# Harnessing Spatial Data Infrastructure for Environmental Management: The Nigerian Case

**By**

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**January 2017**

*A thesis submitted in partial fulfilment of the University's requirements for the Degree of Doctor of Philosophy*

Content removed on data protection grounds

ETHICAL APPROVALS

# Certificate of Ethical Approval

Applicant:

Tubo Warekuromor

Project Title:

PROTOTYPE EVALUATIONS FOR PHD RESEARCH PROJECT; "APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEMS AND SPATIAL DATA INFRASTRUCTURE IN HARNESSING ENVIRONMENTAL MANAGEMENT IN NIGERIA"

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

15 March 2016

# Certificate of Ethical Approval

Applicant:

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Project Title:

SDI Augmentation Framework Validation

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

13 January 2017

Project Reference Number:

P49992

# Certificate of Ethical Approval

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APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEMS AND SPATIAL DATA INFRASTRUCTURE IN HARNESSING ENVIRONMENTAL MANAGEMENT IN NIGERIA

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

27 March 2015

Project Reference Number:

P32575

REGISTRY RESEARCH UNIT

## ETHICS REVIEW FEEDBACK FORM

(Review feedback should be completed within 10 working days)

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Comments by the reviewer

| | |
|---|---|
| **1. Evaluation of the ethics of the proposal:** | |
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| **2. Evaluation of the participant information sheet and consent form:** | |
| | |
| **3. Recommendation:** (Please indicate as appropriate and advise on any conditions. If there any conditions, the applicant will be required to resubmit his/her application and this will be sent to the same reviewer). | |
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# DECLARATION

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## ABSTRACT

This research addresses the need for a sufficient and efficient Spatial Data Infrastructure (SDI) to provide comprehensive spatial data access which meets the spatial data needs for environmental management. The Nigerian case is adopted as a context for this research since it highlights issues that can occur in the development of a large scale federal SDI. This research seeks to identify the issues affecting the adoption of the Nigerian Geospatial Data Infrastructure (NGDI) and to propose, as well as evaluate, solutions that will enable better SDI implementation. It adopted the mixed methods approach, incorporating qualitative, quantitative and design science approaches. It synergised the critical factors needed for SDI implementation using an SDI conformant GIS application. The novel contribution made to SDI research is the development of an SDI augmentation framework which includes at its hub a data access prototype GIS system, which can be implemented in a bottom-up, distributed and scalable manner to improve data access and sharing. The main components of the SDI Augmentation framework are the SDI Data Access Protocol; the SDI Expansion Protocol; and the SDI Continuous Assessment Protocol. The framework was validated by industry experts who confirmed the (a) feasibility and validity of the framework, (b) validity of the proposed bottom-up approach for implementing SDIs, against the current top-down approach (c) sufficiency of the framework components and implementation path, (d) feasibility of replication in practice, and (e) capability of the framework to address issues affecting the adoption of the NGDI and to enable better SDI implementation. Criteria assessed were the ability to (a) improve spatial data access over the web, (b) hasten SDI implementation (c) overcome the challenge of developing clearinghouses (d) harvest economic and environmental benefits from spatial data and SDIs (d) amplify the legislation and enforcement of a user-driven policy and objectives for SDI implementation, and (e) heighten awareness, as well as amplify participation and partnership.

## DEDICATION

This research work is dedicated to the God Almighty, to the Loving memory of my dearest dad, Victor O. Warekuromor, the unprecedented efforts of my mum Janet Warekuromor to carry the burden of both parents since 2002, and to the unflinching support of my siblings, Kingsley, Tonbra and Perezide throughout this journey.

## ACKNOWLEDGEMENTS

My most sincere appreciation goes to God Almighty for giving me great success in the midst of the toughest challenges I have ever had to face. Nana-owei doh! Thank you for the grace, strength and will to persevere despite everything. I love you Lord and I am forever grateful.

I wish to also appreciate my supervisory team, especially Prof. Anne James. You stepped in and everything changed. You are indeed my 'Tamara-diepreye'. I cannot express how grateful I am for the push, encouragement and guidance. You inspire me every day. I say a very big thank you from the bottom of my heart. You are a rare gem. I want to also appreciate Dr Babatunde Anifowose my second supervisor and DoS. Thank you for your excellent supervision from the commencement of this research work to its successful completion. You stood with me and by me, mentoring and pushing me to succeed. Thank you so much for making sure I never gave up. Your relentless spirit is so inspiring and I am so grateful to have you in my team. Also, to Dr Nigel Trodd, thank you for starting the journey with me. You are sincerely appreciated.

To my unbeatable support system, my family and friends (immediate, extended, adopted, church family et al.,), thank you all so much. I love you guys more than you can ever know. Thank you for supporting me, motivating me, praying for me, praying with me, and most of all, believing in my ability to conquer every challenge that comes my way. You guys are priceless and I will forever be grateful to God for placing you all in my life.

I want to also appreciate the academic community at Coventry University, University of Nottingham, University of the Aegean (Open GIS Symposium and Summer School), NDDC, UNESCO, ECOWAS, NASRDA, DPR, FMEnv and all other organisations that facilitated as well as contributed in one way or another to the successful completion of this PhD. You are all sincerely appreciated.

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**ABBREVIATIONS**

ASDI: Australian Spatial Data Infrastructure

AWS RDF:

AWS RDF: Amazon Web Service Resource Description Framework

AWS: Amazon Web Service

CSV: Comma Separated Values

CSW: Web Catalog Service

DPR: Department of Petroleum Resources

ECOWAS: Economic Community of West African States

EGDI: Economic Community of West African States Geospatial Data Infrastructure

EIA: Environmental Impact Assessment

EIA-SDI: Environmental Impact Assessment and Spatial Data Infrastructure

EIS: Environmental Impact Statement

EMP: Environmental Management Plans (EMP)

EMS: Environmental Management Systems

FEPA: Federal Environmental Protection Agency

FMEnv: Federal Ministry of Environment

GIS: Geographical Information System

GML: Geography Markup Language

GPL: General Public Licence

GRASS: Geographic Resources Analysis Support System

GUI: Graphical User Interface

HIS: Health Information System

HTML: Hypertext Markup Language

HTTP: Hyper-Text Transfer Protocol

IEEE: Institute of Electrical and Electronics Engineers

INSPIRE: Infrastructure for Spatial Information in Europe

ISO: International Standard Organisation

KML: Keyhole Markup Language

LIS: Land Information System

LOD: Linked Open Data

“n=….”: Number of observations/samples

NASRDA: National Space Research Development Agency

NDDC: Niger Delta Development Commission

NESREA: National Environmental Standards and Regulations Enforcement Agency

NGDI: National Geospatial Data Infrastructure

NGDI-CF: National Geospatial Data Infrastructure Critical Factors

NOSDRA: National Oil Spill Detection and Response Agency

NSDI: National Spatial Data Infrastructure

OGC: Open Geospatial Consortium

OMPADEC: Oil Mineral Producing Areas Development Commission

OPM: Open Provenance Model

OWL: Web Ontology Language

PDF: Portable Document Format

PHP: Hypertext Preprocessor

PPU: Prototype Performance and Usability

PTF: Petroleum Trust Fund

QGIS: Quantum Geographic Information System

QoS: Quality of Service

RDF: Resource Description Framework

RDS: Relational Database Service

SDI: Spatial Data Infrastructure

SDI-AF: Spatial Data Infrastructure Augmentation Framework

SEA: Strategic Environmental Assessments (SEA)

SOA: Service Oriented Architecture

SOAP: Simple Object Access Protocol

SPSS: Statistical Package for the Social Sciences

SWE: Semantic Web Service

SWE: Sensor Web Enablement

SWE: Sensor Web Enablement

UML: Unified Modeling Language

UNESCO: United Nations Educational, Scientific and Cultural Organisation

URL: Uniform Resource Locator

W3C: World Wide Web Consortium

W3C PROV: World Wide Web Consortium Provenance Model

WFS: Web Feature Services

WMS: Web Map Services

WPS: Web Processing Services

XML: Extensible Markup Language

# 1 CHAPTER ONE: INTRODUCTION

*This chapter conceptualises the purpose of this research. It discusses environmental management in Nigeria, the Environmental Impact Assessment (EIA) system in Nigeria's oil and gas sector and the access to accurate spatial data for EIAs through the Nigerian Geographical Data Infrastructure (NGDI). It identifies the research gaps and defines specific research questions that help formulate the research aim and objectives. It also introduces the approach followed in this research to develop the Spatial Data Infrastructure (SDI) augmentation framework.*

## 1.1 BACKGROUND OF STUDY

The effect of human anthropogenic activities, especially in the face of globalization and the accelerated industrialization of both urban and rural cities are enormous. Some of the consequences of these activities are the influx of new technologies that emit pollutants into the atmosphere, degrade the soil, disrupt biodiversity, pollute the waters, as well as cause other socioeconomic and demographic issues (Michelsen, Cherubini and Strømman 2012, Volante et al. 2012, Frynas 2012, Nwankwo and Ogagarue 2011, Bakar et al. 2011). Environmental management encompasses the different measures and systems employed to eliminate and mitigate the impact of human anthropogenic activities, as well as that of other naturally occurring events on the environment (Gotschol, De Giovanni and Esposito Vinzi 2014). A number of tools have been employed over the years to manage the environment; examples are Environmental Impact Assessments (EIA), Strategic Environmental Assessments (SEA), Environmental Accounting, as well as the deployment of Environmental Management

Systems (EMS) and Environmental Management Plans (EMP), among others. Though each of these environmental management protocols have their distinct features and employ different procedures, they all require spatial data and the accurate analysis of spatial data as a fundamental element for effective execution.

To date, EIA is the foremost environmental management regulatory tool used in Nigeria to aid planning and decision-making towards attaining environmental sustainability. EIA enables the prediction of the impact of a proposed development on the environment, and the propagation of mitigation measures to reduce the severity of the impacts (Ambituuni, Amezaga and Emeseh 2014, Ingelson and Nwapi 2014, Eneh 2011, Anifowose et al. 2011, Ogunba 2004). It is used for the classification, prediction and analysis of environmental impacts prior to the commencement of a proposed development project. The identification of environmental impacts through an EIA rationalizes the decision for the complete abandonment, adjustment or commencement of a development project thus proactively protecting the environment.

The term spatial data is often interchanged with geodata or geospatial data. These sorts of data are held in Geographical Information Systems (GIS) as vector or raster datasets. They comprise of points, lines, polygons (vector) and pixels (raster), used to illustrate spatial objects, surfaces, time and geometry with a direct or indirect reference to a particular location or time (Latre et al. 2013, Goodchild 2011). Spatial data serves as a source of useful information for assessing the environmental impacts of projects and activities before and after execution (Anifowose et al. 2014, Koornneef et al. 2012).

They provide relevant information on the areas where environmental protection is needed and also serve as a basis for future conservation plans (Visconti et al. 2013). They aid businesses and government organizations in the planning, implementation and monitoring of development projects to ensure a more effective management of the environmental impacts and by implication, enable sustainable development (Watson, Boudreau and Chen 2010, Masser, Rajabifard and Williamson 2008). Thus, they are a very fundamental component for socio-economic planning and development.

Spatial data is analysed using GIS or other relevant processing tools to identify relationships between the data and relevant environmental receptors (Ahmad et al. 2016, Anifowose et al. 2014, Musa et al. 2013, Marchant et al. 2013, Fedra 1999). Points of interest and variables with spatio-temporal dimensions like oil wells, pipelines, airports, roads, residential areas and rivers are identified, assessed and the results presented in geographic and statistical models. This assessment is important to ascertain the impact of the proposed project on these points of interest, as well as their combined cumulative impact on the environment. The use of geographical and statistical models thus help to present the spatial data in an understandable form to aid decision making and management. Table 1.1 shows a few examples of areas where spatial data is being used to aid decision making and management.

*Table 1.1: Examples of areas successfully applying spatial data*

| **Area** | **Example of areas applied** | **Source** |
|---|---|---|
| Hydrography and hydrology | To identify and evaluate spatio-temporal changes within the water cycle for a more effective water resource management. | (Yang, Shang and Jiang 2012, Goodall et al. 2008) |
| Environmental protection and management | To identify environmental receptors and their proximity to pollutants or factors that can cause degradation. Spatial data is used to monitor environmental receptors to identify red flags for emergency responses and swift decision making. | (Ambituuni, Amezaga and Emeseh 2014, Latre et al. 2013, Anifowose et al. 2012, Giuliani, Ray and Lehmann 2011, Hese and Schmullius 2009) |
| Public health administration | Spatial data serves as a valuable resource for matching neighbourhood statistics, proximity to clinics, safety, medicines, water source, polluted sites and other relevant information with health records; to provide improved care, identify sources of disease outbreaks, contain disease outbreaks, manage pollution and support decision making. | (Simpson and Novak 2013a, Aji et al. 2013) |
| Maritime administration | Spatial data serves as a valuable source of accurate location and time series data for coastal navigation. It allows for a more effective planning and monitoring of maritime operations like resource distribution, navigation routing and timing, safety operations, as well as other search and rescue operations. It is also an important resource for the development of marine spatial data infrastructure. | (Jay et al. 2016, Hartmann 2015, Idiri and Napoli 2013, Malik et al. 2012) |
| Protection and security services | Spatial data is mapped to location and time tracking data for a more holistic investigation of cases, crime detection, and emergency responses. | (Shiode and Shiode 2013, Hart and Zandbergen 2013) |
| Global positioning systems (GPS) | Forms the basis of wireless navigation systems providing excellent location services and other tracking services that support other sectors like health and fitness, mobile communications technology, delivery and logistics services, among others. | (James et al. 2016, Steenbruggen et al. 2013) |
| Business and management | For merging location and time data to facilitate the planning and execution of business projects. Also been successfully utilised for simulating changes in time and location for a more informed forecast and price mapping. | (Campagna, Ivanov and Massa 2014, Chen, Chiang and Storey 2012) |

In spite of the usefulness of spatial data, and their wide applicability across various sectors, there are still notable problems with their access, use and maintenance. These problems range from the availability of needed spatial data, the presence of incomplete datasets, the cost of acquiring quality datasets, the resolution of the acquired data, as well as its data compatibility and interoperability (Visconti et al. 2013, Devillers et al. 2010). The presence of data with incomplete or distorted elements caused by compatibility, jurisdictional and thematic issues can mislead decision making. Hence the documentation and subsequent dissemination of accurate spatial datasets is important for effective decision making, regardless of the area of application.

Prior to the introduction of GIS in the 1960s, spatial data were typically documented and visualized using paper maps which did not sufficiently support exhaustive spatial analysis and the extensive use of spatial data elements (Goodchild 2014). From a historical point, noteworthy progress have been recorded with the creation and use of spatial data following the change from the practice of using traditional analog processes to collect, produce, process, distribute, document and represent data, to the use of more advanced digital procedures (da Silva et al. 2014, DeGloria et al. 2014, Ramirez 1996). This change has attracted significant investments in the geospatial sector, involving both private and government organisations in many countries, thus triggering the development and application of advanced information system and technology protocols in the geospatial sector (Kim 2015, Rajabifard et al. 2006). Arguably, a consequence of the increased investments, participation and production of spatial data is the mass production of spatial data in formats that are unusable or not re-usable to other users due to compatibility and interoperability issues. Useful resources and time are wasted duplicating efforts reproducing and re-acquiring spatial data in areas where there is no, or poor data infrastructure, thus generating the need for a unified information systems architecture where data can be stored and easily accessed.

In spite of some limitations in practice, information systems technology is considered a fundamental tool for development and economic progress (Lundvall 2016, Shahiduzzaman and Alam 2014, Dittmar 2011). This is evidenced in its contributions to harnessing working processes, administrative functions, and business processes, as well as achieving cost-effectiveness and competitive advantage (Mithas and Rust 2016, Grant 2016, Shao and Lin 2016, Mithas et al. 2012, Nowduri 2011, Soh and Markus 1995). A GIS is an integrated software system which supports spatial data creation, examination, manipulation and presentation (Goodchild 2014, Sánchez-Lozano et al. 2013, Bhat, Shah and Ahmad 2011, Goodchild 2011, Church 2002). GIS allows the overlay and comparison of specific spatial datasets to those from other locations and parameters by presenting these datasets in meaningful and understandable formats such as, statistical charts, reports and maps. Though there are arguments about the usefulness of GIS to perform detailed area-specific analysis for thorough decision making (Zerneke, Buckland and Carl 2013, Musa et al. 2013), GIS is widely used and integrated in private and government organisations to support work processes (Kokalj et al. 2013, Folkeson, Antonson and Helldin 2013). GIS aids the strategic planning and implementation of environmentally sustainable projects, as well as other developmental programs that require spatial data exploration and analysis for decision making (Campagna, Ivanov and Massa 2014, Chen, Chiang and Storey 2012, Watson, Boudreau and Chen 2010). GIS is however limited in its abilities to perform these functions effectively in the absence of accurate, compatible and interoperable spatial data (Zakaria et al. 2015, Maguire and Longley 2005).

Compatibility and interoperability go hand in hand, and they are fundamental elements for the effective use and analysis of any spatial data. Interoperability is the seamless dissemination and utilization of datasets within two or more systems without losing the integrity or credibility of the data (Nativi, Craglia and Pearlman 2013, Latre et al. 2013, Waters, Powers and Ceruti 2009). In the context of spatial data application, semantic interoperability can be defined as the compatibility between two or more systems, so that the systems can communicate, as well as exchange data in a way that it is accepted, understood, and easily translated by the participating systems. Open Geospatial Consortium (OGC) and International Standard Organisation (ISO) standards have been advocated to help address some of the challenges hindering spatial data compatibility by fostering interoperability (Kolb et al. 2013, Batcheller 2008, Woolf et al. 2005, Gotway and Young 2002). They develop open source spatial standards to support the development of spatial data and systems, on both proprietary and non-propriety interfaces. These data standards use data schemas to foster interoperability between spatial data, spatial systems and services. Spatial Data Infrastructures (SDI) are built on the basis of these standards.

