVID-19 vaccine |
| *Interviewee 6* | M&E officer | M&E Unit | 20 years | All immunisation services |
| *Interviewee 7* | GIS analyst | Physical planning unit | 6 years | Land use management, urban planning, scope planning, policymaking, and implementation |

| | | | | |
|---|---|---|---|---|
| *Interviewee 8* | Local Government Immunisation Officer | Primary healthcare department | 20 years | Routine immunisation, polio campaigns, and COVID-19 |
| *Interviewee 9* | Country program assistant for GRID3 | GRID3 Nigeria program technical committee | 8 years | Routine immunisation |
| *Interviewee 10* | Country program assistant for GRID3 | GRID3 Nigeria | 6 years | Polio campaigns |
| *Interviewee 11* | Budget director | Institute for development on agricultural resilience projects | 3 years | Facilitation, conditional management's design development, and livelihood program, sustainability resilience for agriculture |
| *Interviewee 12* | M&E officer | African Institute for development | 3 years | Maintaining an updated database of our beneficiaries across incubation sites |

**4.3 GRID3 Infrastructures Available in Nigeria**

To achieve the first objective of this study, both quantitative and qualitative data were collected and analysed. The data elicited from the participant score a high on the reliability and validity test of Cronbach's Alpha Coefficient[1]. The quantitative data were collected by asking the participants to indicate the extent to which they agree to the availability of the identified geospatial services, data and tools on GRID3 infrastructure. They were asked to rate their level of agreement on a 5-point Likert scale. On the scale, 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree. The responses given by the participants were analysed using mean item score. The result of the analysis is presented in Table 4.2. As indicated in the table and based on a cut-off point of 3.61, the participants agreed that cadastral services (3.86) and location-based services (4.4) are geospatial services that are available on GRID3. Settlement mapping (4.53), infrastructure mapping (4.4), mobility data (4.4), population data (4.4), sub-national boundaries (4.3), population estimates (4.2), and population housing census (4.1) are the geospatial data that are available on

[1] *The reliability and validity of the data elicited from the participants were confirmed by calculating the Cronbach's Alpha Coefficient. Cronbach's Alpha Coefficient is a measure of scale reliability and reliability. The alpha coefficient for the questionnaire items is .899, suggesting that the items have relatively high internal consistency, reliability, and validity (Panayides, 2023).*

GRID3. The geospatial tools and technologies that are available on GRID3 are satellite imagery (4.1), dynamic modelling (3.7), average nearest neighbour analysis (3.7), and buffer-zone analysis (3.7). A one-way ANOVA was conducted to determine whether or not there is a statistically significant difference between the responses of the participants. The result of the one-way ANOVA is presented in Table 4.3. The result revealed that there was a statistically significant difference between the identified five groups (F (14, 193) = [F- 2.64], p = [p-0.00]). This means that the geospatial tools and technologies are distinct and important to the participants.

For the qualitative data, the interviewees were asked to identify the geospatial services, data, and tools that they have utilised on GRID3. Table 4.4 presents the concepts that were extracted from the responses of the participants. Table 4.4 shows that all the 12 participants have utilised geospatial services, data, and tools on GRID3. The interviewees reported the use of GRID3 infrastructures such as population data, road network, and boundary data. This is demonstrated in the following excerpts:

*We make use of GRID3 infrastructures when we are carrying out urban renewal projects. It helps us to know the specific number of health facilities that are being captured in the geospatial database so far, and then see, perhaps we need to do some updates locally on our own to provide more health facilities. So, it's not directly supporting our health delivery service, it's more like getting the primary source of data needed to guide our urban renewal projects.*

*Interviewee 7*

*We have developed four quadrant LAS tools and we are currently developing a school placement optimization tool. The tool gives advice to policymakers on where to place schools in terms of access and population of school going children.*

*Interviewee 9*

*We use what was called VACTRACK – vaccination tracking system, where health workers, the vaccinators were given mobile trackers, which they moved alongside with them to all those settlements. So, at the end of the day, we see what settlements was visited, and which settlements was not visited during the for the polio campaign*

*So, in the health space, we provided a GIS maps to support various program, various immunisation program areas, such as measles, yellow fever, even the polio itself, and then the COVID-19 vaccinations, and currently also developing a digital micro planning application, or digital micro planning toolkit that will allow health workers to have access to their own data, for them to be able to use those datasets to conduct planning to conduct micro planning at that community level.*

*We have also developed what is called a school placement optimization tool. This tool allows us to visualise the current existence of schools that are available in Nigeria, and also* *locations where we need to have additional schools, because no child should travel more than two kilometres to access a school.*

*We have four core data layers; we have four core geospatial data layers. One is the population estimates. We have the ingredient population estimates at 100 metres per 100. This is done by estimating how many people live in each cell across the country and is broken down by age and sex. Number two, we have comprehensive settlement locations. This allocation of settlement across the country, all communities across the state plus FCT. The third data layer is the administrative boundary. So in this case, we have the operational boundaries at state level, local government level as well as ward level. Lastly, we have the infrastructure data. So, this includes points of interest, such as health facilities, schools, farmland, water points, IDP camps, markets, and roads - about 21 points of interest. And overall, we have over 500,000 data points on the dignitary portal*

Interviewee 10

The responses from the interviewees confirmed the findings from quantitative analysis. For instance, interviewee 1-10 confirmed the availability of population data, satellite imagery, and infrastructure data on GRID3. The new geospatial services and tools that are available on GRID3 and revealed by qualitative data are school placement optimization tool, four quadrant LAS tool, vaccination tracking services, GIS maps, and digital micro planning tool.

Table 4.5 shows the categories of GRID3 infrastructures that were formed from the available GRID3 infrastructures. As shown in Table 4.5, three categories were formed from the GRID3 infrastructures. These include geospatial services, tools, and data. These categories led to the formation of the theory which states that GRID3 infrastructures entail geospatial services, geospatial data, and geospatial tools. Three categories of GRID3 infrastructures emerged from the research findings to form a theoretical framework of the GRID3 infrastructures (see Figure 4.5). This framework explains the available geospatial services, tools, and data on GRID3. The framework presents the insights into the nature of GRID3 infrastructures and opportunities for expansion of the infrastructures.

This finding suggests that GRID3 infrastructure is a geospatial database where users can generate geospatial data such as boundary data, population data, and infrastructure data. Geospatial data that are available on GRID3 identify specific locations. The geospatial services on GRID3 enable the users to access, process, and manage geospatial data using geospatial tools and technologies. Such services include the creation of maps, population estimate, and boundary location. The findings of his study and its explanations are in line with the conclusions by Qiu et al., (2019), Van Den Hoek et al. (2021), Jochem and Tatem (2021), Ocansey (2019), and Jhamba et al. (2020). These studies have indicated that GRID3 infrastructure is a multi-virtual organisation infrastructure that is composed of open-source geospatial dataset, multi-application grid laboratory, geospatial services and technologies, and geoprocessing routine in which spatial relationships between feature and data as well as mobility data, population data, settlement mapping, infrastructure mapping, and sub-national boundaries can be generated.

**Table 4.2: Mean score analysis of availability of geospatial services, data and tools on GRID3 infrastructure (Source: Author)**

| Column1 | Mean | Standard Deviation | Sample Variance |
|---|---|---|---|
| **Geospatial Services** | | | |
| Location-based services | 4,4 | 0,632456 | 0,4 |
| Cadastral Services | 3,866667 | 0,833809 | 0,695238 |
| Air Pollution and Evaluation | 3,266667 | 1,099784 | 1,209524 |
| **Geospatial data** | | | |
| Settlement Mapping | 4,533333 | 0,743223 | 0,552381 |
| Infrastructure Mapping | 4,428571 | 0,755929 | 0,571429 |
| Mobility Data and Analysis | 4,4 | 0,736788 | 0,542857 |
| Population Data and Analysis | 4,4 | 0,632456 | 0,4 |
| Sub-national Boundaries | 4,333333 | 0,723747 | 0,52381 |
| Population Estimates | 4,2 | 0,774597 | 0,6 |
| Population Housing Census | 4,133333 | 0,63994 | 0,409524 |
| **Geospatial Tools and Technologies** | | | |
| Satellite Imagery | 4,133333 | 0,99043 | 0,980952 |
| Dynamic Modelling | 3,733333 | 1,032796 | 1,066667 |
| Average Nearest Neighbour Analysis | 3,733333 | 0,883715 | 0,780952 |
| Buffer-Zone Analysis | 3,733333 | 1,099784 | 1,209524 |
| Hotspot Analysis | 3,428571 | 1,01635 | 1,032967 |

**Table 4.3: Analysis of Variance of availability of geospatial services, data and tools on GRID3 infrastructure (Source: Author)**

| ANOVA: Single Factor | | | | | | |
|---|---|---|---|---|---|---|
| **SUMMARY** | | | | | | |
| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
| 4 | 14 | 62 | 4,428571 | 0,417582 | | |
| 3 | 14 | 55 | 3,928571 | 0,686813 | | |
| 3 | 14 | 46 | 3,285714 | 1,296703 | | |
| 4 | 14 | 62 | 4,428571 | 0,571429 | | |
| 5 | 14 | 61 | 4,357143 | 0,401099 | | |
| 4 | 14 | 58 | 4,142857 | 0,43956 | | |
| 4 | 14 | 59 | 4,214286 | 0,642857 | | |
| 5 | 14 | 63 | 4,5 | 0,576923 | | |
| 5 | 13 | 57 | 4,384615 | 0,589744 | | |
| 5 | 14 | 60 | 4,285714 | 0,527473 | | |
| 2 | 14 | 60 | 4,285714 | 0,681319 | | |
| 3 | 14 | 53 | 3,785714 | 1,104396 | | |
| 3 | 14 | 53 | 3,785714 | 0,796703 | | |
| 3 | 14 | 53 | 3,785714 | 1,258242 | | |
| 3 | 13 | 45 | 3,461538 | 1,102564 | | |
| **ANOVA** | | | | | | |
| **Source of Variation** | **SS** | **df** | **MS** | **F** | **P-value** | **F crit** |
| Between Groups | 27,39629 | 14 | 1,956878 | 2,649959 | 0,001487 | 1,743322 |
| Within Groups | 142,522 | 193 | 0,738456 | | | |
| Total | 169,9183 | 207 | | | | |

**Table 4.4: GRID3 infrastructures available in Nigeria (Source: Author)**

| **Concepts from responses** | **Participants** |
|---|---|
| Urban renewal projects | Interviewee 1-7 |

| | |
|---|---|
| Road networks, | Interviewee 1-7 |
| Population data | Interviewee 1-12 |
| Administrative and geographical boundaries | Interviewee 7, 8, |
| Road network for the old Nigeria | Interviewee 1-7 |
| Satellite imagery | Interviewee 1-7 |
| State boundary data | Interviewee 1-7 |
| Ward, local government, and school boundaries data | Interviewee 1-7 |
| Location of public and private health facilities in Nigeria | Interviewee 1-7 |
| School placement optimization tool | Interviewee 9, 10 |
| Four quadrant LAS tools | Interviewee 9 |
| Vaccination tracking services | Interviewee 10 |
| GIS maps | Interviewee 10 |
| Digital micro planning tool | Interviewee 10 |
| Infrastructure data | Interviewee 10 |
| Settlement data | Interviewee 10 |

**Table 4.5: Categories and theory of GRID3 infrastructures available in Nigeria (Source: Author)**

| **Concepts** | **Categories** | **Theory** |
|---|---|---|
| Location-based services and cadastral Services | Geospatial Services | GRID3 infrastructures entail geospatial services, geospatial data, and geospatial tools |
| Settlement mapping, infrastructure mapping, mobility data and analysis, population data and analysis, sub-national boundaries, population estimates, population housing census, and GIS maps | Geospatial data | |
| Satellite imagery, dynamic modelling, average nearest neighbour analysis, buffer-zone analysis, school placement optimization tool, four quadrant LAS tool, and digital micro planning tool | Geospatial Tools and Technologies | |

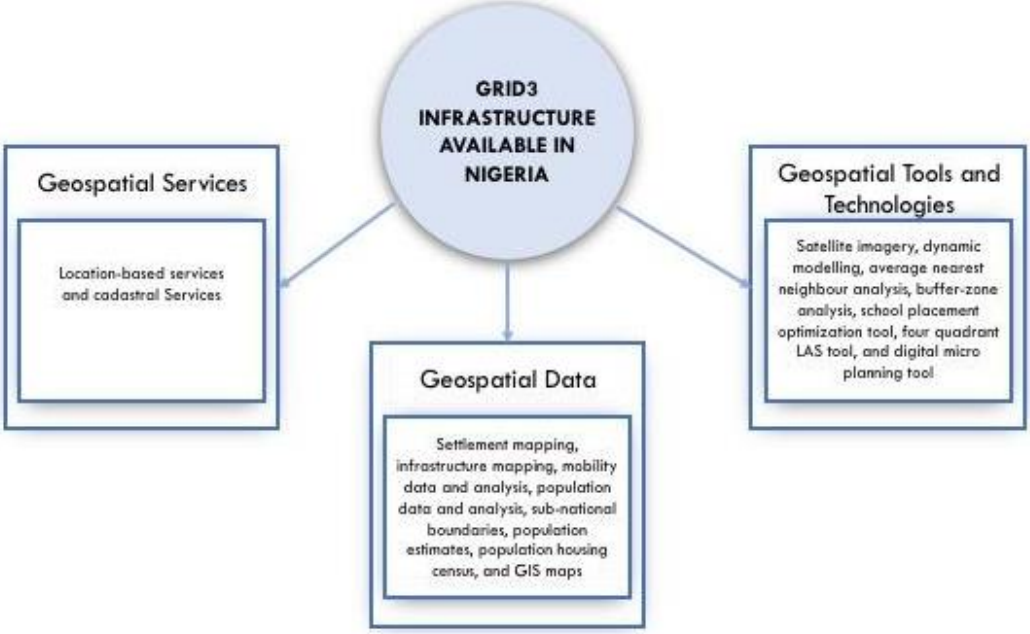


**Figure 4.5: Theoretical framework of the GRID3 infrastructures (Source: Author)**

## 4.4 Use of GRID3 Infrastructures for Sustainable Development in Nigeria

To achieve the second objective of this study, questionnaire survey was used to elicit information from the participants on the use of GRID3 infrastructures for sustainable development in Nigeria. The participants were asked to rate the usefulness of GRID3 in the identified health care-related sustainable development. The usefulness level of each of these uses were rated by the participants on a 5-point Likert scale where 1=Very Un-useful, 2=Somewhat Un-useful, 3= Somewhat Useful, 4= Useful, and 5=Very Useful. Table 4.6 shows the results of the mean item score analysis of the data elicited from the participants. As shown in the table, all the items in the questionnaire were rated as useful for health care-related sustainable development in Nigeria. This means that all the uses of GRID3 infrastructures for sustainable development in Nigeria as identified in the questionnaire had a mean item score of 3.61 and above. *Verification of health facilities* scored the highest mean score of 4.4; while *COVID-19 surveillance* scored the lowest mean score of 3.73. The implication of this result is that GRID3 infrastructures are useful for micro planning of immunisation services, verification of population for immunisation, determining immunisation coverage rate, generation of COVID-19 dispersion maps, COVID-19 contact tracing, and COVID-19 surveillance.

The above findings were subjected to further analysis by conducting a one-way ANOVA to determine whether or not there is a statistically significant difference between the ratings indicated by the participants. As shown in Table 4.7, the results of the one-way ANOVA revealed that there was not a statistically significant difference between the responses of the four groups of participants identified by the one-way ANOVA ($F (12, 167) = [0.76]$, $p = 0.68$). The qualitative data for this objective was collected by asking the interviewees if they have used GRID3 to support health care microplanning, policies, management, and delivery. They were also asked to share their experience with the use of GRID3 data, services, or tools. The interviewees were asked to describe the usefulness of GRID3 in the implementation and monitoring of the SDGs and to identify which of the health-related SDGs they have implemented and monitored using GRID3 between *SDG3* – Good Health and Wellbeing and SDG6 – Clean Water and Sanitation. The challenges that the interviewees were faced with in using GRID3 for micro-planning and decision making were investigated. Questions were also posed to the interviewees regarding the preference for and comparison between GRID3 and convention geospatial mapping tools (paper maps and hand drawn illustrations).