An SDI employs these interoperability standards to enable the seamless access to spatial data (Gunay, Akcay and Altan 2014, Sutanta, Rajabifard and Bishop 2010). The wide distribution of standardized spatial datasets to users at different locations through access networks and clearinghouses like geoportals and other network technologies is anticipated to alleviate the problems with data access and sharing (Rautenbach, Coetzee and Iwaniak 2013). This should reduce the cost of obtaining and accessing data, as well as aid the delivery of better and faster services to increase productivity.

Key examples of pioneer SDIs are INSPIRE (Infrastructure for Spatial Information in Europe) in Europe, the NSDI (National Spatial Data Infrastructure) in America and the ASDI (Australian Spatial Data Infrastructure) in Australia (Tumba and Ahmad 2014). Though these SDIs have led the way for SDI implementation and have also recorded some successes, there are still challenges with achieving seamless spatial data access and sharing from the clearinghouses, as well as ensuring effective partnership arrangements at all levels (Agunbiade, Rajabifard and Bennett 2014, Tonchovska and Adlington 2011a, Paudyal, McDougall and Apan 2011). A recent report on INSPIRE (European Commission 2016) concluded that, “Good progress in implementation been made in only the few Member States where the necessary investments were made and implementation of the Directive was aligned with wider national action on open data policies and better eGovernment services”, and that “Based on the evaluation results, it is clear that greater effort at all levels by all actors is needed in the future”. Also, a strategy report for 2014-2016 for the NSDI(Federal Geographic Data Committee 2013) shows that the keys goals to “Develop Capabilities for National Shared Services” ,” Ensure Accountability and Effective Development and Management of Federal Geospatial Resources” and “Convene Leadership of the National Geospatial Community” are still current and on-going.

Noticeable investments have been recorded in the development of SDIs in both developing and developed nations. These investments are directed at achieving better outcomes through improved policies and protocols for decision-making in environmental management, resource allocation, maritime administration, public health management, and economic development, among others (Harvey et al. 2014, Trapp et al. 2014, Rajabifard, Feeney and Williamson 2002). In 2002, the Nigerian government for instance, joined other countries around the globe to take steps towards funding and developing an SDI at the national level, named National Geospatial Data Infrastructure (NGDI), through policy development and the institution of a coordinating body (Okuku, Bregt and Grus 2013, Makanga and Smit 2010, Ayanlade, Orimoogunje and Borisade 2008, Anifowose, Bamisaye and Odeyemi 2006, Kufoniyi and Agbaje 2005, Agbaje et al. 2005, Ayeni, Kufoniyi and JO 2003). Though the coordinating body for the NGDI was instituted with the helm of affairs at the National Space Research Development Agency (NASRDA) and a draft policy developed in 2003, to date they have been unsuccessful in passing the draft policy into law, and consequently, the specifications and directives of the policy, as well as the clearinghouse, remain unimplemented (Okuku, Bregt and Grus 2013, Idrees et al. 2012, Makanga and Smit 2010, Crompvoets et al. 2004). This indicates major gaps in the implementation of the NGDI because the valuable components for spatial data access, the clearinghouse, together with other institutional arrangements are yet to be fully implemented. The clearinghouse is the fundamental component of the SDI access network that allows the seamless acquisition and dissemination of spatial data. Evidently, poor SDI adoption and implementation is common in developing regions like Africa as there is still a gap in decision makers' awareness, comprehensive knowledge and appreciation of SDI and spatial applications

(Tumba and Ahmad 2014, Ajmi et al. 2014). As a result, SDIs are often challenged by unhelpful government polity and enforcements, as well as the failure to align the benefits of SDIs to socio-economic and development goals. Thus, there are recurring problems with data creation, maintenance, access, exploration and interoperability. The following sections further define these problems and conceptualise the research aim, objectives and methods towards proposing a viable solution.

## 1.2 RESEARCH OVERVIEW

### 1.2.1 RESEARCH PROBLEM

SDIs are yet to sufficiently address the problems of seamless spatial data access, collaboration and sharing as there are still issues with fully implementing the access networks at all levels. There are also cases where regulations do not effectively translate into practice and thus there is need for novel methods to overcome the problem of poor adoption and effectiveness. This research uses the NGDI in Nigeria and the EIA system in Nigeria to address a global problem of effective SDI implementation and its subsequent sufficiency to support spatial data needs for environmental assessments.

As presented in section 1.1, the availability and access to accurate spatial data in Nigeria is an issue which affects the conduct of good quality EIAs. The insufficiency of the current NGDI protocol in Nigeria to serve as a possible solution to address the issue was also described. The feasibility of conducting comprehensive EIAs in Nigeria is thus reduced due to the difficulty faced, the enormous time spent and the financial implications of sourcing quality spatial data from diverse locations. Much of the monies expended and efforts duplicated in sourcing for data that is not reused could be repurposed with the presence of an effective NGDI which includes an effective partnership arrangement for spatial data sharing. Efforts need to be made to communicate the benefits of the NGDI to environmental management stakeholders (government and private sector) as the problem of awareness and comprehensive knowledge of its benefits have been cited as part of the challenge in section 1.1 above. There is the need to identify, and offer better strategies for successfully implementing the NGDI. This is because, funding and developing the NGDI in itself does not guarantee a successful yield of the benefits to which it aspires. The essential infrastructure components (policy, access network, data, standards, and people) have to be effectively synergised before benefits are realised.

To this end, the problem addressed in this research concerns the insufficiency of the NGDI to provide comprehensive spatial data access in the context of environmental management. The research seeks to identify the issues affecting the adoption of the NGDI and to propose, as well as evaluate, a solution that will enable a scalable and sustainable SDI suitable for environmental management.

### 1.2.2 RESEARCH QUESTION

To address the aforementioned problem, this research sought to answer the question below:

*How can a scalable and sustainable SDI be developed which overcomes failings of the NGDI project?*

To answer the above question the following sub questions were formed.

i. *What are the current issues hindering the use of spatial data for environmental analysis?*
ii. *How do the challenges experienced with spatial data use affect environmental management in Nigeria?*
iii. *What is the state of the emerging Nigerian SDI and how does it benefit environmental management?*
iv. *What are the barriers to maximizing SDI adoption to support environmental management in Nigeria?*

### 1.2.3 RESEARCH AIM AND OBJECTIVES

The aim of this research is:

> To develop a new SDI conformant GIS framework that will improve interoperable spatial data access

The following objectives were formulated to achieve the research aim:

1. To review existing theories and practices on the application of GIS and SDI in order to identify the problems obstructing spatial data use for environmental management.
2. To review the use of spatial data for EIA in Nigeria and the sufficiency of the NGDI.
3. To ascertain the critical success factors as well as barriers which affect the successful implementation of an SDI.
4. To develop a novel data access protocol that encourages and improves spatial data access, sharing and overcomes identified barriers.
5. To create a demonstration of the data access protocol in the form of a prototype and evaluate this.
6. To develop a new SDI framework within which the novel data access protocol can flourish and be sustained.
7. To evaluate the developed SDI framework.

### 1.2.4 RESEARCH APPROACH

This research adopted the mixed methods approach, incorporating qualitative, quantitative and design science approaches. A single research approach was found insufficient to fulfil the aim of this research. A literature review was initially conducted to investigate the state of play of environmental management and SDI implementation both in Nigeria and globally. A quantitative survey, called the EIA-SDI survey, was then conducted to identify the spatial data use for EIAs in Nigeria as well as establish the sufficiency of the current NGDI. This further clarified the research problems and the need to develop a prototype solution to address the identified problems. The design science approach therefore absorbed the problems defined in the survey results to develop a new SDI Data Access Protocol and build a prototype. A performance and usability evaluation of the prototype, called the PPU evaluation, was conducted. In order to conceptualise the approach for the SDI framework, which would incorporate the new data access protocol, a further survey, called the NGDI-CF survey, was conducted to identify the factors critical to the successful implementation of the NGDI. The NGDI-CF included a qualitative interview to enable richer data collection. The respondents for surveys and evaluation were NGDI and environmental management stakeholders in Nigeria.

The questionnaire data was analysed quantitatively using SPSS 20 and SPSS 22, the open ended questions were analysed using qualitative content analysis and the interview responses analysed using Nvivo11. The final output of this research, was the SDI Augmentation Framework (SDI-AF), which incorporates the novel data access protocol. The SDI-AF was validated using a validation instrument created specifically for this research. It included an introduction of the framework and its maturity model showing the implementation path, the components of the framework and open ended validation questions. The responses were then analysed using Nvivo11 and the final version of the SDI-AF was thus established.

## 1.3 CONTRIBUTION TO KNOWLEDGE

This research offers a novel contribution to SDI research by providing a validated framework, the SDI-AF, to augment SDI adoption. It synergised the critical factors needed for SDI implementation (people, access network, standards, data and policy), using an SDI conformant GIS application. The development of the SDI–AF, which includes at its hub a data access prototype GIS system which can be implemented in a bottom-up, distributed and scalable manner to improve data access and sharing, is novel. It differs from the NGDI design vision in important ways. It does not rely on a centralised clearing house approach but instead allows peer-to-peer sharing. The framework includes a provenance model that records the derivation history of the data to ensure the quality of data accessed and shared. It amplifies interoperable spatial data access, use, dissemination and collaboration, as well as ensures the semantic interoperability of the individual hubs. This is possible through protocols integrated into the framework to ensure effective partnership arrangement, institutional arrangements, interoperable standards, and operational policies. It also includes a protocol for continuous assessment and the subsequent repositioning of the SDI in order to assure continued quality and appropriateness to task.

The proposed SDI–AF supports data access and sharing over the web, which will consequently improve SDI partnership arrangements as well as the institutional arrangements in Nigeria. This model is of relevance to the geospatial data industry in Nigeria, the oil and gas sector, as well as the information technology and information systems industries. It has the potential to contribute to the development of the smart city projects, the EGDI (Economic Community of West African States Geospatial Data Infrastructure), e-agriculture projects, as well as healthcare epidemic response and crisis response systems in developing countries with limited internet and finance for infrastructure, as well as in developed countries.

The product of this research provides a framework for NGDI implementation in Nigeria (namely the SDI-AF). Importantly, it will contribute to overcoming the challenges of poorly implemented SDIs, as well as aid the effective implementation of new SDIs. This research also contributes an up-to-date analysis of the Nigerian Geospatial Data Infrastructure (NGDI) which shows that despite 14 years development, the NGDI is not delivering its benefits. This is as a result of the fact that the ineffective SDI hinders the access to accurate, interoperable, relevant spatial data for environmental analysis, EIA reporting, and by implication, the quality of environmental decisions made in Nigeria. This finding is novel because an objective, wide-ranging review of EIA-SDI in Nigeria and NGDI effectiveness has not been undertaken previously. A paper has been published from this research in the IEEE International Conference on Computer Supported Cooperative Work in Design in New Zealand. See full reference below;

Warekuromor Tubolayefa, Anne James, Babatunde Anifowose and Nigel Trodd,"A distributed and scalable data sharing approach for Spatial Data Infrastructure", Proceedings of the IEEE International Conference on Computer Supported Cooperative Work in Design, New Zealand, IEEE, April 2017

## 1.4 RESEARCH SCOPE, ASSUMPTIONS AND LIMITATIONS

The scope of this research is limited to supporting environmental management by improving the access to accurate data through SDI. It utilises the Nigerian case to define the problem and proposes a framework that will contribute to SDI augmentation globally. The research employed both empirical data collected via questionnaires and interviews, as well as secondary data collected via literature review.

The EIA system in Nigeria's oil and gas sector was used as the first case in this study as it constitutes the majority of the environmental threats, and thus, the majority of the EIAs in Nigeria are conducted in this sector. The second case used in this research was the NGDI which is the Nigerian attempt of creating an SDI. Participants for each case were selected based on their expertise. Each group represented their knowledge of the NGDI and EIA.

Efforts were made to gather comprehensive data for this research and to ensure a representative sample of the practitioners are presented. The representativeness of the sample is assumed since it is acknowledged that there are larger groups of practitioners.

Research is usually laden with limitations of time and finance. Thus, samples that convincingly represented the experts were collected to minimize the wait time for responses. Another major constraint to data collection is the unavailability and inaccessibility of needed research data due a number of factors like awareness, cost, internet access, communication gaps and the unwillingness of participants to provide relevant information. To minimize this, additional calls and visits were made where possible to clarify the details and remind participants in cases where the response was slow. Also, email communications, the use of online survey, as well as phone communications were adopted to cushion the financial implications of travelling to collect data at every instance. This improved the feedback time as well as the clarity of the responses. The framework was developed for global application but its use requires adaption to the datasets, architecture and standards operating in the user domain.

## 1.5 THESIS STRUCTURE

The thesis is organised as follows:

- Chapter 1 provides the introduction to the work, stating aim, objectives and research approach. It also summarises the contributions to knowledge made by this research.
- Chapter 2 provides the literature review. It covers the specific issues obstructing spatial data use for environmental management, and also reviews the prospects as well as the current challenges of SDIs as a source of spatial data.
- Chapter 3 sets out the methods used to achieve the research aim and objectives, as well as to answer the research question.
- Chapter 4 presents the analysis of the outcome of the EIA-SDI survey conducted to further define the problems obstructing spatial data use for environmental management, using the EIA conducted in Nigeria's oil and gas sector as the case study. This chapter identified more fully, the problem under investigation.

- Chapter 5 details the development of the Data Access Protocol which was deployed as a proposed solution to the problems defined in Chapter Four. It also presents an analysis of the results from the Prototype Performance and Usability (PPU) evaluation which was the instrument used to assess the Data Access Protocol prototype.
- Chapter 6 presents and analyses the results of the NGDI-CF survey, providing an assessment of the factors critical to the NGDI implementation.
- Chapter 7 details the synergy of the findings from the three empirical surveys conducted in this research; EIA-SDI, PPU and NGDI-CF.
- Chapter 8 discusses the development of SDI Augmentation Framework (SDI-AF) from the synergy of findings.
- Chapter 9 discusses and analyses the results from the SDI-AF validation. It also presents the updated and final SDI-AF framework that is proposed in this research.
- Chapter 10 presents the conclusions made in this research as well as the recommendations.

## 1.6 CHAPTER SUMMARY

This chapter discussed the background of this study and highlighted the underlying factors of this research. It was structured into sections that detailed the research problem and the questions the research sought to answer. It defined the research problem, aim and objectives the research sought to address. It also provided an overview of the research approach and method adopted to address the research objectives and achieve the research aim. The scope of the research and its contribution to knowledge was also set out.

# 2 CHAPTER TWO: LITERATURE REVIEW

## 2.1 INTRODUCTION

*This chapter provides a review of literature relevant to this research. It begins with a review of environmental management and EIA reporting, particularly as these pertain to the Nigerian case. Then issues of spatial data use were examined, followed by a consideration of efforts made to develop SDI. The enabling role of web services and related advancements in SDI are then discussed. Finally, the research gap addressed in this research is presented.*

## 2.2 ENVIRONMENTAL MANAGEMENT

As stated in Chapter 1, environmental management issues are a growing concern globally, especially in oil producing countries that are often laden with activities that culminate in environmental pollution and degradation. Environmental management is described in literature as the different measures and systems employed to protect the environment from threats posed by human anthropogenic activities and other naturally occurring events (Gotschol, De Giovanni and Esposito Vinzi 2014, Keene and Pullin 2011). The majority of the current environmental problems are alleged to originate from projects that are executed without sufficient examination and mitigation of possible environmental impacts (Eneh 2011, Anifowose et al. 2011, Leonard and Morell 1981); especially in cases where industrialization focuses mainly on economic gains, with little or no consideration for resource conservation or environmental sustainability. The existence of weak legal frameworks and regulations in developing countries are also alleged to encourage the poor adherence to industry best practices, and thus contribute to the pollution and degradation of the environment (Wilson 2014, Ogbazi 2013, Dow, Siddiky and Ahmmad 2013, Hilson 2012). This has led to the pollution of air and water resources, as well as the destruction of the biodiversity, soil structure, and other traditional economic structures.

Coordinated efforts to manage the environment date back to the 1970s, with the enactment of environmental laws to control pollution, improve public health standards and conserve biodiversity (Khalili and Duecker 2013, Thiruchelvam, Kumar and Visvanathan 2003, Barrow 2002). These have advanced from a set of guidelines for pollution control to more comprehensive measures that integrate planning, control policies, analysis of impacts, regulation, monitoring, prevention and the design of cleaner procedures (Zhu, Cordeiro and Sarkis 2013, Zhang et al. 2011, Sarkis, Gonzalez-Torre and Adenso-Diaz 2010). These measures have been orchestrated to protect environmental aspects like air, water, land, flora, fauna, as well as humans. To date, the most common and viable environmental management measures are the establishment and enforcement of environmental standards, the design of management procedures, Environmental Impact Assessments (EIA), monitoring, environmental audits and the adoption of viable Environmental Management Systems (EMS) (Zhang, Wang and Wang 2014, Khalili and Duecker 2013, Zhu, Cordeiro and Sarkis 2013)

An EMS (ISO14001 of the ISO14000 series) encompasses the planning and development of an environmental policy, the implementation of objectives to achieve set goals, monitoring to ensure corrections and the review of the entire management system (Khalili and Duecker 2013, Sánchez and Hacking 2002). It follows a 'plan-do-check-act' process aimed to rate and ensure environmental performance. An EIA, on the other hand, is carried out before the commencement of the project. It is used to identify and predict environmental impacts, propose environment-friendly alternatives, mitigation measures, and in some cases, the elimination of parts or all of the project to minimise negative impacts on the environment (Ambituuni, Amezaga and Emeseh 2014, Anifowose et al. 2011).

### 2.2.1 ENVIRONMENTAL MANAGEMENT IN NIGERIA

Over the years, Nigeria has continued to encounter enormous environmental problems, degradation and pollution that include gas flares (Nwankwo and Ogagarue 2011), oil spills (Frynas 2012), as well as other socio-political issues like youth restiveness (Nwankwo 2015, Emmanuel and Babatunde 2009, Akpan and Akpabio 2003) and pipeline interdictions (Anifowose et al. 2012). These issues originate from the decades of upstream exploration and production activities as well as the downstream product transportation and distribution activities (Frynas 2012, Frynas, Beck and Mellahi 2000). The majority of the pollution and environmental threats in Nigeria originate from the oil and gas sector (Eneh 2011), hence this research utilises the case of Nigeria's oil and gas sector to assess environmental management in Nigeria.

The drilling of deep exploration wells onshore and offshore across the Niger-Delta region of Nigeria as well as the deployment of pipelines and petroleum tankers across the nation poses serious environmental, cultural, social and public health threats. Though it is impossible to completely eliminate all threats, it is important to apply best practices, safer alternatives and mitigation measures to minimize the impact of these threats. In the bid to minimize the impact of these threats, the Nigerian government has instituted some agencies and they include:

- Department of Petroleum Resources (DPR) which was upgraded from the Ministry of Mines and Power in 1970 but later incorporated under the Federal Ministry of Petroleum Resources in 1975 (Ezeoha et al. 2016).
- Niger Delta Development Board in 1961 (Aghedo and Osumah 2014).
- Federal Environmental Protection Agency (FEPA) in 1988 (Anyanwu 2012, Echefu and Akpofure 2002).
- Oil Mineral Producing Areas Development Commission (OMPADEC) in 1992 (Paki and Ebienfa 2011).
- Petroleum Trust Fund (PTF) in 1994 (Takon et al. 2014).
- Niger Delta Development Commission (NDDC) in 2000 (Takon et al. 2014).
- National Oil Spill Detection and Response Agency (NOSDRA) in 2006 under the Federal Ministry of Environment (FMEnv) (Ambituuni, Amezaga and Emeseh 2014, Elenwo and Akankali 2014).
- National Environmental Standards and Regulations Enforcement Agency (NESREA) 2007 also under the FMEnv (Ambituuni, Amezaga and Emeseh 2014, Ingelson and Nwapi 2014).

These regulatory bodies work in collaboration with the International Oil Companies (IOCs) and the host communities to resolve environmental and socio-political issues surrounding exploration activities. They were set up to define and enforce environmental regulations like EIA in Nigeria.

Before the enactment of acts like the EIA in most African countries like Nigeria in 1992 (Ingelson and Nwapi 2014, Eneh 2011), Ghana in 1994 (Betey and Godfred 2013, Appiah-Opoku 2001), South Africa in 1997 (Morrison-Saunders and Retief 2012) and Kenya in 1999 (Mwenda, Bregt and Ligtenberg 2013), environmental governance was initially not stringent, as some development projects were completed without proper environmental assessment (Olugbenga 2016, Betey and Godfred 2013, Hilson 2012). Nigeria for instance, started oil and gas exploration in the early 1950s with the drilling of deep exploration wells across the Niger-Delta region at Ihuo, Akata 1 and more significantly in Oloibiri (Bayelsa state, previously a part of Rivers state) where oil was first discovered in commercial quantity in 1956 (Akinwale and Akinbami 2016, Ebegbulem, Ekpe and Adejumo 2013, Eko, Utting and Onun 2013, Ogunleye 2008). Production commenced in 1958 and it is still ongoing to this day across several lands and waters in the Niger Delta region of Nigeria.

In spite of the decades of exploration and production, the first attempt at managing the environment was recorded in 1988 after the illegal disposal of toxic waste in 1987 at Koko (Delta state, part of the defunct Bendel state) (Onu et al. 2012, Frynas, Beck and Mellahi 2000, Sangodoyin and Ipadeola 2000, Ihonvbere 1994), which triggered the incorporation of the Federal Environmental Protection Agency (FEPA). There is the argument that the alarming pollution of the Niger Delta emanated from negligence as it is claimed that authorities and stakeholders in Nigeria’s oil and gas industry focused more on obtaining the economic benefits of oil and gas production instead of addressing the imminent threats (Adesola, Adesodun and Adekola 2014, Eneh 2011, Paki and Ebienfa 2011, Ihonvbere 1994). These researches further argue that there is typically a reactive approach to managing environmental threats in Nigeria; where clean-up of polluted areas carried out after the damage has been done, instead of preventing it. Thus, the importance of proactive approaches like EIA becomes clear.

### 2.2.2 EIA REPORTING: THE NIGERIAN CASE

In spite of the limitations in practice, EIA has recorded successes globally by enabling the prediction, mitigation and elimination of negative environmental impacts before the damage is done (Chittock and Hughey 2011, Garrido and Requena 2011, Massoud et al. 2010). According to international best practices for EIA, the EIA process follows the steps listed below:

- Project screening: ascertain the need for an EIA. This is determined by the regulation in the country where the project is being developed.
- Scoping: identify environmental aspects and the possible impacts. Also identify environment-friendly alternatives.
- Examination of alternatives: assess alternative project development procedures to identify method that will exert the least impact on the environmental aspects.
- Description of the project/development action: present selected project plan and objectives following the review of alternatives.
- Description of the environmental baseline: a fundamental to the accuracy of impact prediction and analysis as it presents the current state of the environment, detailing all environmental components. It also includes the description of the present and future state of the environment in the absence of the project.

- Impact analysis: the identification of possible impacts the project would have on the identified environmental components. It includes the categorisation of these impacts in terms of severity and significance. Beneficial and adverse impacts are identified and the magnitude or degree of the impacts analysed using several environmental and statistical analysis in GIS and other relevant software. It also includes public consultation and participation.
- Mitigation or impact management: proposed methods for project execution that would minimize or completely remove adverse impacts predicted during the impact analysis.
- Evaluation of significance: assess the severity of any residual impact left after the mitigation process to determine if it is still safe to proceed with the project.
- Preparation of Environmental Impact Statement (EIS): EIS is the report presented after the conduct of an EIA. It contains the results of the screening, scoping, baseline studies, impact prediction and analysis, as well as the results from public consultation and participation.
- Review of EIS: assess the EIS to ascertain that it adhered to industry best practices.
- Decision making: seek approval from the EIA regulatory body in the county where the project is carried. The final terms of implementation of the project is also decided.
- Follow up: monitoring and audits to ensure project adheres to the objectives established by the EIS. Also to ensure mitigation measures are followed. (Morrison-Saunders et al. 2014, Glasson, Therivel and Chadwick 2013, IAIA 1999)

The EIA act was legislated in Nigeria in 1992 to serve as a regulatory tool for the assessment of environmental impacts prior to the commencement of a development project (Lawal, Bouzarovski and Clark 2013, Ogunba 2004). As part of its objectives, it is anticipated to identify the degree and magnitude of impacts, incorporate public opinions through participation, as well as propose possible alternatives and mitigation measures. An EIA aids planning and decision-making towards attaining environmental sustainability through the prediction of the impacts of proposed development on the environment, the propagation of mitigation measures, as well as project alternatives to reduce or eliminate the severity of impacts (Anifowose et al. 2011). The identification of environmental impacts through an EIA rationalizes the decision for the complete deletion, adjustment or commencement of a development project, thus proactively protecting the environment. Though EIAs have been conducted for over two decades in Nigeria, the expectations of ensuring better environmental performance, especially in Nigeria's oil and gas sector, that constitutes the majority of the pollution and environmental threats in Nigeria, is yet to be achieved (Ambituuni, Amezaga and Emeseh 2014, Anifowose et al. 2014, Lawal, Bouzarovski and Clark 2013, Robinson 2013).

In practice, access to accurate spatial data, little or no compliance to stipulated protocols, inadequate funding, technical knowhow, poor regulation and inadequate enforcement of EIA protocols, oil facility interdiction and poor maintenance of oil and gas infrastructure have been reported to contribute to its significantly poor practical performance (Ambituuni, Amezaga and Emeseh 2014, Anifowose et al. 2014, Lawal, Bouzarovski and Clark 2013, Robinson 2013, Morgan 2012, Paki and Ebienfa 2011, Nawrocka and Parker 2009). In Nigeria's oil and gas sector for instance, EIA is constitutionally regulated by the DPR and FMEnv (Lawal, Bouzarovski and Clark 2013). The presence of multiple regulations is seen to be common in the environmental management sector in Nigeria, especially as it relates to the oil and gas sector. It can be argued that the presence of multiple regulations should ensure a more thorough regulation of environmental systems but some researchers have shared opposing views. They disagreed with the relevance and effectiveness of the multiple regulations, stating evidences of conflicts of interest, duplication of efforts, unnecessary bureaucracies and overlaps (Ambituuni, Amezaga and Emeseh 2014, Ingelson and Nwapi 2014, Lawal, Bouzarovski and Clark 2013, Echefu and Akpofure 2002).

The issue of poor performance of the EIA process as compared to the anticipated outcome is not particular to Nigeria alone, it is reportedly a common problem across developing nations like India (Panigrahi and Amirapu 2012), Bangladesh (Kabir and Momtaz 2012), South Africa (Moja and Mnguni 2014), among others. More importantly, problems with the access and use of accurate spatial data, adequate funding, use of up-to-date technologies, technical knowhow, enforcement of EIA regulation and the adherence to industry best practices are also experienced by these countries.

Spatial data provides the fundamental information needed for EIAs. Thus, the availability of compatible spatial data and the quality of the spatial data accessed for EIA is proportional to the quality of EIA reported and subsequently the quality of environmental management decisions made from it. This is because, the accuracy of the data reflects on the accuracy of the baseline information assessed, the impacts predicted and analysed, the alternatives suggested, the mitigation plans presented, and the environmental management plans drawn from the EIS. Therefore, the seamless and interoperable access to relevant data, the correct interpretation and the timely dissemination of accurate spatial data is fundamental to the success of management strategies.

## 2.3 SPATIAL DATA

Spatial data has been successfully utilised in a number of sectors to aid decision making and management (see Table 1.1 of Section 1.1). It serves as a source of useful information for assessing the environmental impacts of projects and activities before and after execution (Anifowose et al. 2014, Koornneef et al. 2012). It provides relevant information on the areas where environmental protection is needed and also serves as a basis for future conservation plans (Visconti et al. 2013). It aids businesses and government organizations in the planning, implementation and monitoring of development projects to ensure a more effective management of the environmental impacts and by implication, facilitate sustainable development (Watson, Boudreau and Chen 2010, Masser, Rajabifard and Williamson 2008). Thus it is a very fundamental component for socio-economic planning and development.

As stated in Chapter 1, a GIS is an integrated system that aids spatial data creation, storage, visualisation, analysis, manipulation and presentation (Goodchild 2014, Bhat, Shah and Ahmad 2011, Goodchild 2011, Church 2002). It enables a detailed understanding and assessment of the fundamental elements of the data, identifying relationships, patterns and processes. This is possible through spatial and statistical analyses, which are used to carry out baseline studies, confirm postulated hypothesis, predict impacts and forecast impending changes to a location or time. Significant successes have been recorded with the use of GIS, especially for environmental analysis and management. It has been demonstrated to aid strategic planning and implementation of environmentally sustainable projects, as well as other development programs that require spatial data exploration and analysis for decision making (Campagna, Ivanov and Massa 2014, Chen, Chiang and Storey 2012, Watson, Boudreau and Chen 2010). Although significant successes have been recorded with the use of GIS, the absence of accurate, compatible and interoperable spatial data has been said to impair its results (Zakaria et al. 2015, Maguire and Longley 2005).

### 2.3.1 PROBLEMS OBSTRUCTING SPATIAL DATA USE

In spite of the usefulness of spatial data, and its wide applicability across various sectors, there are still notable problems with the access, use and maintenance of spatial data. These problems range from the availability of needed spatial data, the presence of incomplete datasets, the cost of acquiring quality datasets, the resolution of the acquired data, as well as its data compatibility and interoperability (Pôças et al. 2014, Okuku, Bregt and Grus 2014, Visconti et al. 2013, Latre et al. 2013, Harding 2013, Devillers et al. 2010, Waters, Powers and Ceruti 2009). The presence of data with incomplete or distorted elements caused by compatibility, jurisdictional and thematic issues can mislead decision making. These problems also increase the time and resources spent in conducting environmental analysis. Hence the documentation and subsequent dissemination of accurate spatial datasets is important for effective decision making. A brief description of the problems limiting the optimal access and use of spatial is presented below.

- Availability: Most common in countries where spatial data development is yet to be prioritised and sufficiently funded (Okuku, Bregt and Grus 2014). Also, poor sensitisation and awareness of the available dataset or the point of access can hinder users from obtaining needed data to conduct relevant analysis.
- Access: Administrative restrictions and the bureaucratic procedures for accessing spatial data from most organisations, especially government establishments hinder the easy access to spatial data. Also, security issues with privacy and access control, the unwillingness to share data due to lack of collaboration between users and the absence of a unified source of accessing domain-specific data also contribute to data inaccessibility (Latre et al. 2013).
- Accuracy and quality: The presence of data sets with missing components, diverse scales, formats, standard and resolution produces false results when inputted for into environmental assessments (Pôças et al. 2014, Devillers et al. 2010). Most common are the errors of commission and omission where fundamental aspects of the environment may have been omitted and false aspects added (Visconti et al. 2013).
- Usability: This becomes a problem when the available spatial data does not satisfy the user requirements. It is mostly caused by the presence of incomplete, inconsistent and inaccurate data, especially in cases where the metadata has not been properly documented or is unavailable (Harding 2013).

These problems hinder the interoperable access, visualisation, integration, exploration and interpretation of spatial data (Zakaria et al. 2015, Khanlari, Abdilor and Babazadeh

2014, Aji et al. 2013, Tavares, Zsigraiová and Semiao 2011, Maguire and Longley 2005).

### 2.3.2 DATA STANDARDIZATION AND INTEROPERABILITY

As stated in Chapter 1, compatibility and interoperability go hand in hand, and they are fundamental elements for the effective use and analysis of any spatial data or system. Interoperability is the seamless access, sharing and use of spatial datasets within two or more systems without losing the integrity or credibility of the data (Nativi, Craglia and Pearlman 2013, Latre et al. 2013, Waters, Powers and Ceruti 2009). Data standardization entails the procedures and protocols employed to define the data components, specifications, fields and values to ensure conformance to stipulated standards as well as the interoperable use of the data (Steiniger and Hunter 2012, Reichman, Jones and Schildhauer 2011).Standardisation has been demonstrated in practice as a viable method of improving spatial data compatibility and interoperability, especially in large databases, open and cloud sourced data (Wang and Xu 2013, Ortiz 2011, Power et al. 2010). It enables the use of data, technology systems and its corresponding components seamlessly and meaningfully, especially for the exchange of data (Chauhan and Singh 2011).

Spatial data standardization emphasises the alignment of the existing datasets to develop a semantically compatible interchange of data between different types of systems (Steiniger and Hunter 2012, Janowicz et al. 2010, Mohammadi, Rajabifard and Williamson 2010). Enforcing interoperable standards for spatial data enhances data accuracy which is fundamental to improving spatial data quality, thus contributing to addressing the problems obstructing spatial data use discussed in section 2.3.1 above. This reduces the cost, time and resources expended on spatial data integration and analysis.

Open Geospatial Consortium (OGC) and International Standard Organisation (ISO) standards have been advocated to help address some of the challenges obstructing spatial data compatibility and foster interoperability (Kolb et al. 2013, Batcheller 2008, Woolf et al. 2005, Gotway and Young 2002). These standard organisations develop open source spatial standards to support the development of spatial data and spatial systems on both proprietary and non-propriety interfaces. These data standards are encoded with data schemas to foster interoperability between spatial data, spatial systems and services. They define the data classification, features, structure format, resolution, schema and metadata schema, with realistic and replicable standards to ensure the interoperable use within various systems, databases and platforms for analysis. An SDI employs these interoperable standards with the goal of enabling the seamless access to spatial data (Gunay, Akcay and Altan 2014, Giuliani, Dubois and Lacroix 2013, Sutanta, Rajabifard and Bishop 2010).

## 2.4 SPATIAL DATA INFRASTRUCTURE (SDI)

SDIs are born out of the need to provide a comprehensive and collaborative data infrastructure to fuel government planning processes by improving the management and interoperable use of spatial data (Grus et al. 2011). They are intended to make geographic information easily accessible by bringing together spatial data from diverse locations and sources onto a common platform (Vandenbroucke et al. 2013, Vaez and Rajabifard 2012, Rajabifard, Williamson and Feeney 2003). The goal is to overcome the challenge of spatial data availability, accessibility and accuracy by improving the interoperable creation, storage, integration and sharing of spatial data. It is also anticipated to reduce the duplication of efforts resulting from the mass production of already available spatial data.