Grounded theory analytical procedures were adopted to analyse the responses of the interviewees. The concepts that were extracted from the responses of the interviewees and theory that was developed from the analysis are presented in Tables 4.8 and 4.9. The theory that was formulated states that GRID3 infrastructures are useful in the implementation and monitoring of sustainable development goals as per health, wellbeing, water, sanitation, education, food security, and infrastructural development. The grounded theory analysis offers a theoretical framework that explains the uses of GRID3 infrastructures for sustainable development in Nigeria. This is illustrated in Figure 4.6. The findings in Table 4.8 confirmed the findings from the quantitative analysis. Table 4.8 confirmed that GRID3 infrastructures are useful for identifying health facilities, planning for vaccination campaigns, and supporting health care microplanning, policies, management, and delivery. The confirmation provided by the qualitative analysis are evident in the following excerpts:

*I was able to come across the local government catchment area map that was done for the Primary Health Care Development Authority during the process of COVID-19 vaccination. Although there are some limitations to those maps, in terms of graphical presentation, representation landmarks, and missing facilities. In those maps, new facilities are not captured and the existing ones were not updated. This means that GRID3 is useful for sustainable development, but its usefulness is impaired by these limitations.*

*Interview 7*

*GRID3 helps us in micro planning and identification of health facilities and new areas for vaccination exercise. We have worked on clean water and sanitation as SDG goals and GRID3 was useful for us in the programme.*

*Interviewee 8*

*So, the health workers need the information to determine how many vaccines they need, how many other supplies they need in order to carry out their campaigns effectively. And they will need to know the settlement that they need to visit and how many vaccination teams do they need to make sure that they cover those settlements. GRID3 also provides kilometre distance between settlements and the settlement locations. So, it's a very useful tool that they use to determine the micro planning process.*

*Interviewee 10*

The excerpts below show new and interesting findings. These findings indicated that GRID3 infrastructures are useful to collect data about toilet facilities and wash facilities in public places to help in the fight against the COVID-19. The findings likewise indicated that GRID3 infrastructures are useful for addressing out of school children and for showcasing developmental needs to the international donor. The usefulness of GRID3 in the implementation and monitoring of the SDGs such as SDG3 – Good Health and Wellbeing and SDG6 – Clean Water and Sanitation were also revealed by the results. The interviewees provided insights that suggest that GRID3 infrastructures are useful for tracking the implementation of the SDGs such as basic primary health care services, education, and food security. The establishment of a route between the market and the farmlands so that farmers can easily transport their produce to the market after post harvests was also highlighted by the interviewees.

*So, we use GRID3 data to develop microplanning for the measles campaign currently. We have used GRID3 to identify health facilities or potential areas where health workers can situate vaccination points that you can be able to capture most people to be vaccinated*

*We have used it for population estimation, compile lists of settlements. As for Sustainable Development Goals, there is many aspects about it where it is important to utilise geospatial data to make decisions. I will advise the government that there is no need for you to fund a project or program and infrastructure development without knowing where it is needed. The only way you can be able to know is by having coordinates. And when you do have coordinates, you can sit at the comfort of your office and see what is happening.*

*In terms of water, sanitation and hygiene, the map of those who have access to water and those who need drainage systems to avoid floods will greatly help. Data about toilet facilities, wash facilities, in public places, will help in the fight against the COVID-19. For*

*SDG, GRID3 is needed to make very good decisions. We're in a conversation with the Minister of Water Resources in Nigeria to see how we can be able to collaborate.*

*Interviewee 9*

It could be inferred from the findings of this study that the availability of geospatial data on GRID3 has made its use for health care-related SDG possible. It was obvious from the findings that GRID3 infrastructures were highly utilised for immunisation campaigns. Earlier study by Utazi et al., (2020) corroborated this explanation. The study reported the use of geospatial data in measles vaccine coverage through immunisation routine and campaign in Nigeria. With the availability of geospatial data previously unvaccinated children were reached and covered in the immunisation campaign. In immunisation campaigns, the geospatial data provided by GRID3 are also useful for estimating immunisation target population. This assertion is supported by Ghiselli et al., (2019). Ghiselli et al., (2019) reported the use of geospatial data such as satellite imagery for micro planning and targeting of children in Sokoto State, Nigeria for immunisation against vaccine-preventable diseases.

It can be inferred from the findings of this study that GRID3 infrastructures have become relevant in the fight against COVID-19. The findings indicated that GRID3 infrastructures enabled the mapping of those who have access to water, mapping of public toilet facilities, and mapping of public wash facilities. This information was utilised in planning and decision-making for social distancing and measures against the spread of COVID-19. It is not clear from the findings if GRID3 infrastructures were actually used to determine the distribution patterns of COVID-19; however, this was highlighted as one of the uses of GRID3 infrastructures. This was also confirmed by Rahman et al., (2020) which indicated that geospatial data can be used to model the spread and dynamics of COVID -19. The relevance of GRID3 infrastructures in the fight against COVID-19 was supported by Franch-Pardo et al., (2020) and Brito et al., (2020). Studies by Jochem et al., (2020), Utazi et al., (2020), Boo et al., (2020), Juergens (2020), Thomson et al., (2019), and Song et al., (2019) likewise supported the usefulness of geospatial data and tools for health care-related SDG. For example, Jochem et al., (2020) reported the use of geospatial data to classify regular and irregular neighbourhood types. Boo et al., (2020) demonstrated the use of geospatial data for gridded population estimates. Juergens (2020) argued that GRID3 infrastructure is a logistic hub.

**Table 4.6: Mean score analysis of the usefulness of GRID3 in health care related sustainable development (Source: Author)**

| Column 1 | Mean | Standard Deviation | Sample Variance |
|---|---|---|---|
| Verification of health facilities | 4,4 | 0,736788 | 0,542857 |
| Microplanning of Immunisation services | 4,333333 | 0,816497 | 0,666667 |
| Visualising policy scenarios using geospatial data | 4,333333 | 0,723747 | 0,52381 |
| Mapping of identical scenarios | 4,285714 | 0,82542 | 0,681319 |
| Predict the spatial spread and temporal trends of the outbreak | 4,066667 | 0,798809 | 0,638095 |
| Verification of population for immunisation (COVID-19) | 4 | 1,133893 | 1,285714 |
| Health communication | 4 | 0,654654 | 0,428571 |
| Determine immunisation coverage rate | 4 | 0,755929 | 0,571429 |
| Detect non-functional health care facilities and points of care | 3,866667 | 1,125463 | 1,266667 |
| Understand and map human movement | 3,857143 | 1,09945 | 1,208791 |
| Generation of COVID-19 dispersion maps in a city | 3,8 | 1,146423 | 1,314286 |
| Accessing health records, outbreak control | 3,8 | 0,774597 | 0,6 |
| COVID-19 contact tracing, COVID-19 surveillance | 3,733333 | 1,099784 | 1,209524 |

**Table 4.7: Analysis of variance of the usefulness of GRID3 in health care related sustainable development**

| ANOVA: Single Factor | | | | | | |
|---|---|---|---|---|---|---|
| SUMMARY | | | | | | |
| **Groups** | **Count** | **Sum** | **Average** | **Variance** | | |
| 4 | 14 | 61 | 4,357143 | 0,708791 | | |
| 4 | 14 | 61 | 4,357143 | 0,554945 | | |
| 4 | 13 | 56 | 4,307692 | 0,730769 | | |
| 4 | 14 | 62 | 4,428571 | 0,571429 | | |
| 4 | 14 | 56 | 4 | 1,384615 | | |
| 3 | 14 | 54 | 3,857143 | 1,362637 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | 14 | 54 | 3,857143 | 0,593407 | | |
| 3 | 14 | 53 | 3,785714 | 1,258242 | | |
| 4 | 14 | 56 | 4 | 0,461538 | | |
| 3 | 14 | 57 | 4,071429 | 0,532967 | | |
| 3 | 14 | 55 | 3,928571 | 1,302198 | | |
| 3 | 13 | 51 | 3,923077 | 1,24359 | | |
| 3 | 14 | 58 | 4,142857 | 0,593407 | | |
| **ANOVA** | | | | | | |
| **Source of Variation** | **SS** | **df** | **MS** | **F** | **P-value** | **F crit** |
| Between Groups | 8,004518 | 12 | 0,667043 | 0,768745 | 0,681877 | 1,81054 |
| Within Groups | 144,9066 | 167 | 0,867704 | | | |
| Total | 152,9111 | 179 | | | | |

**Table 4.8: Use of GRID3 infrastructures for sustainable development in Nigeria (Source: Author)**

| **Concepts from responses** | **Participants** |
|---|---|
| Useful to identify health facilities or potential areas where health workers can situate vaccination points | Interviewee 1-9 |
| Useful to collect data about toilet facilities, wash facilities, in public places, will help in the fight against the COVID-19 | Interviewee 1-9 |
| Useful to determine kilometre distance between settlements and the settlement locations | Interviewee 1-10 |
| Useful in planning for vaccination campaign | Interviewee 7, 8, 9, 10 |
| Used GRID3 to support health care microplanning, policies, management, and delivery | Interviewee 8, 10 |
| Usefulness of GRID3 in the implementation and monitoring of the SDGs such as SDG3 – Good Health and Wellbeing and SDG6 – Clean Water and Sanitation | Interviewee 7, 8, 9 |
| GRID3 is a useful geospatial mapping tool | Interviewee 1-7 |
| Useful for tracking the implementation of the SDGs such as basic | Interviewee 10 |

| | |
|---|---|
| primary health care services, education, and food security | |
| Useful for addressing out of school children | Interviewee 10 |
| Useful for establishing a route between the market and the farmlands so that those farmers can easily transport their produce to the market after post harvests | Interviewee 10 |
| Useful for showcasing developmental needs to the international donor | Interviewee 11 |

**Table 4.9: Categories and theory of Use of GRID3 infrastructures for sustainable development in Nigeria (Author Source)**

| Concepts | Categories | Theory |
|---|---|---|
| As presented in Tables 4.6 and 4.8 | Health and Wellbeing | GRID3 infrastructures are useful in the implementation and monitoring of sustainable development goals as per health, wellbeing, water, sanitation, education, food security, and infrastructural development |
| | Water and Sanitation | |
| | Education | |
| | food security | |
| | Infrastructural development | |

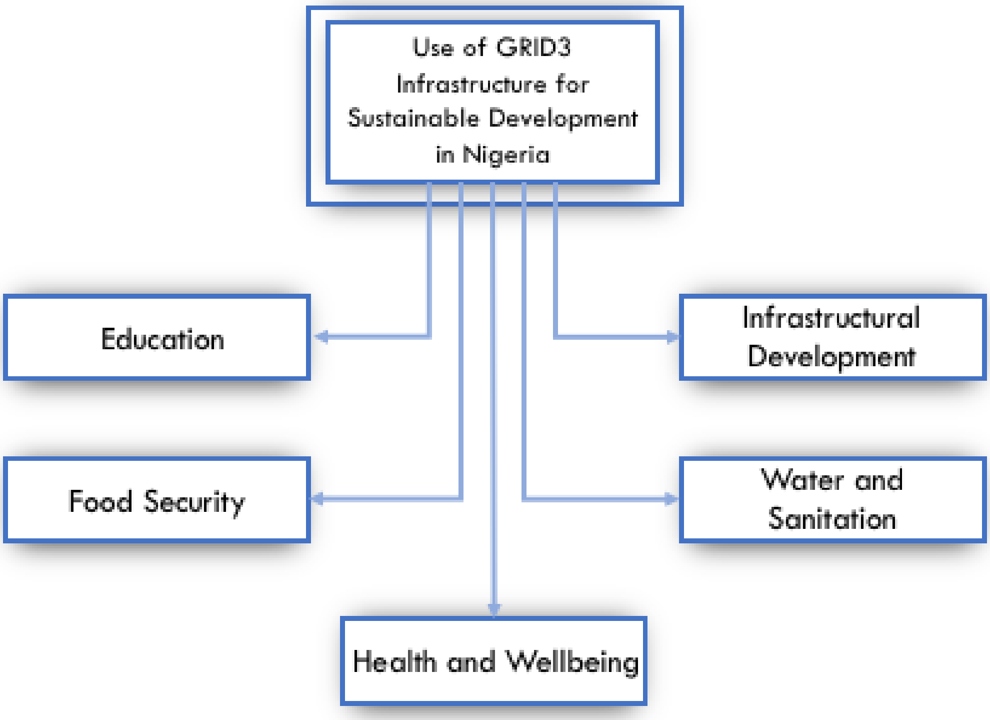


**Figure 4.6: Theoretical framework of the Use of GRID3 infrastructures for sustainable development in Nigeria (Source: Author)**

## 4.5 Level of Sustainability of GRID3 Infrastructures in Nigeria

Questionnaire surveys and interviews were conducted to address the third objective of this study. For the questionnaire survey, the participants were asked to rate the level of sustainability of GRID3 infrastructures using a 5-point Likert scale. On the scale 1=Poor, 2=Fair, 3=Good, 4=Very Good, and 5=Outstanding. Table 4.12 shows the results of the mean score analysis that was conducted for the data collected from the participants. The results in the table show that GRID3 has data accuracy and quality (3.86), spatial analysis functionality (3.86), and analytical capability (3.8). These results suggest that GRID3 is capable of mapping and estimating processes for geospatial data. Whatever data obtained from GRID3 is accurate and of high quality. These three criteria further indicated that GRID3 will continue to be useful and utilised by the end users. A one-way ANOVA was performed to compare the effect of the roles of the respondents on their responses (see Table 4.13). Table 4.13 revealed that there was not a statistically significant difference between the five groups identified by the one-way ANOVA ($F (6, 90) = [0.95]$, $p = 0.45$).

The level of usefulness of GRID3 infrastructures in the implementation and monitoring of Sustainable Development Goals was also investigated. The participants were asked to indicate the level of usefulness of GRID3 infrastructures in the implementation and monitoring of Sustainable Development Goals on a 5-point Likert scale (see Table 4.14). Table 4.14 revealed that the participants agreed that GRID3 infrastructures will continue to be useful in achieving SDGs. There was a statistical difference in the responses of the participants, as revealed by the results of the one-way ANOVA in Table 4.15 ($F (1, 25) = [14.58]$, $p = 0.00$). This result highlighted the importance of GRID3 to the sustainable development of Nigeria and checking of SDGs' indicators.

For the interview, the interviewees were asked how viable GRID3 infrastructures are and if GRID3 will continue to be useful in healthcare delivery. Concepts that were identified from the responses of the interviewees are presented in Table 4.16. As shown in Table 4.16, there was consensus among the participants that GRID3 will continue to be useful for routine immunisation programs and that GRID3 will remain viable if put in efforts to provide what the end users are talking about. This is demonstrated in the following excerpts:

*GRID3 will be sustainable if they keep updating their information and keep getting their services across to the end users. People will always source for geo-spatial data and point out new requirements. People will keep trusting GRID3 data and services, if they put efforts to provide what the end users are talking about. Google is actually competing with GRID3. With Google, End users can actually open the Google Local Guide account on*

*Google Map to update missing places on Google map directly. All Google needs to do is to find information you're uploading, verify it, publish it, and then it becomes available to everybody. So, if GRID3 is not putting in such effort of making their data and services open for people to come in and update, publish, and verify; GRID3 will not be sustainable.*

*Interviewee 7*

*GRID3 will continue to be useful in health care planning and delivery*

*Interviewee 8*

*Beyond COVAX, GRID3 will continue to be useful. In the health sector, micro planning is essential for routine immunisation programs. Routine immunisation will continue after COVID-19 and health workers will have need of geospatial data to support where to carry out immunisation sessions. So, GRID3 is sustainable.*

*Interviewee 9*

The concepts extracted from the responses of the interviewees were formed into categories and used to formulate theory in Table 4.17. The theory declares that the sustainability of GRID3 infrastructures in Nigeria depends on the satisfaction of end users and usefulness of its resources for immunisation programs. A theoretical framework was developed to capture the concepts, categories, and theory extracted from the interviewees' responses (see Figure 4.7). SDGs are complicated and diverse; hence meeting these goals require accurate, timely, and quality data that GRID3 can provide. According to Li et al., (2020), the bottleneck of SDGs requires accurate and analytical tools. It can likewise be inferred from the findings of this study that GRID3 infrastructures are sustainable for as long as they are relevant to achieving the SDGs and useful in measuring the SDGs targets. In the studies by Avtar et al., (2019), Qiu et al. (2019), and Li et al. (2020), the sustainability of GRID3 in its relevance to the implementation of SDGs and monitoring of SDGs targets. Avtar et al., (2019) specifically argued that GRID3 infrastructures are key to achieving SDG 1, SDG 4, SDG 3, SDG 6, SDG 11, SDG 12, SDG 14, and SDG 16. Qiu et al. (2019) maintained that GRID3 infrastructures facilitate the implementation of SDGs and are useful for the assessment of SDGs. Li et al., (2020) concluded that the shortage of in-situ data availability and tracking the progress in fulfilling SDGs could be covered by GRID3 infrastructures.

The calculation of SDG indicators and promotion of sustainable development could be done using GRID3. Mhangara et al., (2019), Llyod et al., (2020), and Jochem et al., (2020) confirmed this assertion. Globally, the usefulness of GRID3 infrastructures in the implementation and monitoring of Sustainable Development Goals has been established. In

China, Chen et al., (2020) measured the progress of SDGs utilising geospatial information. In Bangladesh, Shamsudduha et al., (2019) used geospatial data to monitor SDGs' indicator for water quality and quantity. Similarly, Giuliani et al. (2020), Korkovelos et al., (2019), Van Den Hoek et al., (2021), Mhangara et al., (2019), Li et al. (2018), Van de Homberg and Susha (2018), and Cader et al., (2018) have confirmed the usefulness of geospatial data and tools for supporting SDG indicators. In Nigeria, studies have also confirmed the actualization and monitoring of SDGs using geospatial data and tools (Ujoh et al., 2019 Ajisegiri et al., 2019; Ali et al., 2020).

**Table 4.10: Mean score analysis of level of sustainability of GRID3 infrastructure (Source: Author)**

| Column 1 | Mean | Standard Deviation | Sample Variance |
|---|---|---|---|
| Data accuracy and quality | 3,866667 | 0,833809 | 0,695238 |
| Spatial analysis functionality | 3,866667 | 0,99043 | 0,980952 |
| Analytical capability | 3,8 | 0,861892 | 0,742857 |
| Data availability | 3,533333 | 0,99043 | 0,980952 |
| Cost effectiveness | 3,428571 | 1,34246 | 1,802198 |
| Internet connectivity | 3,4 | 0,985611 | 0,971429 |
| Data literacy | 3,2 | 1,264911 | 1,6 |

**Table 4.11: Analysis of Variance of level of sustainability of GRID3 infrastructure (Source: Author)**

| **ANOVA: Single Factor** | | | | | | |
|---|---|---|---|---|---|---|
| **SUMMARY** | | | | | | |
| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
| 4 | 14 | 54 | 3,857143 | 0,747253 | | |
| 4 | 14 | 53 | 3,785714 | 0,796703 | | |
| 5 | 14 | 53 | 3,785714 | 0,950549 | | |
| 3 | 14 | 50 | 3,571429 | 1,032967 | | |
| 5 | 13 | 43 | 3,307692 | 1,730769 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | 14 | 44 | 3,142857 | 1,67033 | | |
| 4 | 14 | 47 | 3,357143 | 1,016484 | | |
| **ANOVA** | | | | | | |
| **Source of Variation** | **SS** | **df** | **MS** | **F** | **P-value** | **F crit** |
| Between Groups | 6,486292 | 6 | 1,081049 | 0,958047 | 0,458272 | 2,201056 |
| Within Groups | 101,5549 | 90 | 1,128388 | | | |
| Total | 108,0412 | 96 | | | | |

**Table 4.12: Mean score analysis of level of usefulness of GRID3 infrastructures in the implementation and monitoring of Sustainable Development Goals (Source: Author)**

| **Level of usefulness of GRID3 infrastructures in the implementation and monitoring of Sustainable Development Goals** | |
|---|---|
| Mean | 4,5 |
| Standard Error | 0.202999 |
| Median | 5 |
| Mode | 5 |
| Standard Deviation | 0.759555 |
| Sample Variance | 0.576923 |
| Kurtosis | 0.157576 |
| Skewness | -1,22879 |

**Table 4.13: Analysis of Variance of level of usefulness of GRID3 infrastructures in the implementation and monitoring of Sustainable Development Goals (Source: Author)**

| **ANOVA: Single Factor** | | | | | | |
|---|---|---|---|---|---|---|
| **SUMMARY** | | | | | | |
| **Groups** | **Count** | **Sum** | **Average** | **Variance** | | |
| 4 | 14 | 47 | 3,357143 | 1,016484 | | |
| 3 | 13 | 60 | 4,615385 | 0,423077 | | |
| **ANOVA** | | | | | | |

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 10,67175 | 1 | 10,67175 | 14,58591 | 0,000787 | 4,241699 |
| Within Groups | 18,29121 | 25 | 0,731648 | | | |
| Total | 28,96296 | 26 | | | | |

**Table 4.14: Level of sustainability of GRID3 infrastructures in Nigeria (Source: Author)**

| Concepts from responses | Participants |
|---|---|
| GRID3 will continue to be useful for routine immunisation programs | Interviewee 1- 12 |
| GRID3 will remain viable if put efforts to provide what the end users are talking about | Interviewee 7 |

**Table 4.15: Categories and theory of Level of sustainability of GRID3 infrastructures in Nigeria (Source: Author)**

| Concepts | Categories | Theory |
|---|---|---|
| Data accuracy and quality | Usefulness of geospatial data for immunisation programs | The sustainability of GRID3 infrastructures in Nigeria depends on the satisfaction of end users and usefulness of its resources for immunisation programs |
| Spatial analysis functionality | | |
| Analytical capability | | |
| End users satisfaction | Satisfaction of users | |

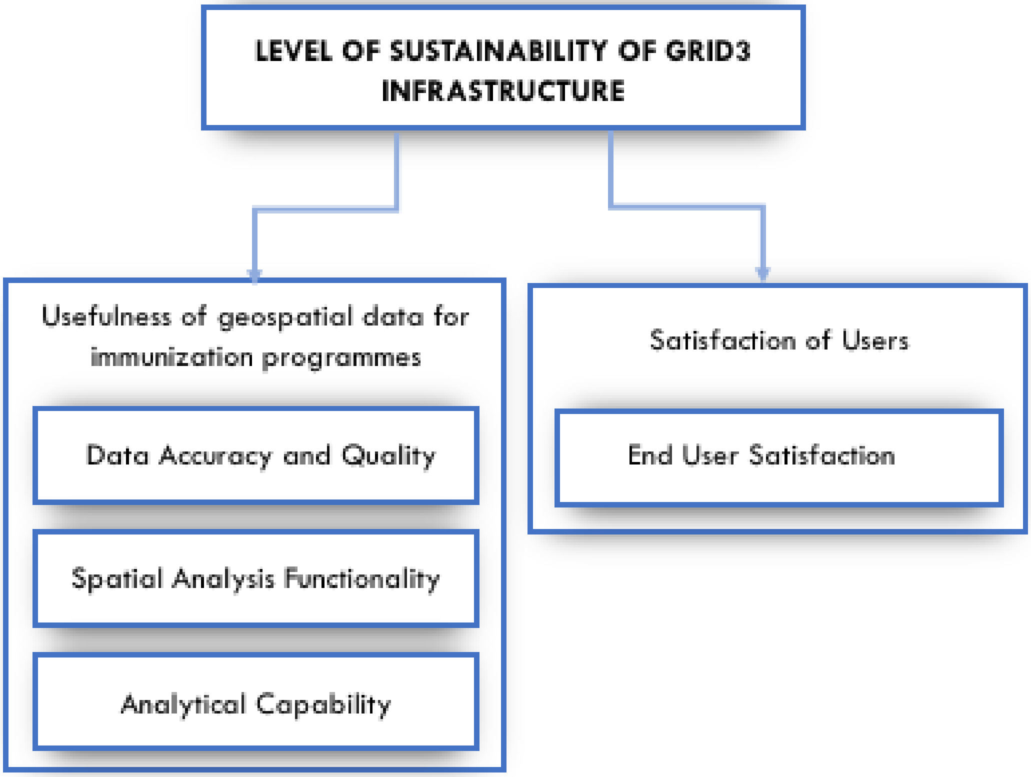


**Figure 4.7: Theoretical framework of the level of sustainability of GRID3 infrastructures in Nigeria (Source: Author)**

## 4.6 Innovative Approaches for Enhancing the Sustainability of GRID3 Infrastructures for Sustainable Development in Nigeria

Investigation of the innovative approaches for enhancing the sustainability of GRID3 for sustainable development in Nigeria was the fourth objective of this study. Both quantitative and qualitative data were collected towards achieving this objective. The quantitative data were collected by asking the survey participants to indicate the extent the identified approaches would enhance the sustainability of GRID3 for sustainable development. The 5-point Likert scale used by the participants to indicate their ratings entails 1=Not at all 2=Very little, 3=Somewhat, 4=Quite a bit, and 5=A great deal. Table 4.16 presents the results of the mean item score analysis that was carried out on the quantitative data. As shown in the table, wide coverage area for GRID3 (4.46) had the highest mean score, while timeliness and compatibility of spatial data (4.00) had the lowest mean score. The highest score recorded by wide coverage area for GRID3 suggests that GRID3 has not covered the whole of Nigeria. Participants in the survey agreed unanimously that GRID3 must have geospatial data about the regions and corners of Nigeria in order to continue to play a crucial role in achieving sustainable development in Nigeria. Other notable approaches from Table 4.16 are development of geospatial tools that operate with big data (4.33), improved documentation and awareness of GRID3 infrastructures (4.33), development of geospatial tools to be user-friendly (4.26), and interoperability of GRID3 infrastructures with other standard based infrastructures (4.20). This suggests that the awareness of GRID3 in Nigeria is still an issue to be resolved. It could be that efforts have not been made by the stakeholders to inform and intimate geospatial data users in Nigeria about the availability and usefulness of GRID3. In another way it could be that geospatial data users lack the capacity to utilise GRID3 tools, data, and services. The findings also suggest that GRID3 infrastructures must be made to be user-friendly. The end users of GRID3 infrastructures must find it easier to use the tools and data that are available on the infrastructures. If this is not the case, users may discontinue its use or opt for a better alternative.

A one-way ANOVA conducted to compare the effect of participants' roles on their responses (see Table 4.17) revealed that there was not a statistically significant difference between two groups ($F (18,247) = [0.36]$, $p = 0.99$).

The qualitative data were collected by interviewing the interviewees on measures that can be taken to enhance the usefulness of GRID3 for social and sustainable development, how GRID3 can be made sustainable, and how GRID3 users can be trained. These questions were premised on the assumption that GRID3 as sustainable development must itself be sustainable. The concepts indicating the measures that can enhance the sustainability of GRID3 as indicated by the interviewees are presented in Table 4.18. These concepts were further categorised and formed into a grounded theory in Table 4.19. The grounded theory offers a theoretical framework that explains the measures for enhancing the usefulness of GRID3 sustainable development. The framework is illustrated in Figure 4.8. The excerpts below show the specific comment regarding the measures that can be taken to enhance the usefulness of GRID3 for social and sustainable development:

*To enhance the sustainability of GRID3, they may not need to carry out a large-scale training for the end users. For example, Google Map started like a normal web page before they get to where they are now. What has helped Google Map is the provision of the local guide on their page. If GRID3 could do such, it will greatly enhance their sustainability. The end users of GRID3 services and data understand their jobs and have been doing some manipulation around the available services and data. So, if GRID3 can make it open source for people to contribute, or just to verify the contribution before they approve. This will greatly enhance their sustainability. GRID3 is limited in some many ways. They need to improve on their user interface, accessibility, and user experience. In fact, they need a mobile* *application. GRID3 is not very interactive and easy to use. While using GRID3 to locate a particular region, you need to log on to the website, then navigate, pick out, and then zoom into this particular region. This is not easy at all.*

*Interviewee 7*

*Updating of GRID3 data and services in terms of data collection in terms of settlements, infrastructure, and hospitals. This will enhance the sustainability of GRID3. Also, when the end users are able to visualize GRID3 services, tools, and data on a web app; their sustainability will be enhanced. I also feel that if GRID3 focuses on key sector priorities like health or education and make it work well in that area. It is going to be easier to move into other sectors like food security, innovation, technology, financial sectors. Gradually people will adopt it and, in the course, will be used as a monitoring and evaluation tool.*

*Interviewee 9*

*The sustainability of GRID3 could be enhanced by engaging with relevant stakeholders to harness data and to give access to any form of geospatial data so that they can upload it on the portal and they can strengthen the availability of the data in the portal. And also, for any maybe survey or any data collection that has been conducted by any government agency, there is a need to capture and added them to the portal in order to strengthen data availability on GRID3*

*Interviewee 10*

*They should find a way to collect feedback from users, especially around technical difficulties, if there's any. So, they can improve on that there should be a feedback mechanism like, like a user.*

*Interviewee 12*

The findings of this study indicated that geospatial data and services such as GRID3 must follow the provisions of the ISO standard 19115. By complying with the international standard for Geographic Information—Metadata, the sustainability or usefulness of GRID3 will be enhanced. By enhancing the analytical capabilities of GRID3, various types of analyses and computations could be done on it. This would greatly support sustainable development. Also, the findings revealed that lack of awareness of GRID3 availability and data inconsistencies are limiting its effectiveness and usage. By creating a wide coverage and engaging in aggressive awareness campaigns, the usefulness of GRID3 will be widespread and it will be continuously used for sustainable development. The findings likewise suggest that integrating new and heterogeneous input data will facilitate the GRID3's interoperability and composition. This will go a long way in supporting the implementation of SDGs. Studies such as Murad (2018), Qiu et al., (2019), Goodman et al. (2019), Yang et al. (2017), and Llyod et al., (2020) have conclusions that are in line with the findings and explanations of this study. For instance, Murad (2018) concluded that the sustainability of GRID3 infrastructures for sustainable development heavily depends on having access to accurate, timely, and compatible geospatial data. Qiu et al., (2019) maintained that uniform and widespread data are necessary to achieve the 17 SDGs.

**Table 4.16: Mean score analysis of innovative approach for enhancing the sustainability of GRID3 infrastructure for sustainable development (Source: Author)**

| Column 1 | Mean | Standard Deviation | Sample Variance |
|---|---|---|---|
| Wide coverage area for GRID3 | 4,466667 | 0,915475 | 0,838095 |
| Improved data reliability | 4,4 | 0,985611 | 0,971429 |
| Improved time of response | 4,4 | 1,183216 | 1,4 |
| Improved data literacy | 4,333333 | 1,175139 | 1,380952 |
| Improved data availability | 4,333333 | 1,175139 | 1,380952 |
| Development of geospatial tools that operate with big data | 4,333333 | 0,9759 | 0,952381 |
| Improved documentation and awareness of GRID3 infrastructures | 4,333333 | 1,112697 | 1,238095 |
| Development of geospatial tools to be user-friendly | 4,266667 | 0,883715 | 0,780952 |
| Improved reference and classification system of geospatial data | 4,266667 | 1,162919 | 1,352381 |
| High processing and storage capabilities | 4,266667 | 0,96115 | 0,92381 |
| Improved output data resolution | 4,266667 | 1,162919 | 1,352381 |
| Improved analytical capability of geospatial data | 4,2 | 0,941124 | 0,885714 |
| Organisation and standardisation of geospatial data | 4,2 | 1,082326 | 1,171429 |
| Interoperability of geospatial data | 4,2 | 0,861892 | 0,742857 |
| Improved data consistency | 4,2 | 1,146423 | 1,314286 |
| Interoperability of GRID3 infrastructures with other standard based infrastructures. | 4,2 | 1,146423 | 1,314286 |
| Improved limited connectivity | 4,133333 | 1,060099 | 1,12381 |
| Improved format and quality of geospatial data | 4,133333 | 1,125463 | 1,266667 |
| Timeliness and compatibility of spatial data | 4 | 1,069045 | 1,142857 |