An SDI is an integration of spatial data which is developed and documented using specified standards, the policies that guide SDI processes, human capital that implements, participates and manages the SDI, as well as the information technology resource that enables the integration, access and dissemination of the SDI data and services. It enables the acquisition, processing, sharing, maintenance and preservation of spatial data through a shared and centralized resource. It is a continuously evolving concept that can contribute significantly to economic development, environmental management and social stability in both developing and developed countries if effectively adopted (Giuliani, Ray and Lehmann 2011, Williamson et al. 2010, Makanga and Smit 2010, Masser, Craglia and Campgna 2010, Rajabifard and Williamson 2008). It has the prospect of harnessing the economy of developing nations through its ability to support the decision making process for many key activities and programs that impede their development. It has the prospect of boosting spatial data sharing and transfer from various sources, thus fostering participative unity, transparency and equity. This enables a relatively equal access to spatial resources within specific localities, nations and regions. Thus it can eliminate the shortcomings often experienced by users of spatial data who require data that are not within their jurisdiction in terms of location, price and technological capabilities.

A fundamental aim of an SDI is to successfully integrate relevant data from different locations, in the right format, and enable the easy access of the data. However, this is only achievable with the enforcement of compatible standards that will enable semantic interoperability (de Andrade, Baptista and Leite Jr 2011). Another challenge with SDI adoption is its ability to enable the subsequent examination of discovered spatial data to establish whether or not it is fit for purpose, thus saving time, cost, energy and other valuable resources (Steiniger and Hunter 2012, Li et al. 2011, Devillers et al. 2010). This is because, significant amounts of the spatial data accessed, especially from volunteered and open sources, either lacks the metadata or has a metadata that has not been completely and correctly updated (Giuliani, Dubois and Lacroix 2013, Mohammadi, Rajabifard and Williamson 2010, Coleman 2010). Therefore deploying procedures to ensure the consistent, complete and correct update of the metadata is important to sufficiently harvest the benefits of SDIs and spatial data.

SDIs are used in various fields like environmental management, public health administration and maritime administration, to share, discover, visualize and retrieve geospatial data (Hartmann 2015, Simpson and Novak 2013b, Latre et al. 2013, Giuliani, Ray and Lehmann 2011). They are either developed as global SDIs which are anticipated to integrate national and regional SDIs to provide global support, national SDIs to support a country, regional SDIs to support a sub-region, state SDIs to support a state, or in smaller scales to support a particular activity, service or population (Coleman, Rajabifard and Kolodziej 2016, Giuliani, Ray and Lehmann 2011, Craglia and Campagna 2009, Rajabifard, Feeney and Williamson 2002, Rajabifard and Williamson 2001, Coleman and McLaughlin 1998). INSPIRE supports environmental management by providing environmental spatial datasets, classified as fundamental datasets to aid environmental analysis and strategies (Giuliani et al. 2016, Vandenbroucke et al. 2009). The goal is to create a widespread and seamless environmental data to increase environmental awareness among stakeholders, as well as facilitate rapid data sharing and collaboration among stakeholders.

The SDI objectives and its corresponding processes are specified by the policy and institutional arrangements which underpins its implementation. Regardless of the objective of an SDI, users require substantial knowledge of the benefits of spatial data and SDIs, as well as sufficient technical knowledge of spatial techniques and applications to sufficiently harvest its benefits (Steiniger and Hunter 2012, Elwood 2008, Masser, Rajabifard and Williamson 2008). This is a gap that governments and businesses, mainly in developing countries like Nigeria, need to fill before they can realise the full benefits of SDI (Okuku, Bregt and Grus 2014, Makanga and Smit 2010, Rajabifard et al. 2006). Other essential parameters are a stable political environment, the institution of appropriate and enforceable legislature, trust between stakeholders, as well as equal opportunities for user participation from the private and public sectors. Thus, there is the need for governments and businesses to make substantial investments in capacity building to improve the knowledge of their staff and stakeholders prior, during and after to SDI deployment.

### 2.4.1 FUNDAMENTAL COMPONENTS OF SDI

SDIs comprise of components which are integrated together to enable users interact with technology as well as themselves to better achieve economic, administrative and environmental objectives. An earlier definition by Coleman and McLaughlin (1998) described SDI as an incorporation of technologies, policies, standards and human resources. A more encompassing definition was later propagated by Rajabifard and Williamson (2001) who defined SDI as an incorporation of standards, people, access networks, policy and data to emphasise on the significant interactions between the data, participants as well as anticipate the fast pace of technological developments. This definition of SDI into five components (standards, people, access networks, policy and data) has been adopted in literature and in practice, as the fundamental components of SDIs (Coleman, Rajabifard and Kolodziej 2016, Idrees et al. 2012, D'Amore, Cinnirella and Pirrone 2012, Paudyal, McDougall and Apan 2011). These components have been adapted at various levels and hierarchies to ensure the interoperable access, use and dissemination of spatial data. Figure 2.1, presents the relationship and purported interaction of the SDI components.

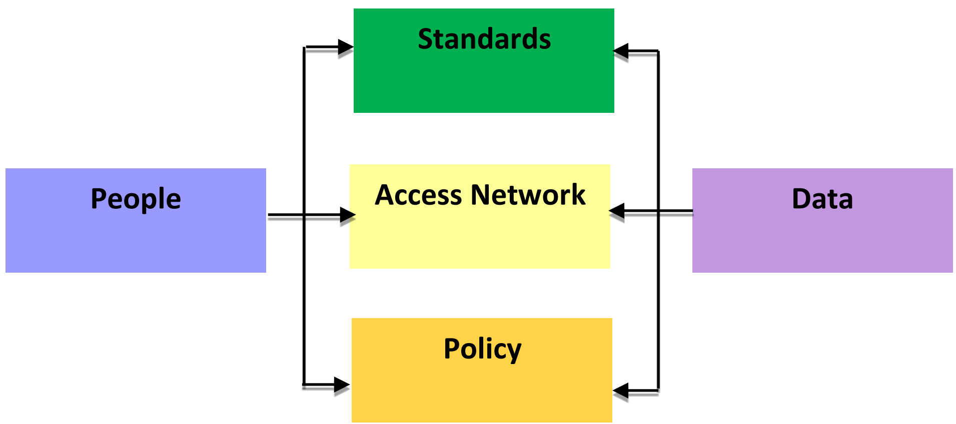


*Figure 2.1: Components of an SDI (adapted from: Rajabifard and Williamson, 2001)*

The following sub-sections present definitions of the five fundamental components presented in Figure 2.1.

#### 2.4.1.1 *POLICY*

SDI policy encompasses the various agreements and arrangements for the integration of the SDI components and the implementation of the SDI. It is often referred to as the legislative or institutional framework. The strength of the SDI policy and the government policy supporting its enforcement determines the strength and pace of the SDI development (Dessers et al. 2010). The policy or institutional framework defines the administrative arrangements for building, maintaining, and accessing the SDI. It also advocates the technical and data standards to be adopted. The role and method of regulation and access control measures are also defined within the policy to ensure effective regulation, privacy, and database security.

#### 2.4.1.2 ACCESS NETWORKS

The access network facilitates the communications between the users and the infrastructure as well as between participating users. It is the technological component of the SDI and comprises of hardware, software and distribution networks. It is a fundamental enabler of participative collaboration within the SDI. It is important for creating a global collaboration of spatial data producers and users to optimise economic, environmental and administrative benefits (Ajmi et al. 2014). The main component of the access network is the clearing house which facilitates access and distribution networks, as well as the web services for cataloguing, accessing, updating and downloading spatial data (Okuku, Bregt and Grus 2014). This is facilitated by the adoption of the interoperable standards advocated within the SDI policy to ensure interoperability amongst the datasets and access protocols. Geoportals are examples of access distribution network frontends. They provide web-based gateways, linking SDI users with the SDI infrastructure.

#### 2.4.1.3 *DATA*

This component of the SDI defines the composition, schema, resolution, geometry, format and metadata of the fundamental datasets to be inputted into the SDI in accordance with the agreed standard documented in the SDI policy and institutional arrangements (Mohammadi, Rajabifard and Williamson 2010). The purpose is to foster compatibility and interoperability between the data produced by different data producers within the SDI. It includes the definition of the data schema, formats, resolutions as well as the metadata schema. Metadata provides fundamental information about the dataset, thus aiding the management, storage, dissemination and consequently the development and maintenance of SDI data (Rajabifard, Kalantari and Binns 2009). It facilitates the accurate use of spatial data by providing sufficient data about data. They include the resolution, format, method of collection, purpose of collection, among other essential information.

#### 2.4.1.4 *STANDARDS*

SDI require interoperable standards to enable the seamless access, use and sharing of data within the infrastructure. The standard component of the SDI covers the interoperable standards enforceable to ensure compatibility at all levels (Percivall 2010, Ghaemia et al. 2010). It includes the technical standards used for the incorporation of technological infrastructures within the SDI. Agreed standards for metadata, access control, data creation and data sharing are fundamental to the implementation of SDIs. OGC and ISO standards are the foremost standards adopted globally.

#### 2.4.1.5 *PEOPLE*

This is an important component of the SDI as the technology and policy cannot thrive without effective synergy with the people participating in the SDI adoption. To ensure this, the people component of the SDI includes partnership arrangements to ensure collaboration among users (Elwood, Goodchild and Sui 2012, Makanga and Smit 2010). It also includes avenues for training and capacity development for users, stakeholders and prospective users to ensure effective adoption. The access rights and the categorisation of the participatory role of each user, stakeholder or regulator are defined in the policy and institutional arrangement (Steiniger and Hunter 2012).

### 2.4.2 CURRENT SDI INITIATIVES AND IMPLEMENTATION

As discussed in section 2.4, SDIs are implemented to facilitate and coordinate collaborative development, access, sharing of spatial data and its corresponding services. Earlier implementation of SDI typically follows the top-down approach, which involves the definition of the policy, technical standards and data standards before implementing the clearing house (Harvey et al. 2012, Georgiadou, Puri and Sahay 2005). The implementation, data standardization and data preparation is usually initiated and managed by the government or its designated agency (Kalantari et al. 2014). In this case, the clearing house which is the fundamental aspect of the access network is scheduled for implementation in the last stages of the SDI adoption. As a consequence, a fully implemented clearing house may not be achieved. Foremost SDI efforts like INSPIRE and the NSDI followed the top-down approach for its implementation (Harvey et al. 2014), and are yet to develop a fully implemented clearing house that supports all aspects of seamless spatial data access and sharing, as well as the partnership arrangements anticipated in the SDI objectives (Agunbiade, Rajabifard and Bennett 2014, Tonchovska and Adlington 2011b, Paudyal, McDougall and Apan 2011). Hence, part of the future directions of INSPIRE and NSDI are to increase investments and implement measures that would improve shared services for data access and dissemination (European Commission 2016, Federal Geographic Data Committee 2013).

The National Geospatial Data Infrastructure (NGDI) in Nigeria was initiated in 2002 but enacted in September 2003 to incorporate spatial data into national development strategies through the National Space Research and Development Agency (NASDRA) (Okuku, Bregt and Grus 2013, Idrees et al. 2012, Nwilo and Osanwuta 2004). The development followed the traditional top-down approach, with the institution of 27 member NGDI committee that is coordinated by NASRDA (Aderoju, Dias and Guimarães 2016, Agbaje, Ingersoil and Mochamuk 2008). The focus of the NGDI was to enhance spatial data availability, access and to communicate data standards as well as partnership arrangements to the all stakeholders and intending users. The NGDI policy includes the coordination of spatial data production, maintenance and dissemination to all stakeholders and intending users (Agbaje et al. 2014). It also includes the establishment, maintenance and management of a geospatial data clearing house at various levels (local, state and federal) of the country, providing collaborative links to the private sector. It was anticipated to help reduce the cost of data access and increase the willingness of stakeholders to share data to reduce the duplication of efforts. Earlier researchers have classified the NGDI as ineffective and in its implementation stage as it is yet to fully deploy its clearing house for the dissemination of spatial data (Crompvoets et al. 2004). More recently the NGDI was classified to be averagely developed on the claim that the "policy and legislation, institutional partnerships, databases and metadata, standards, technology and personnel are under development" (Okuku, Bregt and Grus 2014). This research assesses the emerging NGDI to ascertain its effectiveness and its possible contribution to averting the spatial data challenges facing EIA preparation in Nigeria's oil and gas sector.

## 2.5 WEB SERVICES AND SDI CONFORMANT GIS APPLICATIONS

For an SDI to function accurately, additional technological tools and frameworks are required to integrate the diverse data within the SDI, in a way that it facilitates interoperable data access, processing, visualization, dissemination and sharing (D'Amore, Cinnirella and Pirrone 2012). Data integration within an SDI can be achieved by adopting OGC standards like Sensor Web Enablement (SWE), Web Map Services (WMS), Web Processing Services (WPS), Web Catalog Services (CSW) and Web Feature Services (WFS) (Janowicz et al. 2010). The adoption of these standards simplifies the output accessed by the end user to formats that are easily understood by users with little or no GIS expertise. This enables a more efficient use of spatial data to benefit decision making, especially for those with little GIS expertise. These OGC web services perform different functions but can be aligned together, depending on the requirements of the development, to create a Service Oriented Architecture (SOA) that is scalable and distributed to achieve the aim of the development (Vescoukis, Doulamis and Karagiorgou 2012).

SOA boosts the functionality of systems by facilitating effective integration and communication between system components that are distributed across a network (Bokhari, Azam and Abbas 2015). It utilises XML (Extensible Markup Language) to enable the coupling and communication between distributed systems in a way that security and semantic interoperability is assured. The development of web-service based technologies in SDI as well as the use of service oriented and cloud based architectures have simplified data sharing, and can be adopted to facilitate the more feasible bottom-up approach for SDI adoption (Harvey et al. 2014).

Though the adoption of SOA and cloud services into SDI development promises faster implementation of the clearing house, it also introduces data quality challenges (Kalantari et al. 2014). Thus, there is the need to develop better methods of incorporating SOA and other cloud services with SDI in a way that it still it provides accurate and complete spatial data. There are also documented performance penalty issues that occur with distributed SOAs and web services that affect input validation within the different tiers of a distributed system (Leitner and Cito 2016, Leitner et al.

2012, Charland and Leroux 2011). This reduces the responsiveness of the user interface and in turn increases the execution time. Thus, it is important to distribute input validation adequately and in some cases, introduce a cloud-based middleware which automatically adapts to incoming load to improve performance. Standard web services provided by OGC are core to the data access protocol developed in this research.

## 2.6 THE RESEARCH GAP

As described in Section 2.4.2, the NGDI, which was developed to support environmental management among other applications, has had limited success. However previous published studies on the effectiveness of the NGDI are over a decade old so the questions arise as to whether the NGDI has developed since, and whether it is now effective to support the spatial data needs of EIA and other environmental management protocols. This research therefore, in the context of EIA, seeks to find out what issues hindered the progress of SDI development in Nigeria, ascertain its current state, as well as to provide solutions that will overcome such issues. The researcher suspected that the situation had not changed, and this gave rise to the major research question of:

How can a scalable and sustainable SDI be developed which overcomes failings of the NGDI project?

And the sub questions:

i. What are the current issues obstructing the use of spatial data for environmental analysis?
ii. How do the challenges experienced with spatial data use affect environmental management in Nigeria?
iii. What is the state of the emerging Nigerian SDI and how does it benefit environmental management?
iv. What are the barriers to maximizing SDI adoption to support environmental management in Nigeria?

## 2.7 CHAPTER SUMMARY

This chapter provided a review of literature relevant to this research. It established the research gap this research seeks to address and also articulated the important research questions that will be answered in this research to address the research gap.

# 3 CHAPTER THREE: RESEARCH METHODOLOGY

## 3.1 INTRODUCTION

This chapter elucidates the methodology employed in this research. It details the steps taken to answer the research questions, achieve the research objectives as well as fulfil the aim of this research. It also justifies the selected research approach, design and methods adopted in this research.

## 3.2 RESEARCH APPROACH

A number of research approaches were explored to identify the approach that is best suited for this research. The process of selecting the research approach was driven by the bid to ensure a wider and more comprehensive analysis of the research problem to guarantee the accuracy and reliability of research outputs as well as the validation of the proposed research outputs. First, a literature review was carried out to review the key research themes, establish the research problem and identify the research gap. This informed the formulation of the key research questions, the research aim, as well as its objectives as shown in Figure 3.1.