**Table 4.17: Analysis of Variance of innovative approach for enhancing the sustainability of GRID3 infrastructure for social and sustainable development (Source: Author)**

| ANOVA: Single Factor | | | | | | |
|---|---|---|---|---|---|---|
| **SUMMARY** | | | | | | |
| **Groups** | **Count** | **Sum** | **Average** | **Variance** | | |
| 2 | 14 | 60 | 4,285714 | 0,835165 | | |
| 1 | 14 | 64 | 4,571429 | 0,571429 | | |
| 2 | 14 | 64 | 4,571429 | 0,571429 | | |
| 1 | 14 | 64 | 4,571429 | 0,571429 | | |
| 2 | 14 | 63 | 4,5 | 0,576923 | | |
| 2 | 14 | 62 | 4,428571 | 0,417582 | | |
| 1 | 14 | 59 | 4,214286 | 0,489011 | | |
| 2 | 14 | 61 | 4,357143 | 0,554945 | | |
| 1 | 14 | 61 | 4,357143 | 0,554945 | | |
| 1 | 14 | 62 | 4,428571 | 0,417582 | | |
| 2 | 14 | 61 | 4,357143 | 0,401099 | | |
| 1 | 14 | 64 | 4,571429 | 0,417582 | | |
| 1 | 14 | 62 | 4,428571 | 0,571429 | | |
| 1 | 14 | 63 | 4,5 | 0,576923 | | |
| 2 | 14 | 62 | 4,428571 | 0,571429 | | |
| 1 | 14 | 63 | 4,5 | 0,576923 | | |
| 2 | 14 | 65 | 4,642857 | 0,401099 | | |
| 1 | 14 | 65 | 4,642857 | 0,554945 | | |
| 1 | 14 | 62 | 4,428571 | 0,571429 | | |
| **ANOVA** | | | | | | |
| **Source of Variation** | **SS** | **df** | **MS** | **F** | **P-value** | **F crit** |
| Between Groups | 3,481203 | 18 | 0,1934 | 0,360139 | 0,99306 | 1,64576 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Within Groups | 132,6429 | 247 | 0,537016 | | | |
| Total | 136,1241 | 265 | | | | |

**Table 4.18: Innovative approaches for enhancing the sustainability of GRID3 infrastructures for sustainable development in Nigeria (Source: Author)**

| Concepts from responses | Participants |
|---|---|
| GRID3 App | Interviewee 10, 11 |
| capacity building for end users of GRID3 services and data | Interviewee 1-12 |
| new user interface | Interviewee 7 |
| Accessibility | Interviewee 1-7, 12 |
| user experience and friendliness | Interviewee 1-7, 12 |
| interactive and easy to use | Interviewee 7 |
| Re-train their field officers on how to acquire new and important data | Interviewee 7 |
| keep updating the information | Interviewee 7, 10 |
| Provide local guide on their web page where users can give feedbacks, update new information and develop maps themselves | Interviewee 7, 9, 10, 11, 12 |
| GRID3 need a mobile application | Interviewee 7, 9 |
| Stable and strong network | Interviewee 8 |
| Create awareness about GRID3 | Interviewee , 1, 3, 6, 9 |
| Focus on important sector such as health and education before moving to other sectors | Interviewee 9 |
| Accountability | Interviewee 9 |
| Automation | Interviewee 10 |
| Strengthen data availability | Interviewee 10 |

**Table 4.19: Categories and theory of innovative approaches for enhancing the sustainability of GRID3 infrastructures for sustainable development in Nigeria (Source: Author)**

| **Concepts** | **Categories** | **Theory** |
|---|---|---|
| Improved data reliability, improved data literacy, | Data quality | The usefulness of |

| | | |
|---|---|---|
| improved data availability, development of geospatial tools that operate with big data, improved reference and classification system of geospatial data, improved analytical capability of geospatial data, organisation and standardisation of geospatial data, interoperability of geospatial data, improved format and quality of geospatial data, timeliness and compatibility of spatial data, improved data consistency, and stable and strong network | | GRID3 infrastructures for sustainable development in Nigeria will be enhanced through data quality, wide coverage and awareness, user-friendliness, capacity building, and development of GRID3 mobile app. |
| Wide coverage area for GRID3, and improved documentation and awareness of GRID3 infrastructures | Coverage and awareness | |
| Improved time of response, development of geospatial tools to be user-friendly, improved limited connectivity, new user interface, accessibility, user experience and friendliness, interactive, and easy to use | User-friendliness | |
| GRID3 need a mobile application<br>Automation | GRID3 App | |
| Capacity building for end users of GRID3 services and data, re-train their field officers on how to acquire new and important data, keep updating the information, provide local guide on their web page where users can give feedbacks, update new information and develop maps themselves, focus on important sector such as health and education before moving to other sectors, and accountability | Capacity building | |

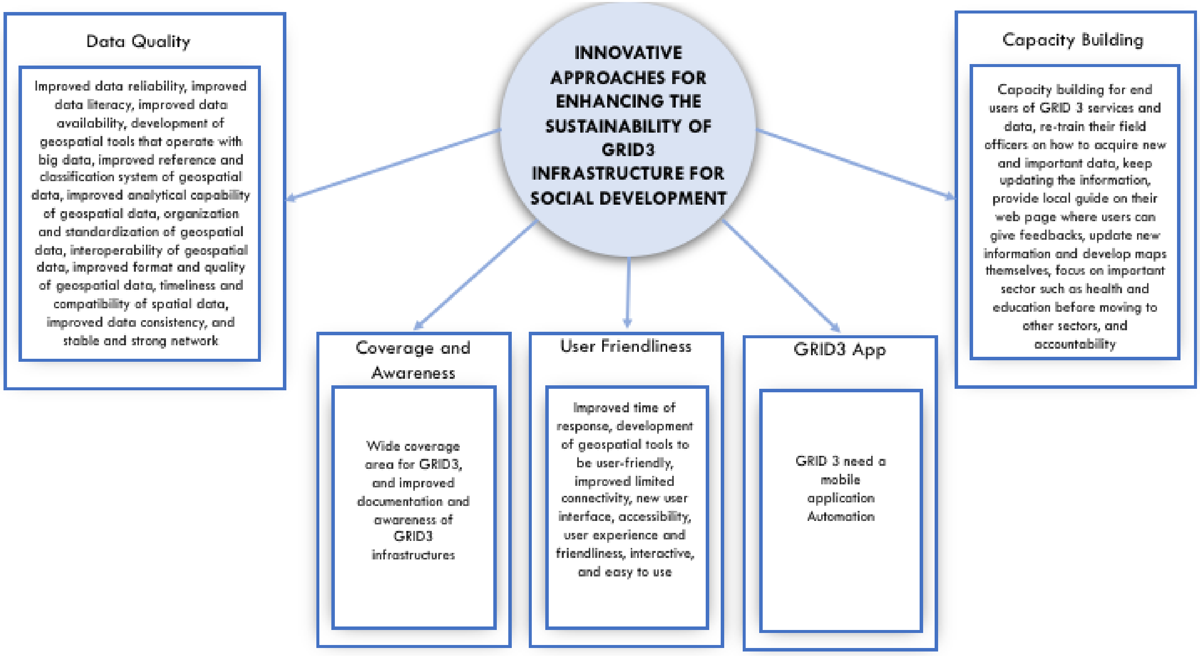


**Figure 4.8: Theoretical framework of the innovative approaches for enhancing the sustainability of GRID3 infrastructures for sustainable development in Nigeria (Source: Author)**

## 4.7 Summary of the Chapter

This chapter presents the results of the analysis of both qualitative and quantitative data, which were utilized to investigate the use and sustainability of GRID3 infrastructure for social and sustainable development. The analysis of the characteristics of respondents indicated that they were geographic and technical professionals that are currently using GRID3 for their day-to-day work. The analysis for GRID3 infrastructure available in Nigeria was revealed in the theoretical framework of the GRID3 infrastructure (Figure 4.5). The framework categorizes the GRID3 infrastructure into the geospatial tools and technologies, geospatial services, and geospatial data that it provides. Each of these infrastructures provides its own use cases for different social and economic components.

The assessment of the use of GRID3 infrastructure for sustainable development shows that GRID3 infrastructure is useful in the implementation and planning of sustainable development goals in the areas of health, wellbeing, water, sanitation, education, food security, and urban infrastructure. The availability of GRID3 infrastructure in Nigeria through its geospatial data has made it possible for health care workers to carry out immunization campaigns, estimate immunization populations, plan and mobilization decisions, as well as other key health-related activities. In addition, the analysis reviewed that the utilization of GRID3 infrastructure extends beyond healthcare and service delivery and that it is considered useful in other critical areas of the SDGs, such as those listed earlier.

The analysis of the level of sustainability of GRID3 infrastructure in Nigeria revealed that it is dependent on the satisfaction of end users and the usefulness of its resources for immunization programs. The usefulness of geospatial data provided by GRID3 relates to the data accuracy and quality, the spatial analysis functionality, and the analytical capability of the geospatial tools and technologies provided.

Information on the innovative approaches that can be adopted to enhance the sustainability of GRID3 infrastructure showed that there is a significant association between end users' satisfaction, integration of new tools and technologies, and the quality of service provided. Data quality, coverage and awareness, user-friendliness, development of the GRID3 app, and capacity building were the recommended ways for GRID3 to further improve its infrastructure to meet current and future demands of the end users and the geospatial community at large.

# CHAPTER FIVE

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Introduction

This chapter concludes the study. In this part, a rundown of the discoveries is laid out to show how the research question and objectives have been tended to. The part likewise features the conclusions from the discoveries, ramifications of the findings, suggestions produced using the conclusions, and areas of future examinations.

## 5.2 Summary of Findings

This research was expected to investigate the utilisation of the sustainability and utilisation of GRID3 infrastructures for social and sustainable development in Nigeria, with the end goal of investigating approaches for improving the sustainability of GRID3 Nigeria. The research question was, to what extent are GRID3 infrastructures sustainable and employed for sustainable development in Nigeria, and what are the ways to enhance the sustainability of GRID3 Nigeria. The research question was isolated into five objectives. The discoveries that give replies to the research question and objectives are as discussed in the ensuing section.

### 5.2.1 Objective 1: Identify the GRID3 Infrastructures Available in Nigeria

This objective was addressed through the findings from the quantitative analysis and theory that was formulated from the grounded theory analysis. The quantitative analysis revealed that location-based services, cadastral services, air pollution and evaluation, settlement mapping, infrastructure mapping, mobility data and analysis, population data and analysis, sub-national boundaries, population estimates, population housing census, satellite imagery, dynamic modelling, average nearest neighbour analysis, and buffer-zone analysis are the GRID3 infrastructures available in Nigeria.

The qualitative analysis gives a theory that states that GRID3 infrastructures entail geospatial services, geospatial data, and geospatial tools.

### 5.2.2 Objective II: Evaluate the Use of GRID3 Infrastructures for Sustainable Development in Nigeria

This objective was addressed through the findings from the quantitative analysis and theory that was formulated from the grounded theory analysis. The quantitative analysis revealed that for sustainable development, GRID3 infrastructures are useful for verification of health facilities. Microplanning of immunisation services, visualising policy scenarios using geospatial data, mapping of identical scenarios, predicting the spatial spread and temporal trends of the outbreak, verification of population for immunisation (COVID-19), and health communication. GRID3 are likewise useful for determining immunisation coverage rate, detecting non-functional health care facilities and points of care, understanding and map human movement, generating of COVID-19 dispersion maps in a city, accessing health records, outbreak control, COVID-19 contact tracing, and COVID-19 surveillance.

The qualitative analysis gives a theory that states that GRID3 infrastructures are useful in the implementation and monitoring of sustainable development goals as per health, wellbeing, water, sanitation, education, food security, and infrastructural development.

### 5.2.3 Objective III: Assess the Level of Sustainability of GRID3 Infrastructures in Nigeria

From the quantitative analysis, this objective was met with the findings indicating that through data accuracy and quality, spatial analysis functionality, and analytical capability the sustainability of GRID3 infrastructures will be secured in Nigeria. The theory from the grounded theory analysis of the qualitative data explains that the sustainability of GRID3 infrastructures in Nigeria depends on the satisfaction of end users and usefulness of its resources for immunisation programs.

### 5.2.4 Objective IV: Investigate Innovative Approaches for Enhancing the Sustainability of GRID3 Infrastructures for Sustainable Development in Nigeria

From the quantitative analysis, it was found that wide coverage area for GRID3, improved data reliability, improved time of response, improved data literacy, improved data availability, development of geospatial tools that operate with big data, improved documentation and awareness of GRID3 infrastructures, development of geospatial tools to be user-friendly, and improved reference and classification system of geospatial data are measures for enhancing the sustainability of GRID3 infrastructures for sustainable development in Nigeria. The sustainability of GRID3 infrastructures can likewise be enhanced through high processing and storage capabilities, improved output data resolution, improved analytical capability of geospatial data, organisation and standardisation of geospatial data, interoperability of geospatial data, improved data consistency, interoperability of GRID3 infrastructures with other standard based infrastructures, improved format and quality of geospatial data, timeliness and compatibility of spatial data, and improved limited connectivity.

From the grounded theory examination, a theoretical framework of the innovative approaches for enhancing the sustainability of GRID3 infrastructures for sustainable development in Nigeria was worked to answer this objective. The theoretical framework expresses that the handiness of GRID3 infrastructures for sustainable development in Nigeria will be upgraded through data quality, wide inclusion and awareness, ease of use, capacity building, and development of GRID3 mobile app.

### 5.3 Implications for Practice and Research

The discoveries of this study can possibly decidedly impact the utilisation and sustainability of GRID3 infrastructures for sustainable development in Nigeria. GRID3 could be widely conveyed to alleviate the spread of COVID-19 in Nigeria through an understanding and modelling of the spatial-temporal elements of COVID-19. The discoveries of this study show that GRID3-based geospatial data and apparatuses can be utilised to situate and find health facilities, circulate health infrastructures, and distribute resources to the needy areas. The study has implications for the utilisation of GRID3 in handling health crises and getting inputs from the COVID-19 pandemic.

Government agencies, public health specialists, healthcare planners, and hospital managers can utilise the discoveries of this study in preparing for emergency reactions and mitigating health challenges. This study adds an original contribution to monitoring and surveillance of public health programs such as COVID-19 vaccination in Nigeria and assessing health-related SDGs like SDG 1, SDG 4, SDG 3, SDG 6, SDG 11, SDG 12, SDG 14, and SDG 16. The study offers a theory for refining GRID3 and health planning.

### 5.4 Conclusions and Recommendations

The rationale for this study arose from the inequalities in geographic access to health care as one of the primary challenges in achieving the Health-related SDG. The need to explore the utilisation of GRID3 as a geospatial tool in tackling health emergencies and obtaining inputs from the COVID-19 pandemic for future preparedness also provides support for this research. In conclusion, this study has clarified that GRID3 infrastructures are available in Nigeria and that geospatial data, tools, and services that are available on GRID3 infrastructures are being utilised in the fight against COVID -19. The implementation and monitoring of SDG goals are being undertaken with GRID3 infrastructures. Improved data quality, widespread coverage, capacity building, and development of GRID3 mobile applications are some of the ways to prepare the end users for optimum use of GRID3 infrastructures and sustainable development.

This study has provided a novel insight into the use and enhancement of the use of GRID3 infrastructures for sustainable development. It provides evidence that school placement optimization tools, four quadrant LAS tools, vaccination tracking services, GIS maps, digital micro planning tools, infrastructure data, and settlement data are available in Nigeria. The study delivers a new perspective on the use of GRID3 infrastructures for the implementation and monitoring of the SDGs, addressing out of school children, and showcasing developmental needs to the international donor.

Findings from this study have made it known that GRID3 will continue to be useful for routine immunisation programs and will remain viable if efforts are made to provide what the end users are agitating for. This insight provides measures for ensuring the sustainability of GRID3 infrastructures in Nigeria. Finally, an emergent theory was identified which substantively explains that the data quality, wide coverage and awareness, user-friendliness, capacity building, and development of GRID3 mobile app are ways to enhance the usefulness of GRID3 infrastructures for sustainable development in Nigeria.

### 5.4:1 Areas for Future Research

Future research should examine the strategies for building the capacities of GRID3 end users. To corroborate this study, there is a need to develop a framework for gathering feedback from GRID3 users, develop a framework for confirming and supporting GRID3 users’ transferred data, and investigate explicit measures for improving users' experiences on GRID3. This can be further supported by a study on the development of an improved interface architecture for GRID3. Through these studies, the right and needed capacity-building framework for the teaming geospatial ecosystem in Nigeria can be best supported and equipped to delivery the social and sustainable development using geodata. To ensure GRID3 infrastructure is widely utilised and adopted in the health sector, there is a need to develop micro planning models for routine immunization programs as well as to evaluate strategies for awareness and adoption of GRID3 infrastructure. Additionally, the appraisal of GRID3 infrastructures in other key development areas such as education, agriculture, and rural administration should be studied. Likewise, an analysis of the viability, functional, and user requirements for a GRID3 mobile application should be conducted.

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## APPENDIX A: QUESTIONNAIRE

**Researcher: TIAMIYU Barakat Bidemi TMYBAR001@myuct.ac.za;**

**barakatbidemi96@gmail.com**

**Supervisor: A. Prof. Nancy Odendaal nancy.odendaal@uct.ac.za**

**Purpose of the questionnaire:** *The purpose of this questionnaire is to investigate the use and sustainability of GRID3 infrastructure in health care delivery, to help in proffering innovative approaches that would enhance the applicability and adaptability of GRID3 infrastructure for social and sustainable development. This questionnaire survey is aimed at GRID3 users in the health care sector. Kindly answer the questions based on your experience.*

**Ethical considerations:** *Participation in this questionnaire survey is voluntary. Data collected in this questionnaire survey will not be shared with anyone and will be used in a combined format.*

### *A: RESPONDENTS SOCIAL ECONOMIC DATA*

*[**Please choose the most appropriate response from the options provided]***

1. **Organisation Name:** ……………………………………………………………………
2. **Role in the Organisation:** ……………………………………………………………………
3. **Educational background of the respondents**: (a) PhD [ ] (b) MSc. [ ] (c) BSc. [ ] (d) HND [ ] (e) OND [ ] (f) Others (please specify)…………………………………………….
4. **Years of Experience**: (a) Less than 5 years [ ] (b) 6 – 10 years [ ] (c) 11-15 years [ ] (d) 16 – 20 [ ] (e) 21 years and above [ ]
5. **Occupation of the respondents**: (a) Geo-spatial Technologists [ ] (b) Public Health Practitioner [ ] (c) Health Facility Administrator [ ] (d) Immunisation/Vaccination Officer [ ] (e) Health Care Monitoring and Evaluation Officer [ ] (f) Others (please specify)…………………………………………………..

### *B: IDENITY GRID3 INFRASTRUCTURE*

To what extent do you agree to the availability of these geospatial services, data and tools on GRID3 infrastructure. Please rate it to your level of agreement (1-5)

| Geospatial Services | | | | | | |
|---|---|---|---|---|---|---|
| **S/No** | **Service, Data and Tools** | **Strongly Disagree (1)** | **Disagree (2)** | **Neutral (3)** | **Agree (4)** | **Strongly Agree (5)** |
| 6 | Location-based services | | | | | |
| 7 | Cadastral Services | | | | | |
| 8 | Air Pollution and Evaluation | | | | | |
| **Geospatial Data** | | | | | | |
| 9 | Mobility Data and Analysis | | | | | |
| 10 | Population Data and Analysis | | | | | |
| 11 | Population Housing Census | | | | | |
| 12 | Population Estimates | | | | | |
| 13 | Settlement Mapping | | | | | |
| 14 | Infrastructure Mapping | | | | | |
| 15 | Sub-national Boundaries | | | | | |
| **Geospatial Tools and Technologies** | | | | | | |
| 16 | Satellite Imagery | | | | | |
| 17 | Dynamic Modelling | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 18 | Average Nearest Neighbour Analysis | | | | | |
| 19 | Buffer-Zone Analysis | | | | | |
| 20 | Hotspot Analysis | | | | | |

***C: EVALUATE THE USE OF GRID3 INFRASTRUCTURES FOR SOCIAL DEVELOPMENT IN TERMS OF HEALTH CARE DELIVERY***

How would you rate the usefulness of the following health care related sustainable development? Please rate the usefulness level of each of these uses using the scale of (1-5).

| S/No | Uses of GRID3 Infrastructure | Very Un-useful (1) | Somewhat Un-useful (2) | Somewhat Useful (3) | Useful (4) | Very Useful (5) |
|---|---|---|---|---|---|---|
| 21 | Microplanning of Immunisation services | | | | | |
| 22 | Visualising policy scenarios using geospatial data | | | | | |
| 23 | Mapping of identical scenarios | | | | | |
| 24 | Verification of health facilities | | | | | |
| 25 | Verification of population for immunization (COVID-19) | | | | | |
| 26 | Generation of COVID-19 dispersion maps in a city | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 27 | Accessing health records, outbreak control | | | | | |
| 28 | COVID-19 contact tracing, COVID-19 surveillance | | | | | |
| 29 | Health communication | | | | | |
| 30 | Determine immunisation coverage rate | | | | | |
| 31 | Detect non-functional health care facilities and points of care | | | | | |
| 32 | Understand and map human movement | | | | | |
| 33 | Predict the spatial spread and temporal trends of the outbreak | | | | | |

## ***D: ASSESS THE LEVEL OF SUSTAINABILITY OF GRID3 INFRASTRUTURE***

34. How would you rate the level of usefulness of GRID3 infrastructures in the implementation and monitoring of Sustainable Development Goals. (a) Very Un-useful [ ] (b) Somewhat Un-useful [ ] (c) Somewhat Useful [ ] (d) Useful [ ] (e) Very Useful [ ]

Using the following criteria, how would you rate the level of sustainability of GRID3, please rate the level of sustainability using the scale of (1-5).

| **S/No** | **Level of Sustainability** | **Poor (1)** | **Fair (1)** | **Good (3)** | **Very Good (4)** | **Outstanding (5)** |
|---|---|---|---|---|---|---|
| 35 | Data accuracy and quality | | | | | |
| 36 | Analytical capability | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 37 | Spatial analysis functionality | | | | | |
| 38 | Data availability | | | | | |
| 39 | Cost effectiveness | | | | | |
| 40 | Data literacy | | | | | |
| 41 | Internet connectivity | | | | | |

***E: INVESTIGATE INNOVATIVE APPROACH FOR ENHANCING THE SUSTAINABILITY OF GRID3 INFRASTRUCTURE FOR SOCIAL DEVELOPMENT***

To what extent will the following approach enhance the sustainability of GRID3 for Social and Sustainable Development.

| S/No | Approach for Enhancing Sustainability of GRID3 | Not at All (1) | Very Little (2) | Somewhat (3) | Quite a Bit (4) | A Great Deal (5) |
|---|---|---|---|---|---|---|
| 42 | Improved limited connectivity | | | | | |
| 43 | Improved data literacy | | | | | |
| 44 | Improved data reliability | | | | | |
| 45 | Improved data availability | | | | | |
| 46 | Development of geospatial tools that operate with big data | | | | | |
| 47 | Development of geospatial tools to be user-friendly | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 48 | Timeliness and compatibility of spatial data | | | | | |
| 49 | Improved analytical capability of geospatial data | | | | | |
| 50 | Improved format and quality of geospatial data | | | | | |
| 51 | Organisation and standardisation of geospatial data | | | | | |
| 52 | Interoperability of geospatial data | | | | | |
| 53 | Improved documentation and awareness of GRID3 infrastructures | | | | | |
| 54 | Improved data consistency | | | | | |
| 55 | Improved reference and classification system of geospatial data | | | | | |
| 56 | High processing and storage capabilities | | | | | |
| 57 | Improved output data resolution | | | | | |
| 58 | Wide coverage area for GRID3 | | | | | |
| 59 | Improved time of response | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 60 | Interoperability of GRID3 infrastructures with other standard based infrastructures. | | | | | |

## APPENDIX B: INTERVIEW GUIDE

**Researcher: TIAMIYU Barakat Bidemi TMYBAR001@myuct.ac.za; barakatbidemi96@gmail.com**

**Supervisor: A. Prof. Nancy Odendaal nancy.odendaal@uct.ac.za**

**Context:** *Thank you for agreeing to participate in this interview. The interview I s designed to investigate the use and sustainability of GRID3 Infrastructure for Social and Sustainable Development in Nigeria.*

**Ethical considerations:** *Participation in this interview is voluntary. Data collected in this interview will not be shared with anyone and will be used in a combined format.*

*A: INTRODUCTORY QUESTIONS [These are personal questions]*

Question 1: Kindly let me know your work responsibilities and that of your department?

[Answer]………………………………………………………………………………………
………………………………………………………………………………………………

Question 2: Please highlight your work experience (State your years of work experience, areas of expertise, etc.)

[Answer]………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

Question 3: Are you familiar with the use of geospatial data and technologies? (Share what you have it for, how you used it and how often do you use it)

[Answer]………………………………………………………………………………………
………………………………………………………………………………………………

*B: MAIN QUESTIONS [These are questions on the use of GRID3 data and technologies]*

**Question 1**: Are you familiar with GRID3 infrastructures?

[Answer]………………………………………………………………………………………
………………………………………………………………………………………………

Probing question: What geospatial SERVICES have you utilised on GRID3?

[Answer]………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

Probing question: What geospatial TOOLS have you utilised on GRID3?

[Answer]…………………………………………………………………………………………………
…………………………………………………………………………………………………………
…………………………………………………………………………………………………………

Probing question: What geospatial DATA have you utilised on GRID3?

[Answer]…………………………………………………………………………………………………
…………………………………………………………………………………………………………
…………………………………………………………………………………………………………

**Question 2**: Have you used GRID3 to support health care microplanning, policies, management, and delivery?

[Answer]…………………………………………………………………………………………………
…………………………………………………………………………………………………………

Probing question: Please share you experience with the use of GRID3 data, services, or tools to render the support above?

[Answer]…………………………………………………………………………………………………
…………………………………………………………………………………………………………
……………………………………………………………………………………………………

**Question 3**: How would you describe the usefulness of GRID3 in the implementation and monitoring of the SDGs?

[Answer]…………………………………………………………………………………………………
…………………………………………………………………………………………………………
…………………………………………………………………………………………………………

Probing question: Which of the health-related SDGs have you implemented and monitored using GRID3? (*SDG3 – Good Health and Wellbeing, SDG6 – Clean Water and Sanitation*)

[Answer]…………………………………………………………………………………………………
…………………………………………………………………………………………………………

Probing question: How viable are GRID3 infrastructures? Would you say that GRID3 will continue to be useful in healthcare delivery?

[Answer]…………………………………………………………………………………………………
…………………………………………………………………………………………………………
……………………………………………………………………………………………………

Probing question: What are the challenges that you are faced with in using GRID3 for micro-planning and decision making?

[Answer]…………………………………………………………………………………………………
…………………………………………………………………………………………………………
……………………………………………………………………………………………………

Probing question: Comparing GRID3 with the convention geospatial mapping tools (paper maps, hand drawn illustrations), which do you prefer and why?

[Answer]…………………………………………………………………………………………………
……………………………………………………………………………………………………

**Question 4**: What measures can be taken to enhance the usefulness of GRID3 for social and sustainable development?

[Answer]………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
…

Probing question: A tool for social development must itself be sustainable, how can GRID3 be made sustainable?

[Answer]…………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………....

Probing question: Do you think it is important to train and support the users of GRID3? How do you think GRID3 can be trained?

[Answer]…………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………………………..

# APPENDIX C: ETHICS APPLICATION AND APPROVAL



## ETHICS APPLICATION FORM

**Please Note:**
Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form **before** collecting or analysing data. The objective of submitting this application *prior* to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook** (available from the UCT EBE, Research Ethics website) prior to completing this application form: http://www.ebe.uct.ac.za/ebe/research/ethics1

| **APPLICANT'S DETAILS** | | |
|---|---|---|
| Name of principal researcher, student or external applicant | | Tiamiyu, Barakat Bidemi |
| Department | | School of Architecture, Planning and Geomatics |
| Preferred email address of applicant: | | TMYBAR001@myuct.ac.za |
| If Student | Your Degree: e.g., MSc, PhD, etc. | Masters in Architecture and Planning |
| | Credit Value of Research: e.g., 60/120/180/360 etc. | 180 Credit Value |
| | Name of Supervisor (if supervised): | A/Prof. Nancy Odendaal |
| If this is a researchcontract, indicate the source of funding/sponsorship | | |
| Project Title | | An Investigation of the Use and Sustainability of GRID3 Infrastructures for Social and Sustainable Development in Nigeria |

**I hereby undertake to carry out my research in such a way that:**

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

| **APPLICATION BY** | Full name | Signature | Date |
|---|---|---|---|
| **Principal Researcher/ Student/External applicant** | Tiamiyu, Barakat Bidemi | | 14th June, 2021 |
| **SUPPORTED BY** | Full name | Signature | Date |
| **Supervisor (where applicable)** | Nancy Odendaal | | 7 July 2021 |

| **APPROVED BY** | Full name | Signature | Date |
|---|---|---|---|
| **HOD (or delegated nominee)** Final authority for all applicants who have answered NO to all questions in Section 1; and for all Undergraduate research (Including Honours). | | | |
| **Chair: Faculty EIR Committee** For applicants other than undergraduate students who have answered YES to any of the questions in Section 1. | Prof. H. von Blottnitz | | 13/09/2021 |

## APPENDIX D: CONSENT FORM

UNIVERSITY OF CAPE TOWN

IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

### SCHOOL OF ARCHITECTURE, PLANNING AND GEOMATICS

TIAMIYU Barakat Bidemi (MSc. Student)
University of Cape Town
Rondebosch, 7701
Cape Town
Cell: (+234)-810-466-7665
Email: TMYBAR001@myuct.ac.za

### CONSENT FORM

**Title of the research project:**
**An Investigation of the Use and Sustainability of GRID3 Infrastructures for Social and Sustainable Development in Nigeria.**

**Name and position of the researcher:**
TIAMIYU Barakat Bidemi, MSc. Student, School of Architecture, Planning and Geomatics, University of Cape Town.

***Please respond to the following:***

| | ***Please tick*** |
|---|---|
| 1. I have read Ms. Tiamiyu's covering letter and understand what kind of information she is seeking from me. | |
| 2. I agree to answer the questions posed in this study, and provide accurate information to the best of my ability. | |
| 3. I understand that my participation is voluntary and that I am free to withdraw at any time without offering reasons. | |
| 4. I agree to take part in this study. | |

Name of the participant (on behalf of the company): ………………………………..

Signed: ............................. Date……….………......................

TIAMIYU Barakat Bidemi (Researcher) Signature: Date: 01/06/2021

***NOTE:*** All the information provided by you on behalf of the company will be treated as strictly confidential. The result will be presented in aggregate format and no individual disclosure will be made.

## APPENDIX E: CONSENT LETTER

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

School of Architecture, Planning and Geomatics,
Faculty of Engineering and the Built Environment
University of Cape Town
Rondebosch, 7701
Cape Town
June, 2021.

Dear prospective participant,

**Re: An Investigation of the Use and Sustainability of GRID3 Infrastructures for Social and Sustainable Development in Nigeria.**

You are hereby invited to participate in an ongoing MSc. (Architecture and Planning) research project aimed at investigating the use and sustainability of GRID3's infrastructure for social and sustainable development, and to proffer innovative approaches that would enhance the applicability and adaptability of GRID3 infrastructure.

This is research being undertaken by Ms. Tiamiyu Barakat Bidemi, a MSc. student under the supervision of Associate Professor Nancy Odendaal of the University of Cape Town. The outcome of the study will be presented in the School of Architecture, Planning and Geomatics in fulfilment of the requirement for the award of a Master of Science (MSc.) in Architecture and Planning.

This research will identify and examine GRID3's infrastructures, evaluate its use for social development in terms of health care delivery, assess its level of sustainability, and investigate innovative approaches for enhancing the sustainability of GRID3 Infrastructure for social development. The questionnaire can be completed in approximately 10 minutes. All useful comments that will aid the researcher in carrying out the study are welcome. All subjects of this research and any information that you shall provide will be protected with unreserved confidentiality.

Should you have any queries or questions for clarification purposes about the study, do not hesitate to contact me on (+234)-810-466-7665 or TMYBAR001@myuct.ac.za. Your timely response will be appreciated.

Thank you for your assistance.

Ms. Tiamiyu, Barakat Bidemi
(MSc. Student/Researcher)

A/Prof. Nancy Odendaal
(Supervisor)

## APPENDIX F: ETHIC COVER LETTER

GRID3 infrastructure is highly useful for geospatial data referencing and analysis of spatial characteristics of health infrastructures. However, the application and operational use of GRID3 infrastructure in a bid to ensure improved efficiency and sustainability of the GRID3 infrastructure in achieving evenly distributed health infrastructures as an indicator of SDGs are unknown in developing countries such as Nigeria. Also, the intricacies surrounding health care delivery have been further heightened by COVID-19 pandemic. These have raised concern on the sustainability of GRID3 infrastructure, geographic patterns and accessibility of health infrastructures, and coverage of COVID-19 vaccine distribution in response to COVID-19 pandemic. Hence, there is a need to investigate the utilisation and sustainability of GRID3 infrastructures for social and sustainable development in Nigeria, towards identifying innovative approaches for enhancing the sustainability of GRID3 infrastructures for sustainable development in Nigeria.