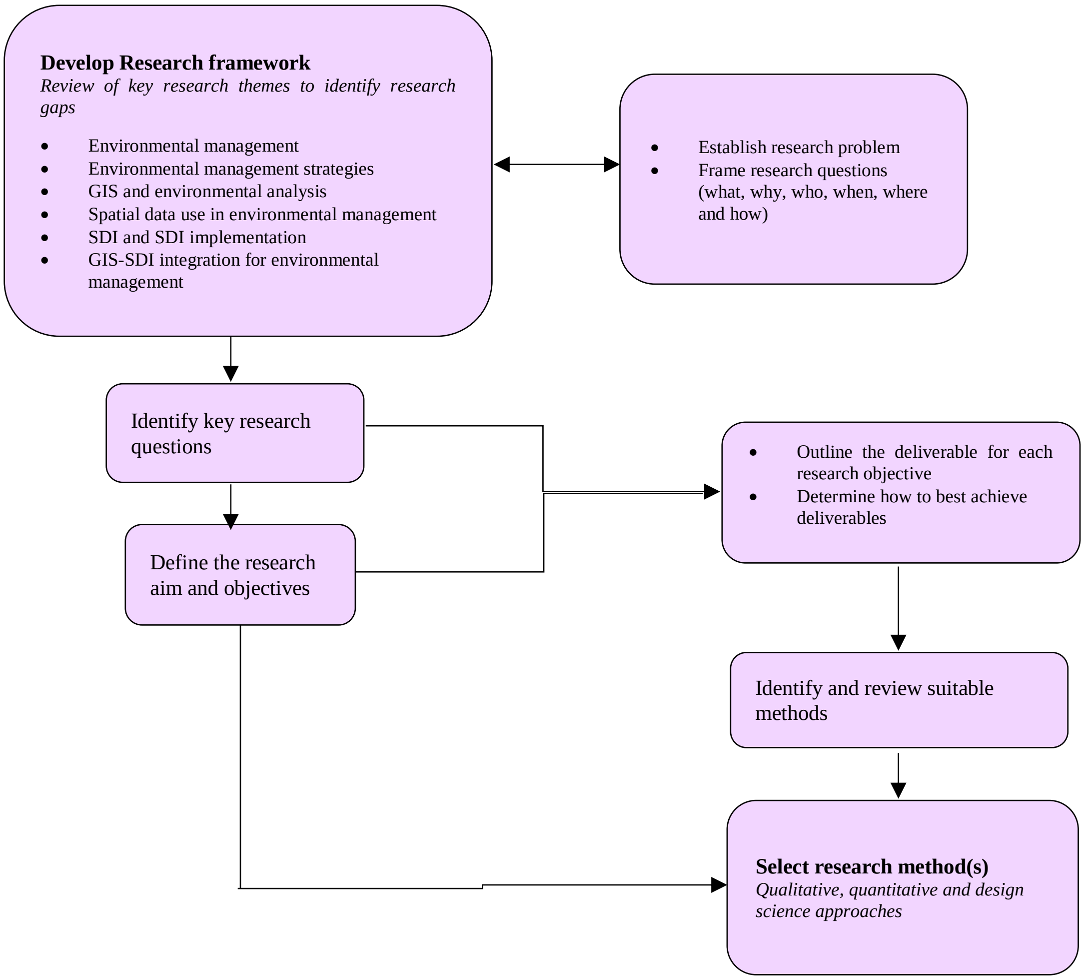


*Figure 3.1: Research method selection process*

Having formulated the research question aim and objectives, consideration were made on how to address them. The adoption of a single approach was found insufficient for responding to the research question and achieving the research aim (and objectives). The mixed methods approach would provide a deeper and balanced understanding of the research problem as well as minimize the weakness of a single approach (Creswell 2013, Krivokapic-Skoko and O'neill 2011, Östlund et al. 2011). This is because, the weakness of one approach will be complemented by the strength of another, and vice versa. This research combined the qualitative, quantitative and design science research approaches, thus, it included a number of surveys. The surveys carried out in this research are listed in Table 3.1 below.

*Table 3.1: Surveys conducted*

| Survey Name | Purpose | Presentation Method | Analysis Method |
|---|---|---|---|
| EIA-SDI | Investigated usage patterns and issues facing environmental stakeholders. | Questionnaire | Quantitative |
| PPU | Evaluated the developed prototype. | Hands-on Experiment and Questionnaire filling | Quantitative |
| NGDI-CF | Investigated effectiveness of NGDI. | Questionnaire and Interviews | Quantitative Qualitative |
| SDI-AF Evaluation | Evaluated the product of the research. | Evaluation instrument and open-ended questions | Qualitative |

## 3.3 JUSTIFICATION OF SELECTED RESEARCH APPROACH

### 3.3.1 QUANTITATIVE RESEARCH APPROACH

The quantitative research approach is a deductive form of research where research data are mainly retrieved from empirical sources or experiments. Analysis is carried out using valid measurements to control the variables from a usually random sample to acquire a generalised view of the research context (Creswell 2013, Allwood 2012, Newman, Isadore, Benz,Carolyn R., 2006). Quantitative research data are measurable numerical data that are sourced empirically from questionnaire surveys, laboratory tests or personal capture as well as from secondary sources like published data. Deductions are made from the descriptive and inferential statistics acquired from the statistical analyses for the assessment of collated data. The quantitative research approach has been shown to be useful for the quantification of the SDI readiness index to assess the status of SDI implementation in several countries in Europe to show that they meet their goals (Nushi et al. 2012, Manfré et al. 2012, Grus et al. 2011, Delgado Fernández, Lance and Buck 2005, Fernández, Cuba and Margaret 2005). This research utilised the quantitative research approach in three surveys; the EAI-SDI survey; the PPU (Prototype Performance and Usability) evaluation and the NGDI-CF (NGDI Critical Factors) survey.

### 3.3.2 QUALITATIVE RESEARCH APPROACH

The qualitative research approach is an inductive form of research where data is sourced from, unstructured and semi-structured interviews, observations, focus groups, as well as literature, to gain a comprehensive insight of a research theme and problem (Creswell 2013, Venkatesh, Brown and Bala 2013, Wisdom et al. 2012). Inferences from a qualitative research are acquired from the data without the introduction of researcher bias or generalisation. It has been utilised alongside other research approaches in SDI implementation studies to define research problem and provide the foundational knowledge needed to execute researches (Grus et al. 2011, Paudyal, McDougall and Apan 2011, McDougall, Rajabifard and Williamson 2007, Rattray 2006).

This research uses qualitative research methods in the NGDI-CF survey and the SDI-AF validation. The NGDI-CF survey explored the critical factors affecting the use of the NGDI while the SDI-AF evaluation sought to ascertain the validity of the SDI-AF as well as its feasibility in practice. It was combined with quantitative research approach in the development and the analysis of the survey responses. Qualitative open ended questions were combined with quantitative survey questions in the NGDI-CF survey to enable a robust assessment of the NGDI challenges. The responses to the open-ended questions were then analysed using qualitative content analysis to provide an understanding the emerging themes. The SDI-AF survey however, employed only qualitative open ended questions for the evaluation and the responses were analysed qualitatively using Nvivo 11.

### 3.3.3 DESIGN SCIENCE RESEARCH APPROACH

The design science research approach aligns the existing theories and practices in the selected field of study with the current debates and problems to develop and validate artefacts, models and systems that present better products, processes, software and solutions to the existing debates and problems (Lacerda et al. 2013). It has been shown to aid the development of decision support systems that better engages the requirements of the stakeholders (decision makers and end users) to create a more user-centred system (Miah, Kerr and Liisa 2014). It begins with the formulation of the research problem which informs the building and evaluation of the proposed prototype solution (Sein et al. 2011). The prototype is further improved through a number of iterations and assessments before publishing the finalised model. It requires substantive background knowledge for the problem definition and the use of case studies for the prototype solution assessment. This research adopted the use case approach for the prototype design, elicitation and validation.

The use case driven approach has been shown to be very useful in software development for designing the requirements of systems based on user requirements, roles and activities as well as for validating designed prototypes (as they capture the system requirements) by exploring the system-user interactions to provide the needed functionalities and facilities (Savic et al. 2012, Bolloju, Schneider and Sugumaran 2012, Drira, Warin and Laroussi 2011). This enables a more user-centred and problem-specific modelling, usability assessment, accessibility assessment and the examination of user experience within the developed system. It also averts the errors of theoretical and empirical generalizations often associated with case study analysis through the use of representative use cases to examine research problem and assess research outputs (Tsang 2014, Yin 2013). This is so because, it allows the readjustment of test objectives in the testing of prototypes for easy simulation to check their consistency and correctness.

Use cases in disaster management have been shown to be valuable for orchestrating a standardized web processing and web service orientation in SDIs (Bernard et al. 2003). The approach has also aided research on the augmentation of the semantic integration in SDI (Vaccari, Shvaiko and Marchese 2009), in the contextualization of SDI implementation models (Drira, Warin and Laroussi 2011), and in the exploration of use cases within a case study has also been reportedly suitable for propagating seamless SDI models (Vaez and Rajabifard 2012). It has also facilitated the integration of environmental models in SDI (Trilles et al. 2013), the management of user-generated data into SDIs (Díaz et al. 2013), and the development of SDI architecture to support a risk management model (Putra, Trias and de Vries 2011). From the foregoing, the design science approach was used in this research to aid the design and implementation of the SDI Data Access Protocol for decision support as well as for enabling the assessment of the protocol to ascertain its usability and potential impact.

Though design science and the deployment of use cases have been advantageous for constructing and testing artefacts before implementing in the real world to save cost and avoid design flaws (Abraham, Aier and Winter 2014), there is the downside of introducing some level subjectivity or informant bias into the design of the use cases (Mettler, Eurich and Winter 2014). These biases if unchecked can lead to the development of systems that provide users with what they think they want rather than what they actually need. In this research, the incremental process was adopted against the waterfall process to allow the evaluation of the system prior to the demonstration to the industry experts. This was done by conducting a technical evaluation which was done internally by the researcher before demonstrating the prototype to industry experts for evaluation (see Section 5.6). Further evaluation of the proposed solution was done by the industry experts following the demonstration of the system to the experts. This was carried out using the PPU and it is presented in Section 5.7 of this thesis. Problems of subjectivity, informant bias or population bias were anticipated during the design of the use cases hence the use cases were developed from the synergy of the EIA-SDI survey results in combination with current literature. This is to balance the information provided by the informants who share common knowledge base, interests or background in Nigeria, as well as any bias that may emanate from the researcher's perspective with the current research trends (Izquierdo-Sotorrío, Holgado-Tello and Carrasco 2016, De Massis and Kotlar 2014). The user groups consulted during the design and development included a number of categories: environmental consultants (which includes EIA preparers), operators (oil and gas operators) and regulators (EIA and NGDI regulators). The involvement of various categories helped to minimise the problems of population bias that is prevalent with design science approach. It ensured that the different perspectives from the user categories were captured.

### 3.3.4 ALIGNMENT OF SELECTED RESEARCH APPROACH

The multidisciplinary research method integrated approaches from social sciences with those from engineering and computing to develop a research methodology that bridges across the technological aspects of SDI implementation with the people, institutional arrangements, data inputs and the processes involved. The mix of quantitative and qualitative approaches with the design science research provided the in-depth knowledge needed for the problem definition and for building the required prototype solution to identified problem.

The quantitative research approach offered a valuable process for the measurement of institutional and organisational characteristics for this research but also presented fewer prospects for the prototype development, appraisal and validation. The design science research however was considered useful for the creation of prototype development, appraisal and validation. It aids the development of the conceptual framework that guides the building, testing and deployment of models using use cases. However, the design science research approach is reportedly flawed by the error of generalization in situations where the design of solutions was not based on in-depth knowledge of the main research elements (Beck, Weber and Gregory 2013, Kuechler and Vaishnavi 2012). For this research, design science approach is combined with qualitative and quantitative research approaches to avoid the error of generalization. This involved integrating the existing theories and practices informed by the qualitative research with the current debates and challenges as well as the organisational views informed by the quantitative surveys to enable a deeper understanding of the research elements.

## 3.4 RESEARCH DESIGN

The research design adopted for this study was built on the foundational principles of the design science research but with the integration of specific components from qualitative and quantitative approaches. It was structured into five key stages as listed below. The design of the research approach is presented in Figure 3.2.

- Stage 1 – Literature Review (Identifying the research questions)
- Stage 2 – EIA-SDI survey and Problem Identification (Investigation and identifying the problems)
- Stage3 – Data Access Protocol, PPU and NGDI-CF (|Developing the solution)
- Stage 4 – SDI Augmentation Framework (SDI-AF) (Further developing the solution)
- Stage 5 – SDI-AF Validation and Conclusions (Consolidating findings and contributing to knowledge)

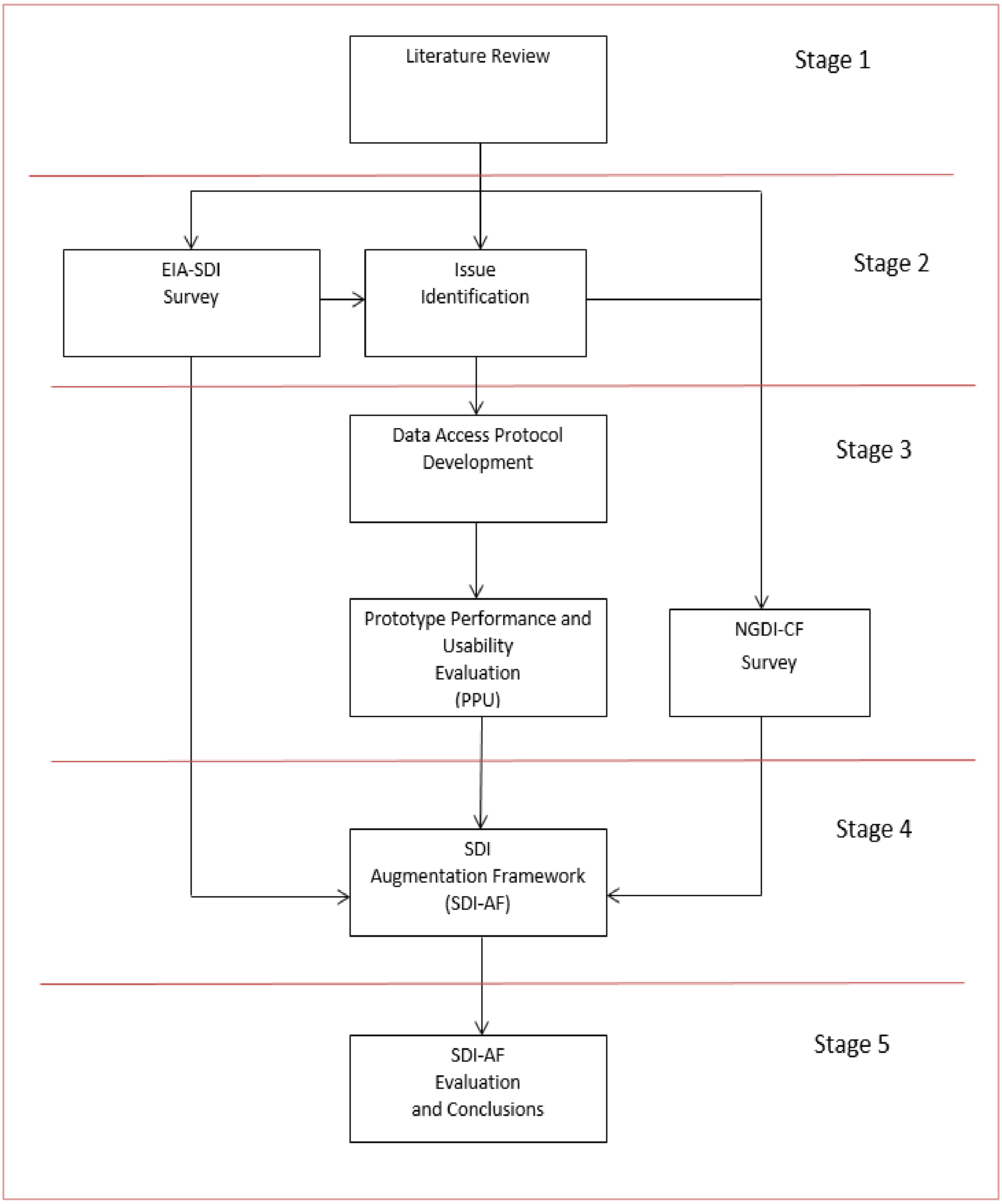


*Figure 3.2: Design of research approach*

## 3.5 RESEARCH METHODS

### 3.5.1 LITERATURE REVIEW

The first stage of this research explored the key research themes. The purpose was to define the research problem, identify the gaps the research was to address, define its aim as well as its objectives. It reviewed the current issues obstructing spatial data use for environmental management, as well as the prospects and challenges of implementing SDI. The literature review was undertaken to understand the current global situation as well as the particulars of the Nigerian case. This is a fundamental part of this research as it provided the background on which the research was developed. The literature review identified the need for accurate, easily accessible and cost-effective spatial data to effectively examine environmental concerns. It highlighted the case of SDI adoption in Nigeria and its potential for improving environmental management following the institutionalizing of the emerging SDI in Nigeria called the National Geographic Data Infrastructure (NGDI) (Ayanlade, Orimoogunje and Borisade 2008, Anifowose, Bamisaye and Odeyemi 2006, Ayeni, Kufoniyi and JO 2003). It also explored the efforts reportedly made to improve environmental regulations in the country (Ladan 2012, Eneh 2011, Chokor 1993) to understand the factors limiting the translation of these policies and programs to effectively support environmental management strategies.

To this end this research explored the nature of data sharing in the multilevel SDI environment, particularly with respect to the organisational issues that affect its ability to support the spatial data needs of its users. It examined the business requirements and driving forces that shape the scope, design, purpose and implementation of SDI to support existing environmental management strategies, as well as the mechanisms and factors that expedite the inter-organisational efforts in relation to supporting environmental management strategies.

### 3.5.2 EIA-SDI SURVEY AND PROBLEM IDENTIFICATION

The EIA-SDI case study was developed to assess the effect of spatial data (access, accuracy and interoperability) on the quality of EIA reported in Nigeria's oil and gas sector and the influence of the emerging Nigerian SDI on EIA reporting. It also examined the prospects of an effective and updated SDI on the working practices of EIA preparation as well as the quality of the EIA prepared. The selection of EIA as the environmental management strategy with which to assess the prospects of SDIs in Nigeria was driven by the fact that EIA is a fundamental environmental management tool from which a majority of other environmental management tools emanated.

Statistical analyses of the survey followed to identify the key findings. The key research findings were used to drive the development of the data access protocol and the proposed solution in the subsequent stages of the research

#### 3.5.2.1 *METHODS: EIA-SDI CASE*

A desk based study was carried out to:

a. Highlight the public and private sector organisations in Nigeria who contribute to or conduct EIA, as well as those that collect, manage and distribute geospatial data;
b. Identify the EIA practitioners within those organisations and establish contact with them;
c. Identify the current EIA jurisdictions in Nigeria; and
d. Ascertain the perceived state of the emergent Nigerian geospatial data infrastructure.