The aim of this research is to explore the sustainability and use of GRID 3 infrastructures for social and sustainable development in Nigeria, with a view to exploring approaches for improving the sustainability of GRID 3 Nigeria.

According to reports, the current COVID-19 pandemic has been declared as the 'worst public health crises in a generation', with over 12 million confirmed positive cases and 556,342 reported deaths across 213 countries as of July 11, 2020. Considering the spatial disparity and population dynamic, it is important to understand and provide geospatial tools, data and services that would help in mitigating the spread of COVID-19. This calls for investigations that will analyse and support the use of geospatial tools such as GRID3 in identifying sites suitable for the development of health facilities, attaining spatial efficiency in the distribution of health infrastructures, and allocating resources to the needy areas. Also, the need to explore the utilisation of GRID3 as a geospatial tool in tackling health emergencies and obtaining inputs from the COVID-19 pandemic for future preparedness provides support for this research. The information that will be provided by this research will enable decision-makers, public health teams, healthcare planners and hospital managers to reliably and reproducibly forecast the spread of COVID-19. This research will also support the government to effectively prepare for the emergency response and mitigate the challenges involved in the front line defence against the COVID-19 outbreak.

Inequalities in geographic access to health care is one of the primary challenges in achieving the Health-related SDG. Tackling this challenge calls for research that will support a better assessment of health-related SDGs and allow improvement in the planning, monitoring and surveillance of public health programs such as COVID-19 vaccination in Nigeria. In addition, the information to be provided by this research regarding the utilisation of GRID3 will be useful to health planners in shifting their policies or health initiatives away from the use of assumptions of spatial homogeneity in health planning. Important and required information regarding the refinement of GRID3 infrastructures and enhancement of their sustainability will also be provided by this research.

Ethics issues that may arise from this research include confidentiality, anonymity, and informed consent. These will be treated by ensuring that the e-mails, phone numbers and names of the participants are not disclosed. Also, participation in the survey will be made voluntary.

## APPENDIX G: INTERVIEW TRANSCRIPT

## INTERVIEW 1

***A: INTRODUCTORY QUESTIONS [These are personal questions]***

Good afternoon sir. My name is Barakat Tiamiyu. I am a master's student at School of Architecture, Planning and Design, and I am conducting this interview. I will like to ask you some question for my research, which is about an investigation on the use and sustainability of GRID3 infrastructure for social and sustainable development in Nigeria.

Question 1: Kindly let me know your work responsibilities and that of your department?

Respondent: Okay. I work at the town planning department. So, most cases I get to use GRID3 most times and for commercial services within the Physical Planning Unit.

Question 2: Please highlight your work experience (State your years of work experience, areas of expertise, etc.)

Respondent: For about six years plus extra. I have worked on town management, urban planning, scope planning, policymaking implementation, as well as developer control.

Question 3: Are you familiar with the use of geospatial data and technologies? (Share what you have it for, how you used it and how often do you use it)

Respondent: Recently, I'm working on a project with some use case with GRID3 for an urban renewal project in Lagos, it goes into details into details

***B: MAIN QUESTIONS [These are questions on the use of GRID3 data and technologies]***

**Question 1**: Are you familiar with GRID3 infrastructures?

Respondent: Yes. I am. I refers to the project and mentioned it while I was trying to gather information and need for a business baseline. I was a point of contact for a project, especially in terms of road networks, population data, as well as administrative boundaries. I am very familiar with data exchange and OpenStreetMap. I get to see that it has some sort of similarities between the two platforms.

*Probing question: What geospatial SERVICES have you utilised on GRID3?*

Respondent: Okay, I recently used it during a trip to Lagos. I extracted data of Lagos state administrative boundary and it detailed down into local government focus areas. I get to discover that most of the roads and some secondary roads that are missing, as well some streets road trip. Another so what I did was that extracted three, and then I also noticed that the second applies, the OpenStreetMap, and then the volunteer data exchange. GRID3 is helpful, especially when it comes to the ward boundaries, and local government boundaries.

*Probing question: What geospatial TOOLS have you utilised on GRID3?*

Respondent: It is not like an editing tools, maybe their software has. I don't know on their platform What I do is to download dataset, then put it onto my own desktop applications.
Like the population data, network boundaries, location of primary schools, public and private facilities as well.

**Question 2**: Have you used GRID3 to support health care microplanning, policies, management, and delivery?

Respondent: When I needed to get it for a certain area of focus – that is when we are carry out research and data generation. We may want to know, the specific number of health care centers that are being captured in the geospatial database so far. and then determine whether to do some updates locally on our own to cover more facilities that are not captured. So, it's not directly supporting health care service, it's more like getting the primary source of data needs to guide our decisions.

*Probing question: Please share you experience with the use of GRID3 data, services, or tools to render the support above?*

Respondent: I think GRID3 have done a good job so far. So far, they are updating new primary care facilities or services that are springing up. So, to the best of my knowledge, some of those facility were captured well so far. It has not come down to the attention, at least within my own micro environment, I know that some new areas have not been captured here.

**Question 3**: How would you describe the usefulness of GRID3 in the implementation and monitoring of the SDGs?

Respondent: Yeah, it is very useful. I think what they should do is validate the data before they get to publish out some data. There was a time I was looking at the positioning of the public dataset and then the coordinates were not showing well. Like you get to pick a coordinate for a particular primary school and then it gets pointed outside the boundary. The coordinate is referencing another place entirely. So, I guess there is a need to retrain field officers on how to acquire data that are precise and accurate. If that is properly checked, it will help to guide people around and provide dataset that are within the real environment. You will be able to know which Primary School is close to you and which one you think you'd like to place elsewhere.

I recently came across the local government catchment area that was done for the Primary Health Care Development Authority during the process of this COVID-19 vaccination. Although there are some limitations to those maps, in terms of graphical presentation and then representation of landmarks and there were missing facilities. I guess those new facilities are not captured yet so, they should come up with a kind of solution. whereby they get to update it or get people to update with Python functions that people always work with.

*Probing question: What are the challenges that you are faced with in using GRID3 for micro-planning and decision making?*

Respondent: Like I said, they should pay more attention to details of datasets.

*Probing question: Comparing GRID3 with the convention geospatial mapping tools (paper maps, hand drawn illustrations), which do you prefer and why?*

Respondent: It actually work a lot more. So, I guess it is question of viability

*Probing question: How viable are GRID3 infrastructures? Would you say that GRID3 will continue to be useful in healthcare delivery?*

Respondent: Yes, they should keep updating the information. They should get valid basic information to get to the end users, the facility managers and the likes. They should build trust for their data. They can model after google where users can contribute to by being local guied and update places on the map. People can find information and verify it, publish it and then it becomes available to everybody. So, if they're not putting in that effort of making it open for people to come in and update and then publish, or they have been able to verify, it will help build trust.

**Question 4**: What measures can be taken to enhance the usefulness of GRID3 for social and sustainable development?

Respondent: They need to make it more openly accessible.

*Probing question: Do you think it is important to train and support the users of GRID3? How do you think GRID3 can be trained?*

Respondent: Oh, well. I think they can carry out large scale training for users. For example, google has many resources and people can easily use it. So, there is the need to train people, at least people who are using their services. I believe people who understand the usage of GRID3 for their job, can easily do some manipulation and then work around the inconsistency around it. But when they can make it open source for people to contribute, or just to verify the contribution before we can apply. it will increase demand and they will need to start training them on how to walk around the functions for the tools.

The user interface should be improved on and made accessible. It would be different with a mobile application. So literally, before you can have access to probably a location, you need to log on to the website, then navigate to go to different datasets and pick out and then zoom into this particular region. It should be made more like Google Map, which is very interactive and easy to use.

Thank you very much.

## INTERVIEW 2

***A: INTRODUCTORY QUESTIONS [These are personal questions]***

My name is Barakat Tiamiyu. I am investigating the use and sustainability of GRID3 infrastructure for social and sustainable development in Nigeria and studying at the University of Cape Town.

*Question 1: Kindly let me know your work responsibilities and that of your department?*

Respondent: First and foremost, I have worked for five years and over. I work with healthcare service department and dealing with caregivers.

*Question 3: Are you familiar with the use of geospatial data and technologies? (Share what you have it for, how you used it and how often do you use it)*

Respondent: We work with GRID3 maps at the office. We utilize it together with other devices and databases.

***B: MAIN QUESTIONS [These are questions on the use of GRID3 data and technologies]***

***Question 1****: Are you familiar with GRID3 infrastructures?*

Respondent: Yes

*Probing question: What geospatial SERVICES have you utilised on GRID3?*

We use it to know the geographic boundaries. And to capture the eligible population in an area.

*Probing question: What geospatial TOOLS have you utilised on GRID3?*

Respondent: What we have is the paper one.

*Probing question: What geospatial DATA have you utilised on GRID3?*

Respondent: We have what we usually use in our area, when we are dealing with wards. You know there are different wards in a local government area. For example, we have those wards that are already captured. So, under the GRID3 map, some areas are not captured. So, we had to locate it or identify it. ourselves

***Question 2****: Have you used GRID3 to support health care microplanning, policies, management, and delivery?*

Yes.

*Probing question: Please share your experience with the use of GRID3 data, services, or tools to render the support above?*

Respondent: We use it to identify areas or facilities within eight meters. To identify location and the population of the people that live in a particular area and then plan for them.

***Question 3****: How would you describe the usefulness of GRID3 in the implementation and monitoring of the SDGs?*

Respondent: It is very useful. Because it helps to identify areas that would be able to be that we didn't know before. It also identifies all the areas or the total number of people living in a particular area, for example, now, the additional amenities or the social amenities legs like radio, television, etc, that are being used in that particular area. So, we have to adapt our strategies to all those places now. It helps to identify the particular places of needs, which then goes to the department leaders, who identify the intended financial boundaries based on the budget that is allocated to us.

*Probing question: Which of the health-related SDGs have you implemented and monitored using GRID3? (SDG3 – Good Health and Wellbeing, SDG6 – Clean Water and Sanitation)*

Respondent: It is very useful, if not we would not be able to identify the issues I have identified. So, but we have to divert strategies when we are able to identify them

*Probing question: How viable are GRID3 infrastructures? Would you say that GRID3 will continue to be useful in healthcare delivery?*

Respondent: The challenge may be a really bad network. if there is a good network, we would be able to get whatever we wanted.

*Probing question: What are the challenges that you are faced with in using GRID3 for micro-planning and decision making?*

Respondent: If it is more digital or on computers we will need to be familiar with the use. So, we need training to use GRID3 or require a computer to use it.

***Question 4**: What measures can be taken to enhance the usefulness of GRID3 for social and sustainable development?*

Respondent: We need to be familiar with its use as civil servants. Onboard us on the use of the digital platform and provide computers, so that you can be able to use it well. Also provide assistance or guidance in every aspect that we might need.

*Probing question: Do you think it is important to train and support the users of GRID3? How do you think GRID3 can be trained?*

Respondent: Very important.

*How do you think GRID3 can be trained?*

Respondent: Everything is dependent on the level. So, if you can come down to the different levels, and train other to cascade down to the lower level.

## INTERVIEW 3

***<u>A: INTRODUCTORY QUESTIONS [These are personal questions]</u>***

Hi, good evening. Thank you for granting me the opportunity. Just to give you a good background on the research, the search is an investigation on the use of GRID3 infrastructure for social and sustainable development. So, I'll be asking you some questions on GRID3 use in Nigeria, how that has been so far, the objective of the research is actually just to proffer solutions or improvements, ideas that can be employed to further enhance the use apart from COVID, for COVAX. And to see if it can be extended to other areas in the society. So, let me just quickly dive into the questions.

*Question 1: Kindly let me know your work responsibilities and that of your department?*

Respondent: I am the national program assistant. Basically, what I do is that I align immunisation activities and GRID3 priority. Secondly, we have a group of committees, and a steering committee, which provide the overall guidelines for the GRID3 Nigeria program. We have the technical committee, which actually carries out the technical activities of GRID3.We have a secretariat that is used to carry out activities. I engage in activities such as stakeholders' engagement, use case developments, implementation and things like that.

*Question 2: Please highlight your work experience (State your years of work experience, areas of expertise, etc.)*

Respondent: So generally, I have been working in the social and health sectors since 2016/2017. I worked with direct consultancy, logistics and the National Primary Healthcare Development Agency. Where we worked on routine immunisation and how to improve immunisation services. From there, I went to Salina and also worked with them on some health sector level, at grade three level. And then we expanded to different sectors such as food security, agriculture, agriculture, food security, financial education, among others. So, I think so far, I have about eight or seven years of experience.

*Question 3: Are you familiar with the use of geospatial data and technologies? (Share what you have it for, how you used it and how often do you use it)*

Respondent: Yes.

***B: MAIN QUESTIONS [These are questions on the use of GRID3 data and technologies]***

**Question 1**: Are you familiar with GRID3 infrastructures?

Respondent: I am actually working to promote the use of the GRID3 data. To generate all the data there. I've introduced GRID3 to multiple organisations for them to make use of the data to guide policy and intervention programs.

*Probing question: What geospatial DATA have you utilised on GRID3?*

Respondent: Okay, so I'll give you an example of one, which is in a sector we have actually collaborated with an organisation before. They were able to make use of GRID3 datasets and population dataset, to determine the number of out of school children. These datasets include population, boundary datasets, etc. In terms of the GRID3 tool, we are currently developing it through colour placement optimization. We basically integrate the four cardinal points with location. It helps to give advice to policymakers on where to put infrastructures/amenities to increase access for population of school going children.

*Probing question: What geospatial SERVICES have you utilised on GRID3?*

Respondent: We are yet to launch our official dispensary launch, hopefully by the end of the year.

**Question 2**: Have you used GRID3 to support health care microplanning, policies, management, and delivery?

Respondent: Yes, we have

*Probing question: Please share your experience with the use of GRID3 data, services, or tools to render the support above?*

Respondent. We used GRID3 data for micro planning and a routine immunisation campaign, which is going on currently. We have created maps for each ward for identifying the health facilities or potential areas where health workers can situate vaccination posts, so that they can capture most unvaccinated people. And one good thing is that the map that we deploy has population estimates in it. So, at the end of the day, we would be able to achieve coverage to a certain level, and determine the list of settlements that were missed in the process of conducting the immunisation.

So, GRID3 provides the available data to solve the problem and then GRID3 is modelling it in a way that can guide policymaking.

I mentioned that we have gotten all this information like population of each settlement, the ward boundary of the settlements, and a cluster of health facilities in those areas. We put it on a map to provide or serve as a guide in providing healthcare service.

**Question 3**: How would you describe the usefulness of GRID3 in the implementation and monitoring of the SDGs?

Respondent: For Sustainable Development Goals, there are many aspects that GRID3 data can be utilised to make decisions. For me personally, without knowing the location and coordinates of any project, there is no need for the government to provide funding, because the project will fail. When you coordinate, you can sit at the comfort of your office and see what is happening. Depending on the resources and kind of detail you have. A good example is when a road infrastructure is awarded, you can view the progress and benefit to the population. So generally, it's something that's highly recommended by Nigerian governments for them to take ownership and leadership to ensure that virtually all data that they are carrying out have geospatial components.

Probing question: Which of the health-related SDGs have you implemented and monitored using GRID3? (*SDG3 – Good Health and Wellbeing, SDG6 – Clean Water and Sanitation*)

Respondent: Definitely, I'm currently trying to explain use cases in that section for water, sanitation and hygiene. What do you think would happen if I had a map of those who have access to water and those who have drainage systems in a state to avoid floods? That also relates to toilet facilities, wash facilities, in public places, so as to curb or fight against the COVID-19. It is very important for us to have this. So, looking at it from water, sanitation, also hygiene, you cannot do with geospatial data? Where would you make very good decisions, we need to get to this point. There are the populations that aren't much at risk. There is also the case of operational risk, among others.

We are in conversation with the Minister of Water Resources to see how we can collaborate to establish support using GRID3.

Probing question: How viable are GRID3 infrastructures? Would you say that GRID3 will continue to be useful in healthcare delivery?

Respondent: Yes. It is useful beyond COVAX and the reason why I said is that it covers all aspects. If you look at the health sector alone and we narrowed it down to micro planning activities, you see we have micro planning for immunizations and those that are for routine immunisation and other diseases. It is something that will keep occurring for as long as we have the need for data to support where we carry out these immunisation activities.

*Probing question: What are the challenges that you are faced with in using GRID3 for micro-planning and decision making?*

Respondent I would say there are lots of challenges. It would be very good if state or local government levels are capable of actually developing their maps themselves. It is something that we want to institutionalise. But before you can even start thinking of institutionalising it within the state, you have to show them the beauty of how to use it.

Presently, we are showing them the beauty of GRID3 by developing these maps for the health sector. And then we are going to see how good it is, so we can take the next step, which is something that we need to discuss within the team.

We need to build capacity for different levels and conduct subsequent capacity building for sustainability purposes. We are thinking of coming up with just an application, whereby it's a tool that creates routine and non-routine services for national primary health care managers. This tool is going to help workers at the state level, to be able to develop maps at that different section or areas. And then with that, they can update information in terms of data collection, settlements, infrastructure, hospital, etc. As long as it's been updated then it can be sustainable. Health workers can continue to train on map use. They will be able to visualise it on a web app or something. But these are still in conversations.

I think in July, we will come to the completion of that by the end of the year, by next year, we should have launched it.

*Probing question: Comparing GRID3 with the convention geospatial mapping tools (paper maps, hand drawn illustrations), which do you prefer and why?*

Respondent: Others are prone to many errors, compared to where you've actually collected data on an application or software like QGIS or ArcGIS. It's garbaging out the exact information which does not change.

**Question 4**: What measures can be taken to enhance the usefulness of GRID3 for social and sustainable development?

Respondent: It is for us to keep creating awareness, which is very important. Awareness does not mean you just tell them you have to create awareness in the way that you solve some of their problems. For example, in a sector like health or education, where it did work well, it is going to be easier to move into other sectors like food, security, innovation, technology, innovation, financial inclusion and things like that. And gradually people tend to adopt it and use it for monitoring and evaluation. For everything that we do, we need to monitor it because accountability is very important. And we need to improve on mistakes.

*Probing question: Do you think it is important to train and support the users of GRID3? How do you think GRID3 can be trained?*

Respondent: Yes. For GRID3. We have not really talked extensively about capacity building and are still in talks with our partner, NASA (National Space Research Development Agency) for implementation. Basically, one of the things they need to do is for them to build the capacity of users. And we've trained some people on the use of the GRID3 portal. Secondly, we need to train them on GIS applications to carry out analysis. So, they can use the data to develop different use cases and to show them how it's been done.

I think that's just the tip of the iceberg of GRID3's capacity. We are coming up with a tool specifically for the educational sector. We intend to train them on that tool, how to use that, to make decisions, and keep updating the data because it becomes outdated after some point. Also, by continuing the use of the data for more informed policy decisions in the health and in the educational sector.

## INTERVIEW 4

***A: INTRODUCTORY QUESTIONS [These are personal questions]***

Hello, good morning. Thank you for your time. Just to give you a background of the research, my research is an investigation of the use and sustainability of GRID3 for social and sustainable development. I am interviewing GRID3 users to find out how they have been using it and how it can be improved.

*Question 1: Kindly let me know your work responsibilities and that of your department?*

Respondent: I am currently GRID3 Country Manager. I work to further strengthen the use and application of the GRID3 data by the Government of Nigeria and also working closely to develop further use cases for how the data can be used in various sectors such as health, education, agriculture, and finance.

*Question 2: Please highlight your work experience (State your years of work experience, areas of expertise, etc.)*

Respondent: I have been working towards the use, and application of geospatial data for sustainable development. For over nine years, I have worked to generate geospatial data to support polio eradication in Nigeria, which was around 2011 -2013/14. We use GIS data, basically settlements, health facilities, and other points of interest, such as schools such as, you know, road network motor parks, to support health workers to conduct micro plans for polio campaigns. And during that period, we use that data to delineate what boundaries for operational purposes that health workers will use, you know, to conduct their microplanning to ensure that every settlement is visited, every session is captured and visited for polio campaigns targeting under five children. And in that period, we have used various technologies in order to actualize the coverage of the settlements. In this case, we use what was called TRICARE system, VTS vaccination tracking system, where the health workers, the vaccinators were given mobile trackers, which they moved alongside with them to all those settlements. At the end of the day, we see what settlements were visited, and which settlements were not visited during the campaign. So, down the road to 2017, we realize that these datasets really made a lot of success around polio eradication and it has made a significant impact in terms of coverage, reaching children who are under five years. We then expanded the program to collect additional data that has to do with environment, education, agriculture, finance, and all that aspects. To generate these datasets, which get back to the

GRID3 program. GRID3 expanded this data collection, like I mentioned, to the remaining state in Nigeria during the polio eradication. Only 11 states were high risk, they were considered high risk states with the highest number of polio cases. So, the mapping, the data collection, and the GIS application was only mainly in those 11 states. GRID3 expanded to the remaining 25 states, and covered additional sectors for overall sustainable developments, and to to strengthen the availability of the data, to strengthen its use across different sectors, to improve service delivery, as well as sustainable development.

***B: MAIN QUESTIONS [These are questions on the use of GRID3 data and technologies]***

**Question 1**: Are you familiar with GRID3 infrastructures?

Respondent: Yes.

*Probing question: What geospatial SERVICES have you utilised on GRID3?*

Respondent: if you say geospatial service, I want to understand that you are referring to maybe some of the services that we provide to the governments with regards to the GRID3 program.

Okay, so there are various services that we render to the government or that we also currently render to the government across a variety of sectors. Let me begin by or let me just focus my response to health and maybe perhaps education. In the health space, we provided GIS maps to support various programs, various immunisation program areas, such as measles, yellow fever, even the polio itself, and then the COVID-19 vaccinations. Currently, we are developing a digital micro planning application or digital micro planning toolkit that will allow health workers to have access to their own data to be able to use those datasets to conduct planning at that community level. The services were basically GIS base maps for these different program areas, at different levels, and local government level. In the education space. We have also developed what is called school placement optimization. This tool allows us to visualise the current existing schools that are available in Nigeria and also locate where we need to have additional schools; because no child should travel more than two kilometres to access a school. It's important to correctly look at the spread of the existing schools that we have - primary and junior secondary schools, and also their locations, to know if we need to have additional schools. So, no child should travel more than two kilometres in order to access school. This is really helping decisions around addressing out of school children. And this tool is currently domiciled within UBEC (Universal Basic

Education Commission). They also use it to establish alternate school programs, which is a program currently being implemented or to be implemented by the Ministry of Humanitarian Affairs and Management especially.

*Probing question: This answers the questions of the tools available at GRID3.*

Respondent: Yes, is this

*Probing question: What geospatial DATA have you utilised on GRID3?*

Respondent: Currently, we have four core data layers. We have four core geospatial data layers, one is the population estimates at 100 metre per 100. Which is estimating the how many people live in each location across the country, which is broken down by age and sex. Secondly, we have comprehensive settlement locations. This aggregate settlements across the country, all communities across the state that are closed FCT. The third data layer is the administrative boundary. So, in this case, we have the operational boundaries at state level, local government as well as ward level. And lastly, we have the infrastructure data, which includes points of interest, such as health facilities, schools, farmland, water points, IDP camps, roads, and there are about 21 points of interest. Overall, we have over 500,000 data points on the GRID3 portal.

**Question 2**: Have you used GRID3 to support health care microplanning, policies, management, and delivery?

Respondent: Like I mentioned earlier, most of those maps that we produce, were mainly designed to support micro planning. For the health workers, before they conduct campaigns or routine immunisation, they need to have an estimate of how many children are living within a ward or within a health facility catchment area. And these children are targeted for the campaign or for those vaccines. For a vaccine, you have to have a target population. For routine immunisation, you would be looking at children that are one year old or under one year of age. For the polio program, you would be looking at children under five years. For measles, you would be looking at children from nine months and adults between four to five years. Sometimes, children between seven to eight years, nine to 10 years are being vaccinated. All these different age groups or target populations need to be estimated at the ward level or health facility catchment area level. The health workers need the information to determine how many vaccines they need, how many other supplies they would need in order to carry out their campaigns effectively. And they will need to know the settlement that they need to visit. To know where the settlement is located and how many vaccination team they would need to make sure that they cover those settlements. This is how the micro planning process happens and for which those maps that we provide to determine the population estimates across the different wards and settlements. It also provides distance in kilometer between settlements and the settlement locations. So, it's a very useful tool that they use to determine the micro planning process.

**Question 3**: How would you describe the usefulness of GRID3 in the implementation and monitoring of the SDGs?

Respondent: GRID3 is a very useful tool to track the implementation of the SDGs because it helps to track or to address out of school children. For example, in the education space, you will need this kind of information to determine how many children to be targeted, how many children are reached, which of course, will form part of the SDGs indicators for education, basic education access. This is fundamental to increasing access to education. GRID3 placement optimization tool will help you to determine where you can situate amenities or reach children that do not have access to school. So, it gives you the clear visibility of where you can reach them and what services you need to take to them. When you talk about basic primary health care, which is fundamental, GRID3 helps to determine health services that people need to receive. For example, when there is a case of malaria, Hepatitis A or B, or any other cases that require the patient to go to the hospital, you need to visit first primary health care facilities to first present your case and then determine if you will need to take vaccine for prevention, which will improve our healthcare coverage. It helps you to track indicators around basic primary health care services that have been provided. For the agricultural sector, GRID3 has a use case around food security, that is to ensure food security in this country, which also relates to one of the goals of the SDGs. You can utilise the geospatial data layers to estimate or delegate farmland and to establish harvest periods for those farm lands. Also, to determine the markets for the farm produce after being produced. So, you can establish a route between the market and the farmlands so that those farmers can easily transport their produce to the market after post harvests.

**Question 4**: What measures can be taken to enhance the usefulness of GRID3 for social and sustainable development?

Respondent: We would require automation around the areas that have been mentioned. We actually have a domicile GRID3 data portal on the NPHCDA and there is a government agency -National Space Research Agency. We work with various government agencies to strengthen and ensure availability of the data by engaging with relevant stakeholders to harness and provide access to any form of geospatial data. Hence, they can upload it on the portal and they can strengthen the availability of the data in the portal. And also, for any survey or any data collection that has been conducted by any government agency will try to capture that and also added into the portal in order to strengthen the availability of data.

## INTERVIEW 5

***A: INTRODUCTORY QUESTIONS [These are personal questions]***

Thank you very much for your time and for granting me the opportunity to conduct this interview. So just to give you a background on what the study is about for my master thesis at the University of Cape town. I am conducting an investigation on the use and sustainability of GRID3, to explore ways that GRID3 can be better improved for sustainability and adaptability of GRID3 to help solve social and sustainable development issues in Nigeria. The focus of the research is on health education. I would like to get insight from the education sector as well, which would be helpful for this to explore approaches to the new method which we can better improve the application.

*Question 1: Kindly let me know your work responsibilities and that of your department?*

Respondent: Okay, thank you very much. Let me start by introducing myself. I work at the America University of Nigeria, Institute for Development on Agricultural Resilience Projects and also as the Budget Director

*Question 2: Please highlight your work experience (State your years of work experience, areas of expertise, etc.)*

Respondent: It's been about 3 years in my current position. I manage the facilitation, conditional management's design development and livelihood program in my current position. I have delivered humanitarian programming around livelihood, it creates all kinds of sustainability resilience for agriculture.

***B: MAIN QUESTIONS [These are questions on the use of GRID3 data and technologies]***

**Question 1**: Are you familiar with GRID3 infrastructures?

Respondent: Yes, I did. So, GRID3 is the key for some experimental work on a budget in which we take some coordinates for a funds well project. We had about 80 participants who are farmers that are supported and to help determine where pumps should be located in the northern part of Nigeria.

*Probing question: What geospatial SERVICES have you utilised on GRID3?*

Respondent: Yes, I was working on a better program in Lagos that was far back in 2000/2002. There are a few we had which are similar to these but it was coordinated to access facilities in Lagos.

*Probing question: What geospatial DATA have you utilised on GRID3?*

Respondent: Yes, we utilise the data. I think they provided all this information on their application or use it to also support the coordinator application.

**Question 2**: Have you used GRID3 to support health care microplanning, policies, management, and delivery?

Respondent: True for some of my colleagues, it was an opportunity for us to also showcase what we have an opportunity for to donors to see wherever they are, where some of our clients are located. And they can also now interact with some of them. It's almost like they see the reality of what we claim them and the location at which we are doing it, which they can easily track or monitor.

**Question 3**: How would you describe the usefulness of GRID3 in the implementation and monitoring of the SDGs?

Respondent: It helps to increase job quality and create a level of visibility of the work we are doing. For project monitoring, it validates the data being collected, because it shows the reality of those data and where they are located. It also helps to see the interrelationship between those locations and as well as limited partners, and also reps to also look at. Normally, they just do graphical spread of your beneficiaries across a particular location. Not in some cases, you may not know that you are teaching more to one side, I noticed this GRID3 experience is also opposed to moving houses, so that it also helps in planning future interventions.

*Probing question: How viable are GRID3 infrastructures? Would you say that GRID3 will continue to be useful in healthcare delivery?*

Respondent: I hope that it will continue to be more standardised in the sense that it opens up more opportunities, and support to end-users. The coordinates should provide more than just the location or the data per view.

*Probing question: What are the challenges that you are faced with in using GRID3 for micro-planning and decision making?*

Respondent: This is all the areas at which we have applied the good guys to some bit of security challenges around this location. So sometimes we need to provide some additional support which will be able to assist us in getting better. With the level of understanding of work with the sun about what he suggested, we have to retrain our returning employee to use the GRID3 portal. It would be good to do the analysis of the data collected, then just seeing it online, to help shorten time spent on a project.

*Probing question: Comparing GRID3 with the convention geospatial mapping tools (paper maps, hand drawn illustrations), which do you prefer and why?*

Respondent: GRID3 has a higher level of data accuracy and it is faster to access.

**Question 4**: What measures can be taken to enhance the usefulness of GRID3 for social and sustainable development?

Respondent: They should develop an application. They should help with the processing of data to reduce turnaround time.

*Probing question: A tool for social development must itself be sustainable, how can GRID3 be made sustainable?*

Respondent: Participants engagement is quite important. They should get users or participants at every level so that they can also contribute to the process of standardisation or increasing the benefits or reaching out to as many as possible. For people to see themselves in the process of developing an application on a platform and determining the choice to go with it. It also supports marketing and creates resources to support the process, and engage some public government.

*Probing question: Do you think it is important to train and support the users of GRID3? How do you think GRID3 can be trained?*

Respondent: It is definitely important. It is learning as a continuous process. People should be trained on the use of GRID3 to explore and find new knowledge. Therefore, it is a training that should be continuous and create opportunities to network with people Muslims so that we can achieve greater opportunities.

Users should access training and there should be TV support online. Provide certification for diverse areas of geospatial data. Provide opportunities to access and contribute to the platform. I think of one line of work at this moment. Face to face meet ups might be quite expensive than online training online.

*Thank you so much for your time, and we provided very good insights for this study. Thank you, sir.*

## INTERVIEW 6

***A: INTRODUCTORY QUESTIONS [These are personal questions]***

Nice to meet you. Thank you for coming on, especially on short notice. Just to give a short background on what the study is about, it is an investigation on the use and sustainability of GRID3. I want to investigate new approaches that can be adopted to better improve GRID3 for social and sustainable development.

Question 1: Kindly let me know your work responsibilities and that of your department?

Respondent: Let me just do a brief introduction. I remain Mukhtar Mohammed, I'm the monitoring and evaluation person for the building resilience to sustainable agriculture project at the African Institute for Development at the American University of Nigeria. My department is responsible for maintaining an updated database of our beneficiaries across incubation sites, and to work on approaches to better improve our intervention plans to better the life of our beneficiaries across the sites.

Question 2: Please highlight your work experience (State your years of work experience, areas of expertise, etc.)

Respondent: Data management, organisational research? Program money.

***B: MAIN QUESTIONS [These are questions on the use of GRID3 data and technologies]***

**Question 1**: Are you familiar with GRID3 infrastructures?

Respondent: Yes, I've done certain surveys using geospatial data technology, especially with GRID3 just recently.

*Probing question: What geospatial SERVICES have you utilised on GRID3?*

Respondent: Most of our service, we leverage on that because it's easier for you to pinpoint locations, especially those working in the agricultural livelihoods sector. It's better to have an accurate location where your beneficiary farmer is working, especially for their farm size, location, to also understand the topography around that area. Therefore, using the information to better improve on the delivery approach for the project.