The key research questions for the EIA-SDI study were:

1) How effective is the current strategy for coordinating EIA in Nigeria's oil and gas sector?
2) What are the current practices and issues surrounding geospatial data access and use for EIA preparation in Nigeria's oil and gas sector?
3) How effective is the emerging SDI in Nigeria and how does it affect the quality of EIA prepared in Nigeria's oil and gas sector?
4) What are the recommendations for achieving more effective SDI-EIA integration?

The following areas were therefore assessed:

a. The specific EIA activities ongoing in Nigeria and the influence of the current regulatory arrangement on the effectiveness of EIA in Nigeria's oil and gas sector.
b. Challenges obstructing the use of spatial data for EIA reporting and its consequence on the quality of EIA reported in Nigeria's oil and gas sector.
c. The perceived effectiveness of the NGDI and how improving its effectiveness might change the working practices of EIA preparation and regulation.

The questionnaire survey consisted of five sections as shown in the Table 3.2 below. The detailed questionnaire survey deployed for the EIA-SDI case is presented in Appendix I.

*Table 3.2: Components of the EIA-SDI questionnaire survey*

| **EIA-SDI QUESTIONNAIRE SURVEY ELEMENTS** | **TOPICS COVERED** |
|---|---|
| Section 1 | Consent form for ethics and data protection |
| Section 2 | Comprised of questions about the surveyed organisation, the type of EIA activities on-going in the surveyed organisation, as well as its spatial distribution, to help decipher the variation of EIA activities across Nigeria. |
| Section 3 | This section focused on retrieving information about the experience of the EIA preparer with the use of spatial data when preparing EIA reports. It also highlighted the types and sources of spatial data utilized by EIA preparers, as well as the difficulties associated with spatial data use. |
| Section 4 | This section emphasised on the inherent factors that constrain the use of geospatial data for EIA preparation in Nigeria's oil and gas sector. It highlighted the role of the regulators, preparers and oil companies, as well as their contributions to the issues currently being experienced. It also highlighted the role of the emerging geospatial data infrastructure in alleviating the problems of spatial data use. Emphasis was placed on the |

| | |
|---|---|
| | effectiveness of the current spatial data infrastructure and suggestions for possible improvements. |
| Section 5 | This section focused on retrieving information that will enable the deciphering of the level of effect National Geospatial Data Infrastructure (NGDI) has on the performance of EIA practitioners. It also created the room for the collection of viable suggestions of how the emerging spatial data infrastructure can be better implement to benefit EIA preparation. |

This study aimed at assessing the effects of spatial data on the quality of EIA reported in Nigeria's oil and gas sector and the influence of SDI on the working practices and quality of the EIA reported. An estimate of the public and private sector organisations in Nigeria who contribute to or conduct EIA was drawn from the list of certified EIA preparers from 2009 to 2014 (see Table 3.3). The sampling frame for this research was defined to cover only EIA preparers certified under the key regulators in Nigeria's oil and gas sector (DPR and FMEnv) and not the entire population of EIA preparers in Nigeria. This is to ensure that the results produced are proportional and representative of the views of the DPR and FMEnv certified EIA preparers in Nigeria's oil and gas sector.

*Table 3.3: Number of certified EIA preparers from 2009 to 2014*

| **Year** | **Number of registered EIA preparers** |
|---|---|
| 2009 | 234 |
| 2010 | 279 |
| 2011 | 298 |
| 2012 | 311 |
| 2013 | 262 |
| 2014 | 273 |
| 2015 | Not yet collated |

Source: Department of Petroleum Resources (2014)

In order to ensure the validity and reliability of the data collected from the purposive sample of certified EIA preparers, the systematic sampling method was adopted in the definition of the target sample for the questionnaire survey (see Table 3.4).

*Table 3.4: Systematic sampling of collected sample*

<table>
<tr><th colspan="4">Sampling Feature</th><th colspan="6">Description/Results</th></tr>
<tr><td colspan="4">Target Population/ Sampling frame; N</td><td colspan="6">311 Certified EIA preparers</td></tr>
<tr><td colspan="4">Nature of Sampling Frame:</td><td colspan="6">Contact of certified EIA preparers itemized in random order</td></tr>
<tr><td colspan="4">Sample size; n</td><td colspan="6">103</td></tr>
<tr><td colspan="4">Sampling interval; k</td><td colspan="6">= 311/100 = 3.01<br>k≈3</td></tr>
<tr><td colspan="4">Randomly selected sample element; j</td><td colspan="6">2</td></tr>
<tr><td colspan="10">Where j= 2, the first kth element = j + k; thereafter; j + 2*k; j + 3*k …… j +103*k;<br>Thus, the target population was selected from the list of EIA preparers listed on the random numbers below;</td></tr>
<tr><td>5</td><td>8</td><td>11</td><td>14</td><td>17</td><td>20</td><td>23</td><td>26</td><td>29</td><td>32</td></tr>
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<tr><td>275</td><td>278</td><td>281</td><td>284</td><td>287</td><td>290</td><td>293</td><td>296</td><td>299</td><td>302</td></tr>
<tr><td>305</td><td>308</td><td>311</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

The systematic random sampling was adopted as the most suitable and cost effective sampling method for this research as the sample population contains a homogenous subgroup of EIA preparers in Nigeria's oil and gas sector. The stratified random sampling was not considered suitable in this case because majority of the oil and gas activities occurs in the southern part of Nigeria (south, south west, and south east) and the high rate of insurgency in the north east will hinder the possibility of locating EIA preparers resident in this area. Also, the use of non-probability sampling was not considered suitable for this research due to the obvious biases that surround the use of this sampling method. It has been characterized in most cases as being judgemental and may not effectively represent the opinions of EIA preparers from all the different demographic subgroups and geopolitical zones in Nigeria. A systematic sample of 100 respondents was drawn from the list of EIA preparers sourced from the regulators and every *3rd* sample was randomly selected as the target population to avoid bias (see Table 3.4). In conducting the sampling, precautionary measures were taken to avoid the usual errors that surround the use of systematic probability sampling so as to get a representative sample of the whole population. A total of 65 responses were collected within the time frame set for the collection of responses. The quantitative questions were analysed statistically using SPSS 20 and SPSS 22 while the qualitative open ended questions were analysed using qualitative content analysis. The results are presented in Chapter 4 of this thesis.

### 3.5.3 STAGE 3: DATA ACCESS PROTOCOL, PPU AND NGDI-CF

This section presents the methods employed for the development of the solution to the problems identified in Stage 2. It covers of the development of the Data Access Protocol, the Prototype Performance and Usability (PPU) evaluation, and the NGDI Critical Factors (NGDI-CF) evaluation. The Data Access Protocol was designed to address the problems identified in the EIA-SDI case. A prototype was developed. The PPU evaluation encompasses the prototype's performance as well as its usability in Nigeria, while the NGDI-CF survey assessed the factors critical to the successful implementation of the NGDI. The synergy of the results from both evaluations in combination with those from the EIA-SDI survey informed the development of the SDI augmentation framework (SDI-AF).

The following sub-sections detail the methods employed in the order which they were performed; use case development, data access protocol and prototype development, PPU evaluation and NGDI-CF evaluation.

#### 3.5.3.1 *USE CASE DEVELOPMENT*

This part of the research involved the utilization of use cases to explore the viability of implementing GIS integrated SDI model to support environmental management strategies using EIA as the representative case. Use cases were designed using ArgoUML which is a platform that allows the development, testing and validation of use cases virtually. This is very important to this research as it saves the time and resources it would cost to try developing the actual system without verifying the validity. Model development is done in a number of iterations which is accompanied by a number of significant changes that would be very expensive for this research if the initial model development is not done virtually.

In the design of the use cases, the key findings from the questionnaire survey were aligned with current research to define the system requirements. These requirements were defined to highlight the needed tools and datasets for the design of the conceptual framework for the prototype development. The development of the use cases was formalised and validated by repeat iterations to improve use case scenarios and methods. It explored the possibility of developing a unified system for conducting environmental analysis in which the goals of the SDI are aligned with that of the users (environmental consultants, administrators and other users) for better data integration and for more accurate environmental analysis. This was developed on the basis of SDI components illustrated in Figure 2.1. It encompasses the development of the required data access network, the institutionalisation of the policies governing its use, and the data standards for improved data accuracy and integration, the users (people), as well as the data.

The use cases were developed based on the requirements, as well as challenges documented by EIA practitioners in the EIA-SDI case. Thus, it explored the issues with data access, data accuracy, cost of access, as well as the problem of the data integration highlighted by the questionnaire survey. The development of these use cases informed the conceptualization of framework for the prototype development. The goal was to improve the access of EIA preparers to standardized spatial datasets but also encourage consistent training and development of these EIA preparers to improve the quality of EIA prepared.

#### 3.5.3.2 *DATA ACCESS PROTOCOL AND PROTOTYPE DEVELOPMENT*

The method employed for the development was the design science method. The appropriate stages in this case were: problem identification; defining the objective; design and development; and demonstration. The outputs from the EIA-SDI case in Stage 2 (Section 3.5.2) informed the problem identification for this section of the research. Access to complete and accurate spatial data was highlighted as a major challenge to EIA preparation. Therefore, the objective for the novel data access protocol was to *provide a lightweight and flexible SDI data access protocol that can be accessed using mobile devices as well as computers*.

To achieve the design objectives, the requirements for the design and development of the solution was established. The spatial data for the prototype development was sourced and cleaned up in QGIS. The prepared data was imported into Postgres sever using PgAdminIII to ensure the spatial elements of the data were well documented. This was then imported into the Geoserver instance. The SDI database was designed following the concept of linked open data (LOD) utilized by (Harvey et al. 2014) to implement an SDI that connects to and publishes data from different standardized sources on the web. The Geoserver instance served as the Geoportal from which the datasets were served to the data access prototype. Within the Geoserver, these datasets were documented in OGC and ISO standards and retrievable in various GIS and in OGC compliant formats from the data access prototype or via the Geoserver. Open source GeoEXT java program was utilised in collaboration with OpenLayers, java script EXT and HTML to develop the front end of the data access prototype on Amazon Web Server (AWS).

The iterative prototype development process was adopted over the waterfall process as it enabled the technical assessment and subsequent debugging of the prototype at each stage of the development. Observations and tests were done to identify lapses. Identified changes were made and integrated into the next iteration to save time, and develop a more improved prototype that meets the goals of the development. On completing the prototype development, the prototype was demonstrated and evaluated.

#### 3.5.3.3 *PPU AND NGDI-CF EVALUATION*

The demonstration of the prototype for assessment included a prototype performance and user (PPU) evaluation. For the PPU evaluation, users were made to go through a number of tasks and answer specific questions. The questions sought to examine the usability, validity and reliability of the prototype, as well as its ability to contribute to addressing current challenges faced with spatial data access, sharing, and use for environmental management in Nigeria. Appendix III shows the PPU evaluation script.

The NGDI-CF evaluation was undertaken to augment the results from both the EIA-SDI survey and the PPU evaluation. It was conducted to analyse the NGDI to ascertain the current status of the NGDI following past implementation attempt and also identify the factors critical to effective NGDI implementation. A questionnaire with Likert scale questions was used and also interviews with semi-structured questions were conducted. The semi-structured questions were used to assess the institutional factors and encourage a robust discussion of the issues identified within the interview. Appendix II shows the NGDI-CF survey questionnaire.

The sample population for the PPU and the NGDI-CF were selected from a purposive sample of the surveyed environmental consultants (which includes EIA preparers), operators (oil and gas operators) and regulators (EIA and NGDI regulators), based on their familiarity with the NGDI. An additional set of regulators from NASRDA, the coordinating body for the NGDI, was included in the NGDI-CF evaluation. The regional SDI regulator, ECOWAS (Economic community of West African states) was also included for a more robust data gathering. The selected sample is hereafter referred to in this thesis as 'experts' or 'industry experts'. 24 industry experts responded to the PPU and NGDI-CF surveys. A focus group was also conducted as a part of the NGDI-CF to encourage a richer discussion of the factors critical to the NGDI implementation. Though the respondents included active members of the geospatial industry in Nigeria who would have participated in the past implementation of the NGDI, the responses were balanced out by other respondents from the focus group as well as the individual interviews conducted. This was employed to help overcome any obvious informant bias or conflict of interests. A total number of 37 participants were present at the focus group. Participants of the focus group were active members of the geospatial industry in Nigeria with sufficient experience with the NGDI. Therefore, the total number of participants that contributed to the NGDI-CF was 61; with 24 contributing to the quantitative survey. The quantitative survey responses in the PPU and NGDI-CF were analysed statistically using SPSS Version 22 and are presented in Chapters 5 and 6 respectively.

The semi-structured, open ended interview questions were analysed qualitatively using Nvivo 11. Nodes were used in Nvivo to generate the themes based on the content of the interview and the relevance of the information provided by the participants. The nodes were defined and labelled according to the research questions. That is, responses that addressed a particular research question were grouped together so as to simplify the process. This was done by first preparing the data in a Word document so as to run auto coding in Nvivo. Themes were developed by identifying the relevant information in the data from the transcript. Some parts of the coding were done during the transcription which was done using NCH Express Scribe software. Notes were taken during the transcription and tagged 'Rnotes:' to emphasize on the new knowledge and understanding reached while transcribing the data, as well as to note down the researcher's perspective of the issue discussed. On the transfer of the transcriptions to Nvivo, the coding process continued after auto coding the data to arrange them according to the responses that addressed each of the research questions defined for this research.

The research questions were reviewed to ascertain the characteristics of the questions so as to identify the coding method that is suitable for this research. The evaluation coding method was selected as it was most consistent with the investigated research questions. The In vivo, magnitude and process coding methods (Onwuegbuzie, Frels and Hwang 2016), were not adopted as they were not considered to be consistent with the prototype evaluation and research questions. The research questions were further reviewed to ensure the assigned codes effectively represented the relevant information retrievable from the data. This is to avoid the error of generalisation and ensure the research stays focused on the research scope. The error of generalisation and the deviation from the research scope is a common error in qualitative analysis as it is very easy to get lost in dozens of interesting data provided during the interview. To avoid this error, the research questions were then transformed into focus prompts. For instance, research question 3 which states;

*What is the state of the emerging Nigerian SDI and how does it benefit environmental management?*

Was transformed to a focus prompt which states;

*In describing the state of the NGDI, participants* ________________________________

The blank spaces were used to represent the information in the data that addresses the focus prompts and thus stay within the scope of the research. Child nodes and other sub categories were created within the data to represent consistent themes within each research question. This was reassessed in iterations to arrive at the final nodes.

### 3.5.4 STAGE 4 – SDI AUGMENTATION FRAMEWORK (SDI-AF)

This stage involved the development of the SDI Augmentation Framework (SDI-AF) which was developed to support the use of the data access protocol developed in Stage 3. The SDI-AF is the culmination of the research and forms the main contribution to knowledge.

Figure 3.3 depicts the process of knowledge gathering for the formalization of learning which in this research, is the development of the SDI-AF. As shown, data gathered from the literature review served as the foundation for deploying the EIA-SDI case presented in Chapter 4, which in turn served as the basis of the data access protocol and prototype development. The prototype was developed to demonstrate the SDI data access protocol to aid the full implementation of the NGDI. The prototype evaluation included the demonstration of the prototype through a walk-through exercise carried out by the participants who in turn answered interview questions to access the PPU evaluation. Participants also addressed questions on the state of the current NGDI in Nigeria as well as identified the factors critical to the successful implementation of the NGDI. The outcomes from these three components were then synergised with literature to develop the SDI-AF.

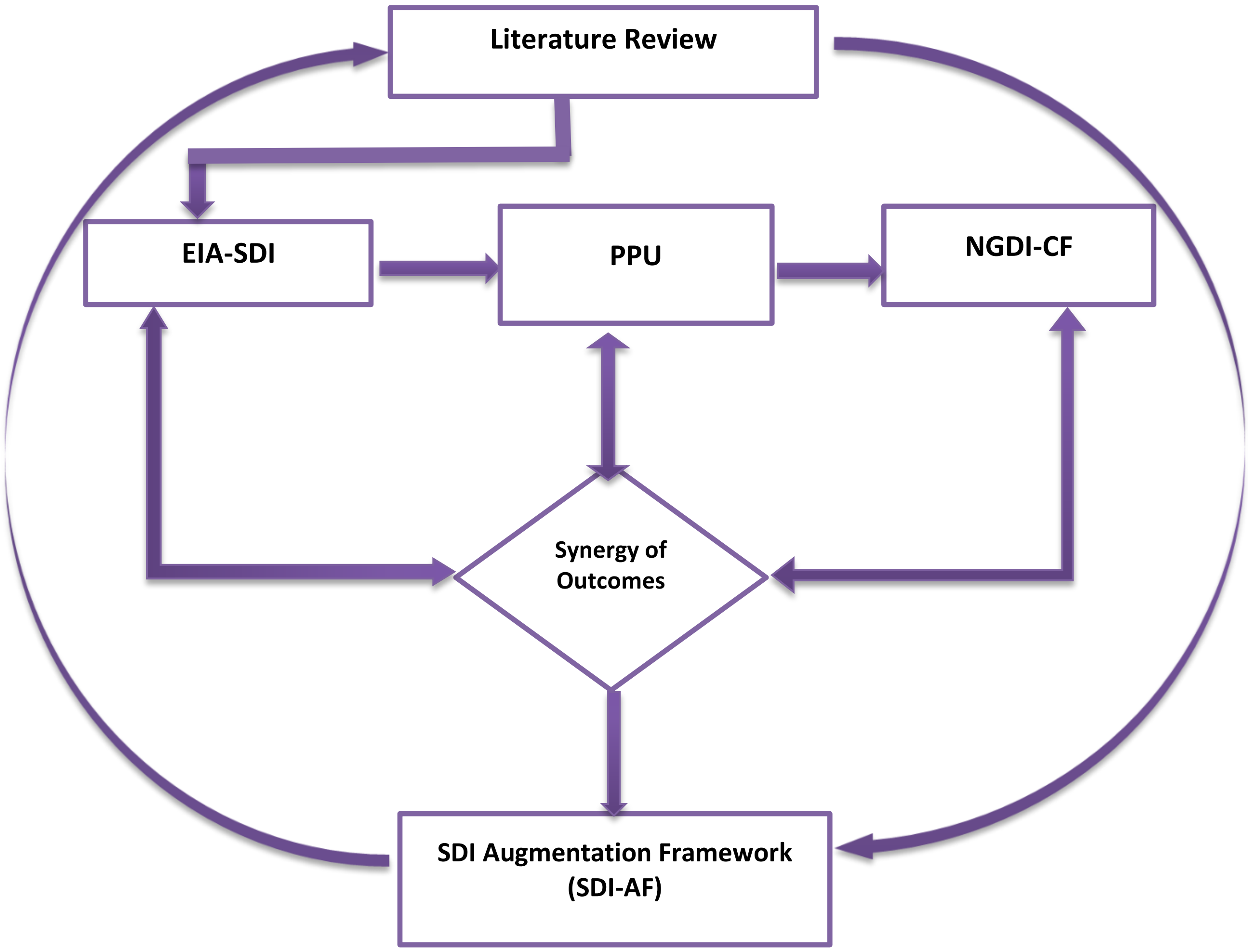



*Figure 3.3: SDI-AF development process*

### 3.5.5 STAGE 5 – SDI-AF VALIDATION AND CONCLUSIONS

This was the final stage of the research and it involved the validation of the proposed SDI-AF using a validation instrument. The results of the validation were analysed and presented in Chapter 9 of this thesis, with the research conclusion presented in Chapter 10 of this thesis.

#### 3.5.5.1 *FRAMEWORK VALIDATION METHOD*

The framework validation was completed by industry experts in the field of spatial data infrastructure (NGDI in Nigeria). They assessed the validity and feasibility of implementing the framework in practice and gave comments on areas for improvement. Participants were briefed via telephone, and on consenting to participating in the study, a framework validation instrument was sent to them via email. The email contained the participant information and consent information, with details of the framework attached in a document tagged ‘Framework Validation Instrument’ (see Appendix VI). The document comprised of an introduction of the SDI-AF, the components of the SDI–AF and the validation questions. Semi-structured and open-ended questions were employed to enable experts comment on the fundamental components of the framework. This allowed experts to comment freely with little restrictions and to tailor their comments to the focus of this research. The purposive non-probability sample design was adopted against the probability sample design to tailor the selection of the most useful respondents to address the final research objective which is “to evaluate the developed SDI framework”. The inclusion criteria for the participants were their knowledge and hands-on experience with the emerging NGDI. Five (5) principal members of the committee that coordinated the NGDI took part in the SDI-AF validation. The five (5) participants comprised of two (2) experts from the coordinating agencies group, two (2) experts from the academia group and one (1) expert from the partner agency group with some cases of overlaps as there are experts who are in academia that fall under two or more categories. The agencies and institutions represented by the participants have staff sizes of between 1000 – 5000 active staff members. The participants were representatives of these organisations like it was with the NGDI committee, and thus responded on behalf of these larger organisations (see Section 9.2). They were contacted because of the fundamental role they played in the development of the NGDI and their experience with the problems that hindered its implementation. As a result, they provide the critical perceptive needed to ascertain the validity of the framework and the feasibility of replicating it in practice to ensure the full adoption of the NGDI. The industry experts responded to the validation questions and returned their responses via email. Further clarifications on their responses were carried out via follow-up emails and telephone conversations.

#### 3.5.5.2 *FRAMEWORK VALIDATION CRITERIA*

Industry experts assessed the SDI-AF based on the following criteria;

- The feasibility and validity of the framework.
- The validity of the proposed bottom-up approach for implementing SDIs, against the current top-down approach.
- The sufficiency of the framework components and implementation path.

- The clarity of the framework and implementation path to ascertain the feasibility of replication it in practice.

The problem addressed in this research was the insufficiency of the NGDI to provide comprehensive spatial data access which meets the spatial data needs for environmental management (see section 1.2.1). The SDI augmentation framework was proposed to address the issues affecting the adoption of the NGDI and to enable better SDI implementation. To this end, the validation questions also included the framework's capability to contribute significantly to the following;

- Improving spatial data access over the web.
- Hastening SDI implementation.
- Overcoming the challenge of developing clearinghouses.
- Harvesting economic and environmental benefits from spatial data and SDIs.
- Amplifying the legislation and enforcement of a user-driven policy and objectives for SDI implementation.
- Heightening awareness, as well as amplifying participation and partnership.

The instrument used, 'Framework Validation Document', which includes the validation questions can be found in Appendix VI.

## 3.6 HYPOTHESIS FORMULATION

It is anticipated that the development of a framework, that will incorporate GIS applications in conformance to SDI protocols, will improve NGDI implementation in Nigeria and augment interoperable spatial data sharing partnerships to support environmental management. It is hoped to also strengthen the established SDI adoption policies in other developing and developed countries.

The EIA-SDI case and NGDI-CF cases were formulated to provide a comprehensive understanding of the current spatial data problems hindering effective EIA reporting in Nigeria as well as the sufficiency of the current NGDI protocols in Nigeria. It was therefore anticipated that the development of an SDI conformant GIS framework that aligns with the needs and of an insufficient SDI would improve the NGDI implementation in Nigeria by amplifying interoperable spatial data access and sharing partnerships to support environmental management. This was aimed at strengthening the existing SDI implementation protocols, especially those struggling to attain or sustain an effective implementation, as well as aid in the effective deployment of new SDIs. To this end, the SDI–AF was proposed.

The hypotheses were defined to confirm the following constructs;

- the impact of an effectively updated NGDI on the way EIA is being carried out in the Nigerian oil and gas sector and by implication, environmental management,
- the prototype as an effective demonstration of accessing SDI data,

- the prototype's ability to address the concerns of accessing data through the NGDI, and
- The validity and reliability of the framework to improve SDI adoption and thus improve spatial data access.

To this end, five main hypotheses were defined in this study as follows;

- $H_1$: *The NGDI is insufficient to support the geospatial data needs for Nigeria*
- $H_2$: *An adequately updated NGDI will have significant influence on the way EIA is being carried out in the Nigerian oil and gas sector.*
- $H_3$: *The Data Access Protocol is an effective demonstration of accessing SDI data*
- $H_4$: *The Data Access Protocol addresses the challenges of accessing NGDI data*
- $H_5$: *The SDI-AF, which includes the provenance enabled, scalable, bottom-up distributed approach for SDI data access over a web, the SDI governance protocol and critical assessment protocol, would improve SDI adoption.*

Hypotheses 1 to 4 were assessed quantitatively using SPSS while Hypothesis 5 was assessed qualitatively from the content analysis of the SDI-AF validation responses.

## 3.7 JUSTIFICATION OF METHODS

In the bid to assess the sufficiency of the selected methods, the methods were matched with the research questions and the deliverables were outlined to alignment of the research questions to the selected methods.

*Table 3.5: Alignment of research questions and methods*

| RESEARCH QUESTION | METHOD(S) | DELIVERABLES |
|---|---|---|
| What are the current issues hindering the use of spatial data for environmental analysis? | • Review literature | • Statement of research problem<br>• Outline of key research questions<br>• Research aim and objectives<br>• Draft first version of research methodology<br>• First version of literature review |
| How do the challenges experienced with spatial data use affect environmental management in Nigeria? | Qualitative and Quantitative<br>• Review literature<br>• EIA-SDI survey | • Updated literature review<br>• Redefined research problem, questions, aim and objectives<br>• Update research methodology<br>• Survey results |
| What is the state of the emerging Nigerian SDI and how does it benefit environmental management? | Qualitative and Quantitative<br>• Review literature<br>• EIA-SDI survey and NGDI-CF survey<br>o Statistical analysis of survey results<br>o Qualitative analysis of interview and open-ended survey questions | • Synthesised results |
| What are the barriers to maximizing SDI adoption to support environmental management in Nigeria? | Qualitative, Quantitative<br>• Review literature<br>• NGDI-CF survey | • Updated literature review<br>• Redefined research problem, questions, aim and objectives<br>• Conceptual factors for SDI Augmentation Framework |
| How can a scalable and sustainable SDI be developed which overcomes failings of the NGDI project? | Qualitative, Quantitative. and Design Science research approaches<br>• Review literature<br>• Experiment using 'use cases'<br>• Prototype development<br>• PPU evaluation<br>• NGDI-CF Outcomes<br>• Framework development and validation | • Prototype<br>• Evaluated SDI Augmentation Framework |

## 3.8 ETHICAL CONSIDERATIONS

This research was conducted in strict adherence to the ethics of conducting academic research. Appropriate ethical approval was sought and approved by the Coventry University's Ethics Approval team. Emphasis was made to ensure the proper referencing and presentation of reported literatures. Sensitive information from the use cases, questionnaires and evaluation remains confidential and was utilised for research purposes only. In the case of the online questionnaire, the information was provided online and participants were required to agree to participate before being allowed to access the questionnaire.

## 3.9 CHAPTER SUMMARY

This chapter discussed the research approach and methods selected for this research. It defined the research into five stages within which the research questions, aim and objectives were answered. It also discussed the contributions of the individual stages to the final research output to address the problem investigated in this research.

# 4 CHAPTER FOUR: EIA-SDI CASE

## 4.1 INTRODUCTION

This chapter presents and discusses the results of the EIA-SDI case. The EIA-SDI case investigated the effects of spatial data (access, accuracy and interoperability) on the quality of EIA reported in Nigeria's oil and gas sector and the influence of the emerging Nigerian SDI on EIA reporting. This study helped develop the foundation for this research. It highlighted the current issues limiting spatial data use and EIA preparation in Nigeria's oil and gas sector. It raised questions about EIA preparation and the regulation of EIAs in Nigeria's oil and gas sector to ascertain that the EIAs are prepared accordance to industry best practices, and also looked examine the effectiveness of the current strategy for coordinating EIA in the sector. It also went further to investigate the level of effectiveness of the emerging NGDI to support the spatial data needs for EIA preparation. It explored the likely benefits of implementing an effective SDI in the sector and its subsequent potential effect on the quality of EIA reports.

The following sections present the analysis of the questionnaire survey responses collected from the EIA-SDI case. Section 4.2 presents the descriptive statistics and discusses the preliminary questionnaire findings while section 4.3 presents the inferential analysis carried out on key questionnaire outcomes.

## 4.2 DESCRIPTIVE STATISTICS

The survey was distributed online (via www.survey.bris.ac.uk/coventry/nigeriansdi) to 103 certified EIA preparers across the six geopolitical zones of Nigeria and it recorded 65 responses. Results from similar surveys conducted in Europe in 2002 to 2003 recorded a total of 50 responses (14 responses in 2002 and 36 responses in 2003) from 22 European countries, and in 2009 recorded 128 responses from 31 European countries (Craglia, Pavanello and Smith 2010, Vanderhaegen and Muro 2005), while the survey conducted in Lambardia, Europe recorded 40% response rate with 27 responses out of the 60 sent out (Craglia and Campagna 2010). The respondents for the EIA-SDI case was a representative sample of the 311 DPR and FMEnv certified EIA preparers in Nigeria's oil and gas sector. Thus, it is important to note that though the results of the questionnaire are assumed to reflect the views of 'all' EIA preparers in Nigeria's oil and gas sector, it is a representative sample of the certified EIA preparers drawn from the six geopolitical zones of the federation. The survey was designed into four parts as presented in Table 3.2 in Chapter 3. The following sub-sections present the results of the survey in descriptive statistics.

### 4.2.1 EIA-REPORTING ORGANISATIONS AND THE ONGOING EIA ACTIVITIES

This section presents the surveyed organisations, the type of EIA activities on-going in the organisations, as well as its spatial distribution. This is to help decipher the variation of EIA activities across Nigeria.

#### 4.2.1.1 *LOCATION*

Results of the questionnaire showed a fair distribution of EIA-reporting organisations across the six geopolitical zones of Nigeria with majority of the preparers located in the south-south zone (48.90%) and the south-west zone (36.40%). However, none was recorded to have been located in the north-east zone of Nigeria and this can be attributed to the long term battle with insecurity and insurgency that has made such areas somewhat inaccessible (see Figure 4.1).

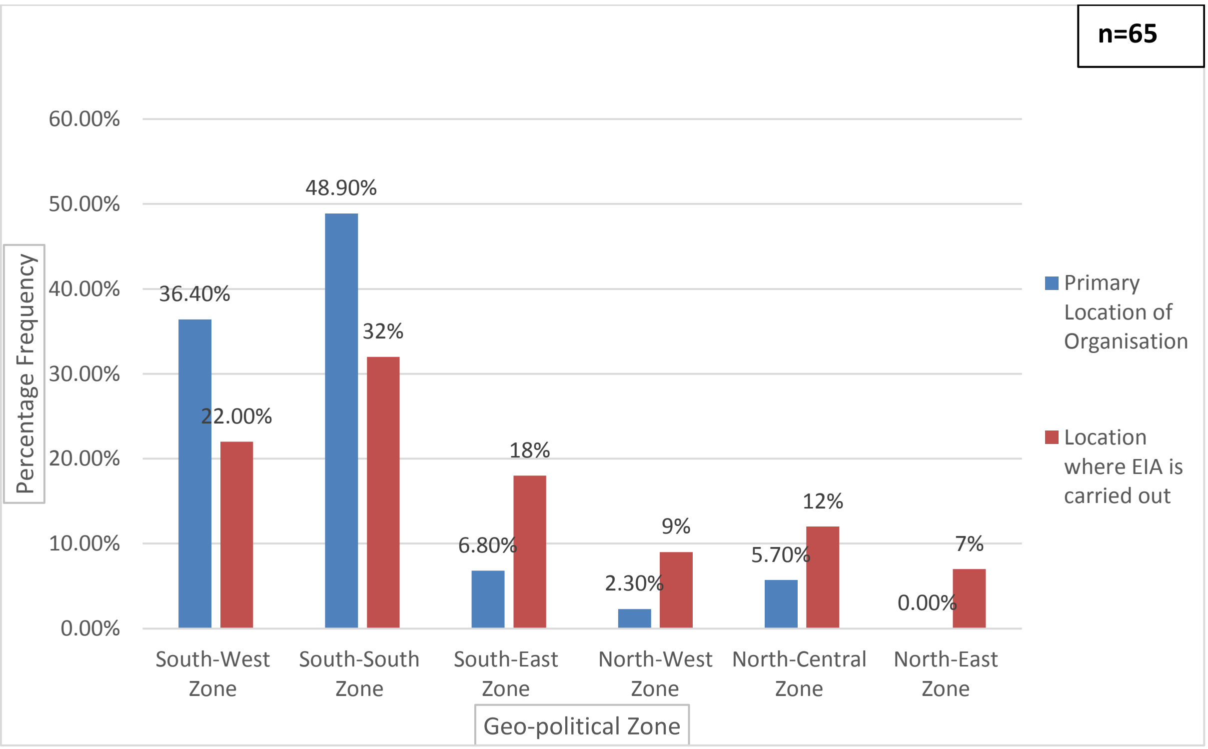



*Figure 4.1: Primary location of EIA organisations and the location where EIA is carried out*

7% of the EIA carried out was seen to have been done in the north-east zone while the majority (32%) of EIA carried out was seen to have been done in the south-south zone of Nigeria. The south-south zone of Nigeria comprises of the oil producing states in the country where most of the oil and gas exploration, production and transportation activities are situated. Thus, it is not surprising that majority of the EIAs conducted as well as the organisations carrying out the EIAs are located within the south-south zone of Nigeria. For the purpose of this research, emphasis was not made on the actual GPS coordinates of these locations but they were grouped into the various geo-political zones existing in Nigeria as shown in Table 4.1.

*Table 4.1: Components of the Nigeria's geopolitical zones*

| S/N | GEOPOLITICAL ZONE | COMPONENTS |
|---|---|---|
| **1.** | South-West Zone | Ekiti, Lagos, Ogun, Ondo, Osun, and Oyo |
| **2.** | South-South Zone | Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, and Rivers |
| **3.** | South-East Zone | Abia, Anambra, Ebonyi, Enugu, and Imo |
| **4.** | North-West Zone | Kaduna, Kano, Katsina, Jigawa, Kebbi, Sokoto, and Zamfara |
| **5.** | North-Central Zone | Benue, Kogi, Kwara, Nassarawa, Niger, and Plateau |
| **6.** | North-East Zone | Adamawa, Bauchi, Bornu, Gombe, Taraba, and Yobe |

#### 4.2.1.2 *ORGANISATIONAL ROLE AND CAPABILITIES*

***Role of Organisation in EIA Preparation***

The role and capabilities of the organisations in EIA reporting was examined to identify their level of experience in EIA preparation, their use of spatial data and their subsequent knowledge of spatial data usage issues. 48% of the EIA organisations surveyed were seen to perform both roles of carrying out and preparing formal EIA reports, as well as contributing to various environmental analyses for EIAs. 35% of the organisations surveyed only carried out and prepared formal EIA reports while 17% of the organisations contributed to several environmental analyses. 83% of the surveyed population carries out and prepares formal EIA reports while 17% contributes to key environmental analysis that makes up EIAs (see Figure 4.2 below).