*Probing question: What geospatial DATA have you utilised on GRID3?*

Respondent: We utilise the tools and we have done something with them. Like collecting geospatial data for some of our beneficiaries, data management and have worked with some of the GRID3 team to better improve how we report the data. On the GRID3 service aspect, I'm not very sure what area you want us to talk about. But I'm sure I've used the tool and many data aspects.

*Probing question: Please share your experience with the use of GRID3 data, services, or tools to render the support above?*

Respondent: The experience has been wonderful to me. It's been educational. It has widened my horizon on the use of geospatial data especially with the quoting of the spatial data in integration sites, leverage on satellite imagery that are accurate to do a better representation of the data. It has been lively and educated.

**Question 3**: How would you describe the usefulness of GRID3 in the implementation and monitoring of the SDGs?

Respondent: It is useful and you will agree with me that the world is a global village now. It is running away from analog approaches and digitising our integration approaches using the data, especially these geospatial data, has gone a long way to improve our intervention plan. And we hope to continue to leverage on what GRID3 is providing.

*Probing question: How viable are GRID3 infrastructures? Would you say that GRID3 will continue to be useful in healthcare delivery?*

Respondent: Yes. In fact, I think we need to even improve on the on the service approach to make it more readily available for the development partners to leverage. We are looking at working with the digital aspect for data management. Beyond 50 years.

*Probing question: What are the challenges that you are faced with in using GRID3 for micro-planning and decision making?*

Respondent: I think the challenges don't necessarily have anything to do with GRID3. I think it has so much to do with the Nigerian geospatial Institute or landscape. Unfortunately, I don't know if there's a satellite that is specifically used in Nigeria. It would have helped us to leverage on what is available and make it better. So, the challenge doesn't necessarily have to do with GRID3, we just need to improve on our geospatial infrastructure.

*Probing question: Comparing GRID3 with the convention geospatial mapping tools (paper maps, hand drawn illustrations), which do you prefer and why?*

Respondent: With the innovation GRID3 stands out. I'd like them to continue to learn and probably improve the services they provide.
They need to consider the user friendliness. Google Maps is kind of tacky. GRID3 is quite user friendly. So, it's better to use.

**Question 4**: What measures can be taken to enhance the usefulness of GRID3 for social and sustainable development?
Respondent: Like I said earlier, it should be made more readily available for their development partners to latch on. It should be more readily available, like what Google Maps is doing. I understand that even Google Maps is very difficult to manage. GRID3 should try as much as possible to make their services readily available for others to work on. And then that way, it will improve your service perfectly.
*Probing question: A tool for social development must itself be sustainable, how can GRID3 be made sustainable?*

Respondent: I think basically, they should make it accessible. Apart from being seen as user friendly, of course, they should find a way to collect feedback from users, especially around technical difficulties, if there's any. So, they can improve on that, there should be a feedback mechanism for users. There are reporting mechanisms like you have for Kobo collect Open Data kits, data collection, feedback where people can report issues or any difficulty in a particular type of data. We can traditionally leverage or something like that. And then to collect feedback from users to improve service.
*Probing question: Do you think it is important to train and support the users of GRID3? How do you think GRID3 can be trained?*

Respondent: Sure, capacity development goes a long way in improving service provision, especially if there are new innovations or new technical components they are trying to bring into the service provision. They should try as much as possible to organise a capacity development session for even if it is not for everybody, do the kind of training of trainers that can be cascaded down and they train people who are directly using the services.
This training method should be a hands on approach. Training for different degrees of users of GRID3, they can use electronic medium for the training like Google meet or something, even if it is quarterly. Just to build the capacity of your users for new innovative areas.

*Thank you very much. That is the end of the interview. Thank you for your time.*

## INTERVIEW 7

*A: INTRODUCTORY QUESTIONS [These are personal questions]*

Question 1: Kindly let me know your work responsibilities and that of your department?

My name is Barakat Tiamiyu. And we're conducting an assessment on the use of the GRID3 for social and sustainable development. What we are doing today is just to ask and inquire how we can better improve GRID3.

Question 2: Please highlight your work experience (State your years of work experience, areas of expertise, etc.)

RESPONDENT: Monitoring and Evaluation Officer. M&E Unit, Ogo Oluwa LGA. I have served at the department for 21 years ago.

Question 3: Are you familiar with the use of geospatial data and technologies? (Share what you have it for, how you used it and how often do you use it)

RESPONDENT: All the immunisation, either RIA, campaign or activities etc.

*B: MAIN QUESTIONS [These are questions on the use of GRID3 data and technologies]*

**Question 1**: Are you familiar with GRID3 infrastructures?

RESPONDENT: The LIO helped me to know the map. Because the map is placed in the LIO office, so that everyone can look. It helped us to locate all our community nearby. To either the Fulani community, and nearby communities. It has been four weeks since we collected the map and it has helped us for our RI activities.

Probing question: What geospatial SERVICES have you utilised on GRID3?

RESPONDENT: Yes, we are using it. Because Ogo Oluwa is between Atiba LGA and Ogbomoso south in Oyo state, to know our boundary. In Osun state, Ogo Oluwa is within and the map helps us to know our boundary.

*Probing question: What geospatial TOOLS have you utilised on GRID3?*

RESPONDENT: It is a larger map that explains everything clearly. So, it helps us. Like I said, we need more training to know better than this level. We need more training.

*Probing question: What geospatial DATA have you utilised on GRID3?*

RESPONDENT: The LIO helps me, because I work with him. He helps me to explain those that I don't understand. So, we need training, so I will understand more than my colleagues.

**Question 2**: Have you used GRID3 to support healthcare microplanning, policies, management, and delivery?

RESPONDENT: No, it is not only for RI. Even the NET Campaign that we are starting the training for tomorrow, it will help us. To locate all the settlements.
*Probing question: Please share your experience with the use of GRID3 data, services, or tools to render the support above?*

RESPONDENT: It is not a challenge. Our LIO will call all our focal points to come to the office. We look at the previous one while looking at the map, it helps us to update the map. It helps.

**Question 3**: How would you describe the usefulness of GRID3 in the implementation and monitoring of the SDGs?

RESPONDENT: The M&E Officer, Logistician, LIO, CCO and all the program officers. Before our validation exercise, the CCO will check the data of all the health facilities that are offering ROI, with their register card and request that they used to collect the vaccine, before the validation exercise. On that day, the LIO will be seated to check whether the data was validated before the validation meeting was changed or permanent. Before we upload to DHIS2.
*Probing question: How viable are GRID3 infrastructures? Would you say that GRID3 will continue to be useful in healthcare delivery?*

RESPONDENT: It helps us in routine immunisation and the NET Campaign to locate our settlement. And delta. Like Fulanis for example, they like to be pregnant all the time. We do outreach for below under-5 in those settlements, to attend ANC. When they give birth, we do BCG, so those are the data we update.
During the first dose of COVID-19 vaccine, it helped us to locate our settlement, it helped us.
*Probing question: What are the challenges that you are faced with in using GRID3 for micro-planning and decision making?*

RESPONDENT: Shortage of staff. We have a shortage of staff. Because in my health facilities, OIC is the one that attends to all the clinics and writes all the registers. So, the work is too much for one person, let's face it. This is our challenge: shortage of staff. All our health facilities in Ogo Oluwa, we do not have enough staff. If you have a nurse, record officers, or

nurses to attend to a client, but here we only have a person to attend to the client. The workload is too much.
There are also hard to reach areas. Because it is in a rural LGA.
The challenges we have in our settlement is that, because of the Fulani problem, most of our settlements are relocating. When we have this map, it helps us to locate and go to that area and see if the settlement exists. The map helps us to go straight to that settlement.

*Probing question: Comparing GRID3 with the convention geospatial mapping tools (paper maps, hand drawn illustrations), which do you prefer and why?*

RESPONDENT: Yes, it was hand-drawn. The focal person drew it for his/her ward. But the one you gave us captures everything. It is a larger map that explains everything clearly. So, it helps us. Like I said, we need more training to know better than this level. We need more training.

**Question 4**: What measures can be taken to enhance the usefulness of GRID3 for social and sustainable development?

RESPONDENT: Yes. We need support with our outreach. You know our area is rural, we use bike to go for outreach. No fuel or impress, so if our Oga or NGO will support us to encourage our staff or OIC. If you have an opportunity to give us either an impression or stipend to fuel the bike or small thing to door outreach.
We need a phone or a laptop. We also need funding or motor bikes to move from one settlement to another settlement for outreach, mobilisation, advocacy etc.

## INTERVIEW 8

*<u>A: INTRODUCTORY QUESTIONS [These are personal questions]</u>*

Question 1: Kindly let me know your work responsibilities and that of your department?

My name is Barakat Tiamiyu and I am conducting this assessment to evaluate the use of GRID3. Before I start, do we have your consent to start this interview?
RESPONDENT: Yes, let’s start

Question 2: Please highlight your work experience (State your years of work experience, areas of expertise, etc.)

RESPONDENT: I am the Local Immunisation Officer of Ogo Oluwa local government given the ROI facility to vaccinate the children in the community. My name is Hassan Olukayode Okanla, in the PHC department. I have worked in the department for three years. I started October 2019.

Question 3: Are you familiar with the use of geospatial data and technologies? (Share what you have it for, how you used it and how often do you use it)

RESPONDENT: BCG, Poliomyelitis, Penta hepatitis, TT.

*<u>B: MAIN QUESTIONS [These are questions on the use of GRID3 data and technologies]</u>*

**Question 1**: Are you familiar with GRID3 infrastructures?

RESPONDENT: We have a local government map which distinguishes our local government from other local governments and other states. So as to prevent any fault, for example, there is a nomadic gas belonging to our own local government, but the main village is for Osun state so if not because of that map, you know, we cannot iron it out easily.
Yeah. You see, we have 10 wards, each focal person with a supervisor will draw a map of their wards, bringing it back to us, where we collate it together. And that's what will show us where to go. Because we are focused on people living there. So, by the time they bring the map, that map will be a guide and for us to go and check them on the field, the map will lead us to meet them and even in the time of ODK, when they wanted to do the ODK. We followed that map from one local government to another easily. Like Ogbomoso south and Ogo Oluwa, you can easily jump into Ogbomoso south from Ogo Oluwa. He didn't follow that map. He followed the hand drawn map. The map you sent is clear, yes, it’s clear.

*Probing question: What geospatial SERVICES have you utilised on GRID3?*

RESPONDENT: Local government has its own map, that is, Ogo Oluwa local government and all over Oyo state. So, we use that one only and we follow it.

**Question 2**: Have you used GRID3 to support health care microplanning, policies, management, and delivery?

RESPONDENT: For immunisation, for things like no NIPDS and including COVID that we just recently finished. We used the mapping. So, it guides us not to go astray, then we limit ourselves to just our local governments.
For all programs, both routine and campaign. Polio is one of the campaigns.
*Probing question: Please share your experience with the use of GRID3 data, services, or tools to render the support above?*

RESPONDENT: I think yes, like the distribution of nets now, the net will be distributed to each ward. And when they follow that map, they will not miss any village. You know, they will be in the wards, so they will know if these villages come or they did not, that map will show them the route to the ward. Although, they mobilise us to bring people from that ward, which has been done but not withstanding that map stands as evidence to move.

**Question 3**: How would you describe the usefulness of GRID3 in the implementation and monitoring of the SDGs?

RESPONDENT: So, the road leading to, if I want to move from ward one to ward two, you know there is a link. So, if you follow the map, it helps.
Since they're coming for collection of vaccines, there was no need for that. I had mentioned that the maps were also used for finding and travelling to the locations during the immunizations.
*Probing question: How viable are GRID3 infrastructures? Would you say that GRID3 will continue to be useful in healthcare delivery?*

RESPONDENT: If they will print on these micro plans, if you want to advise that it will be a little bit old, okay. So apart from that, there is not much because when we have the target population, then we it is there then we work on the target population, which will show you the amount of vaccine you collect and the same thing applies to these net distributions. You have your target population, they will know the number of checks they give to you, which we give to the villages. So, in term of micro planning, no issue
If you didn't validate like that, we are nomadic, they migrate. So that's why we are upgrading our plan periodically
*Probing question: What are the challenges that you are faced with in using GRID3 for micro-planning and decision making?*

RESPONDENT: The challenges we face is that if you come to Ibadan to collect vaccines, now they are giving us transport fare but initially it was not so. Then, back to the LGA for our people to come from their various villages to come and collect vaccines is a problem.

Also, for those who go out for outreach is also a problem, because local governments are no longer helping. So, it's a major challenge. Then the issue of roads, it is only during the rainy season we issue about transportation in some areas. But now the local government is trying to grade those roads. So, the major issue now is that of vaccine collection from LGA to each facility because you know, our local government is a rural local government, whereby we have many communities that come to the secretariat to come and collect the vaccine and other antigen. Now, with that, they will come, though they'll use their money since they are government workers.

Our facilities are a little bit far. Okay. And these people, for them to take pain, leave the facility down, they will need money for transportation, and it's not easy for me to go about to collect them and bring them to work. Yeah.

**Question 4**: What measures can be taken to enhance the usefulness of GRID3 for social and sustainable development?

RESPONDENT: Okay. So, we have training, we have net training which we can even show them that map also. Okay, okay. We have net training tomorrow for the supervisors. So, if you will come, then it'll be good even if it's just to see the supervisors. Okay, you know we are five LIOs, so we came with a car that will make us go too fast. Okay

INTERVIEW 9

*A: INTRODUCTORY QUESTIONS [These are personal questions]*

*Question 1: Kindly let me know your work responsibilities and that of your department?*

Thank you very much. My name is Barakat Tiamiyu. I am investigating the use and sustainability of GRID3.

*Question 2: Please highlight your work experience (State your years of work experience, areas of expertise, etc.)*

My name is Bola Ayangbaye. I'm the LIO, local government immunisation officer, Akinyele local government. We render immunisation services for children between ages 0-5 years. I have worked for 30 years. I am in charge of CT, IPV and CV, PCV.

*B: MAIN QUESTIONS [These are questions on the use of GRID3 data and technologies]*

***Question 1****: Are you familiar with GRID3 infrastructures?*

Yes

*Probing question: How viable are GRID3 infrastructures? Would you say that GRID3 will continue to be useful in healthcare delivery?*

In terms of the location of the settlements and knowing the distance between each settlement, it also demarcates the boundary between the settlements.

We would like if you ask us before you do any map like this again, so we can contribute to it. So that we can tell you about the new settlements so you can add them into the map, and you should make it more elaborate.

*Probing question: What are the challenges that you are faced with in using GRID3 for micro-planning and decision making?*

Respondent: One of the challenges we are facing is outreach services, there is no fund for outreach services, so it is hard for us to go into the interior, so, some children are unable to access immunisation, which is very dangerous to the children.

Is that the only challenge?

No, we have a lot of challenges such as, in our ATO unit, we have no generators and electricity supply is not stable as you will need to do one of the challenges we're facing is particularly in outreach services, there is no phone for the outreach surfaces that are so we are needed to go into the interior that is the ATO which is to catch our minister of children some new way to assess this position, which is very, very dangerous children just accident and is not only out to reach your wealth, so many challenges, like in our ag now employ units and so forth who have generics that we can use to free the gen neuron to feast on ice pack bits D Jen is not. Okay. So, um, D in D ageing, we don't have much a distinct we don't have a Napa Napa is not wisdom they know that is just like a rush people do demos of Africa, they are not enough sufficient for us, especially if we are programmed to do so, all does this give us to this offence

*Probing question: Comparing GRID3 with the convention geospatial mapping tools (paper maps, hand drawn illustrations), which do you prefer and why?*

The maps we have now make it easy to reach some areas. Most of the new settlements are not incorporated into the map, and they are not bold enough, there are new settlements every day. Though, have you ever used geospatial maps apart from the ones we sent? I have never used geospatial maps apart from GRID3.

**Question 4**: What measures can be taken to enhance the usefulness of GRID3 for social and sustainable development?

It boosts and encourages...you know what I mean. We have a lot of settlements that are hidden but this map reveals it which makes it very good. The data you get, where do you enter them? It was entered into DHIS, then we also use GVGN.

It would be great to add the roads and boundaries between settlements and even the distance between them

*Probing question: Do you think it is important to train and support the users of GRID3? How do you think GRID3 can be trained?*

Training, if you train it, we would improve our knowledge on using the maps and reading it. What other programs do you think the map will be useful for apart from covers and immunisation service? There is COVID, even NET distribution, which is the one we want to do now. It will also help us in many other different ways.