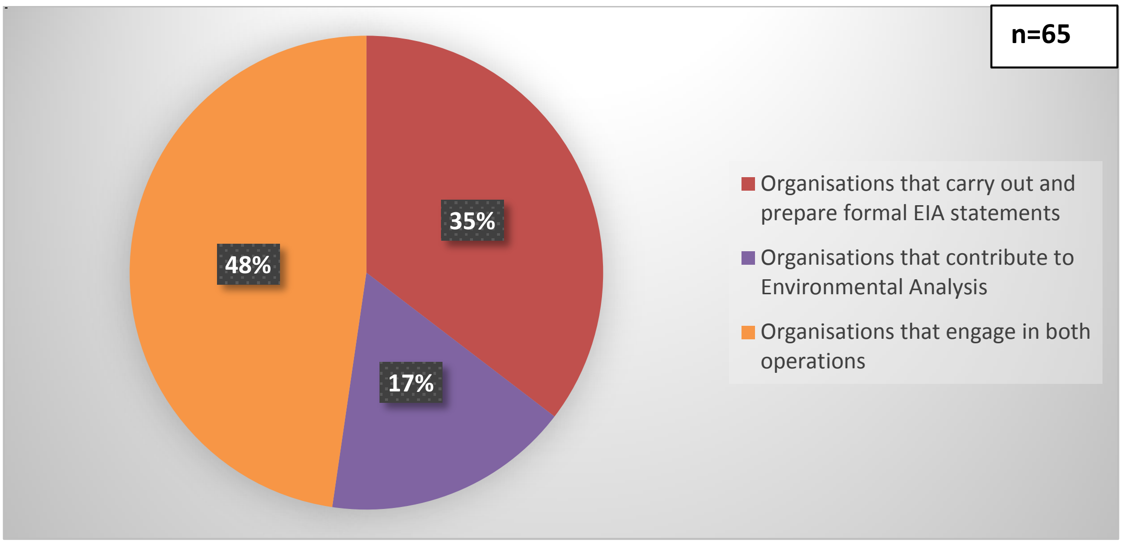



*Figure 4.2: Role of organisation in EIA preparation*

This justifies the experience and credibility of the respondents to answer questions regarding EIA reporting and the use of spatial data for EIA reporting in Nigeria's oil and gas sector. The experience and credibility of the respondents was further adjudged from the type of project EIA is prepared for, the number of EIAs they perform annually, the number of EIA preparers involved in the preparation of an EIA, the time taken to complete an EIA and the annual turnover the organisation accrues from EIA preparation. The majority (34.41%) of the EIA projects executed by the EIA preparers surveyed was conducted in the oil and gas sector; 14.16% of the EIA reported was done on oil and gas exploration, 11.11% on oil and gas production while 9.14% on oil and gas transportation.

Results also show a seemingly high percentage frequency for construction projects (9.68%), projects on environmental health (8.24%), disposal of waste (8.06%), the extractive industry (5.73%) and the energy industry (5.56%), which are sectors of industry with close relationship with the oil and gas sector. An oil and gas project involves a number of land surveys, construction works, environmental health, hazard and risk management, waste disposal, extraction works, chemical and mineral testing, as well as telecommunication installations before, during and after the project (see Figure 4.3).

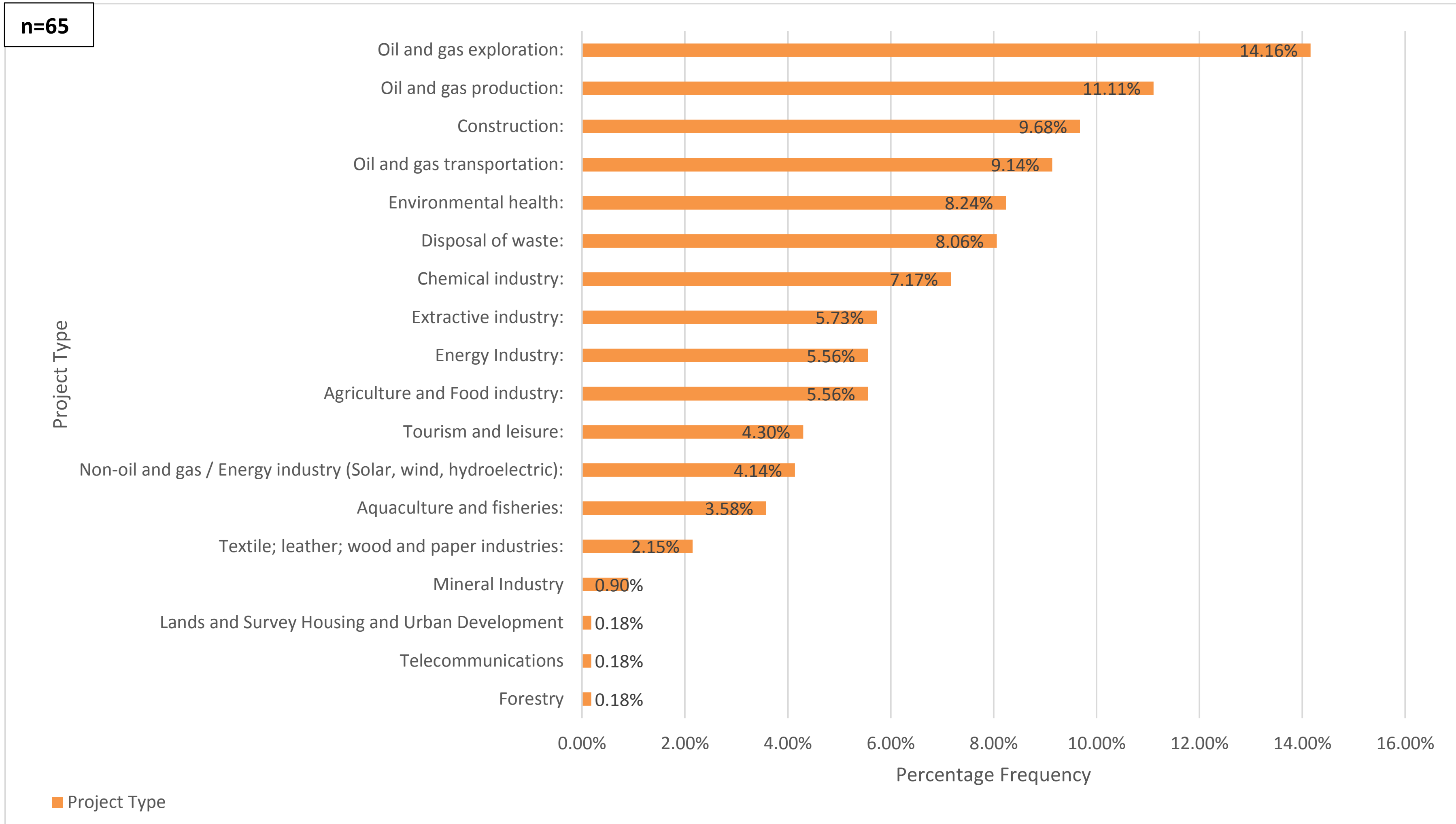



*Figure 4.3: Type of project for which EIA is reported*

#### 4.2.1.3 *EIA PREPARERS*

To justify the credibility of the surveyed organisations and the responses of the EIA preparers in these organisations, the survey went further to examine the staff involved in EIA preparation in the bid to ascertain the strength of the human resource researchers posit as an indicator for an organisation's capabilities (Antony, Malik and Blumenfeld 2012).

***Average Number of Full-time EIA Preparers***

As shown in Figure 4.4 below, the majority (36.40%) of the surveyed population indicated that 6-10 EIA preparers are actively involved in the preparation of an EIA report, while 21.60% of the organisations indicated that 1-5 EIA preparers are actively involved in the preparation of an EIA report.

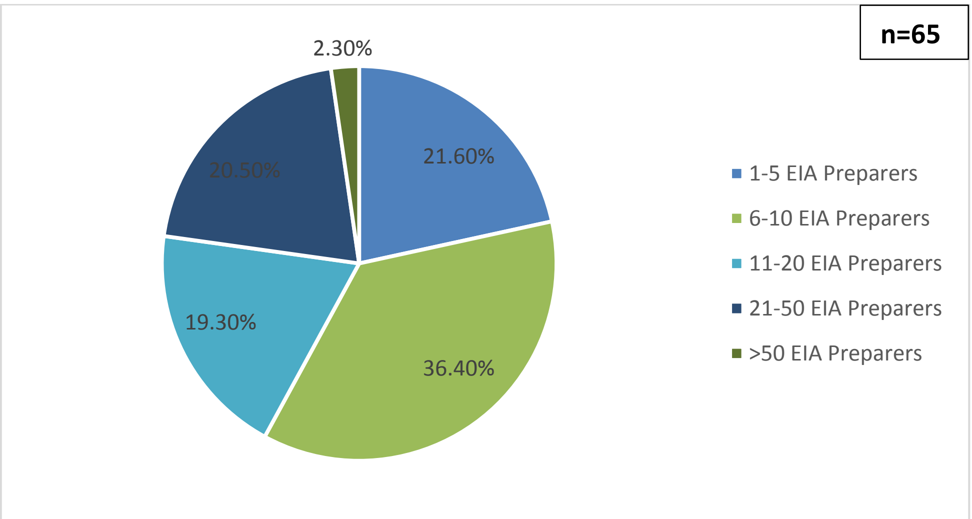



*Figure 4.4: Average number of full-time EIA preparers*

20.50% of the organisations are seen to have 21-50 people working on a report, while 19.30% are seen to have 11-20 people actively working on a report. Only 2.30% of the organisations indicated to have over 50 EIA preparers working on an EIA report.

### *Average Time Taken to Complete an EIA Report*

Figure 4.5 shows the average time it takes the surveyed organisations to complete an EIA report. 36.40% of the EIA preparers surveyed are seen to complete an EIA within 6 months to 1 year while 22.70% indicated that it took them 1 year to 2 years to complete an EIA. None (0%) of the EIA preparers indicated it took them longer than two years to complete an EIA. 2.30% of the population claimed to have completed an EIA report in less than 2 weeks, 5.70% within 2 weeks to 1 month, 17.00% within 1 month to 3 months and 15.90% within 3 months to 6 months. It is however important to note that the results contain responses from organisations that carry out or prepare formal EIA as well as those that contribute to environmental analysis for EIAs (see Figure 4.2).

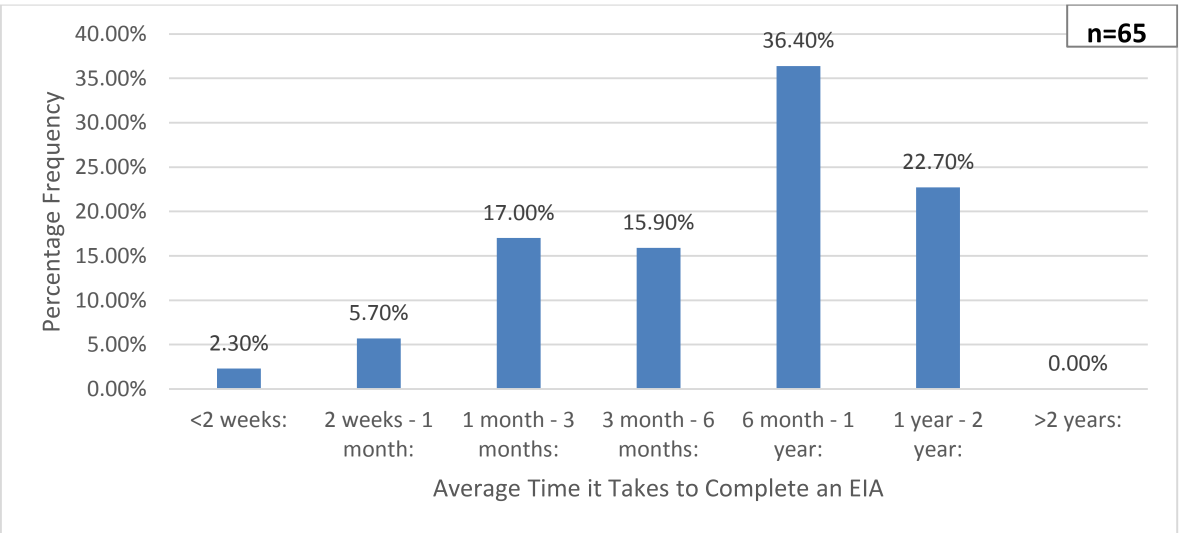
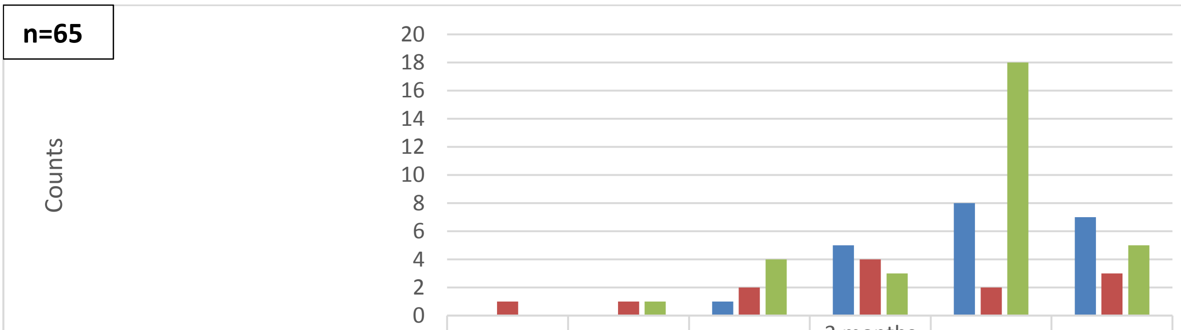



*Figure 4.5: Average time it takes to complete an EIA report*

A cross-tabulation of the role of the organisations surveyed with the average number of active EIA Preparers and the average time it takes to complete an EIA revealed that organisations that contribute to environmental analysis takes a shorter time to complete EIA reports (See Figure 4.6 below).

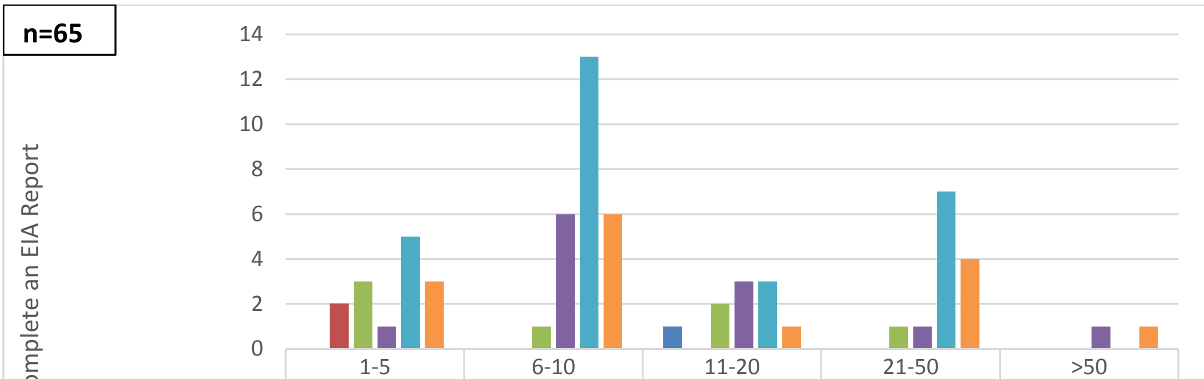



| | <2weeks | 2weeks - 1 month | 1 month - 3 months | 3 months - 6 months | 6 months - 1 year | 1 year - 2 years |
|---|---|---|---|---|---|---|
| Carry out and prepare formal EIA statements | 0 | 0 | 1 | 5 | 8 | 7 |
| Contribute to Environmental Analysis | 1 | 1 | 2 | 4 | 2 | 3 |
| Organisations that engages in both operations | 0 | 1 | 4 | 3 | 18 | 5 |

Time taken to Complete Operation

*Figure 4.6: Comparing the time taken to complete an EIA with the organisation's role in EIA preparation*

On comparing the time, it takes to complete an EIA in the surveyed organisations with the number of EIA preparers actively involved in the preparation, it was observed that a higher percentage (20%; 13) of surveyed organisations complete an EIA between 6months to 1 year with an average of 6 to 10 EIA preparers (see Figure 4.7). The organisation that claimed to have completed EIA reports in less than 2 weeks had an average of 11 to 20 EIA preparers working actively on an EIA report.




| | 1-5 | 6-10 | 11-20 | 21-50 | >50 |
|---|---|---|---|---|---|
| <2weeks | 0 | 0 | 1 | 0 | 0 |
| 2weeks - 1 month | 2 | 0 | 0 | 0 | 0 |
| 1 month - 3 months | 3 | 1 | 2 | 1 | 0 |
| 3 months - 6 months | 1 | 6 | 3 | 1 | 1 |
| 6 months - 1 year | 5 | 13 | 3 | 7 | 0 |
| 1 year - 2 years | 3 | 6 | 1 | 4 | 1 |

Frequency

*Figure 4.7: Average number of active EIA preparers in an organisation and the average time taken to complete an EIA report*

***Number of EIA Carried Out Annually***

Figure 4.8 shows the average number of EIA conducted in the surveyed organisations annually. 34.10% (30) of the organisations claimed to complete 1 to 5 EIA reports annually while 22.70% (20) claimed to complete 11 to 25 EIAs annually. As shown in the bar chart in Figure 4.6, none of the organisations is seen to complete over 500 impact assessments annually.

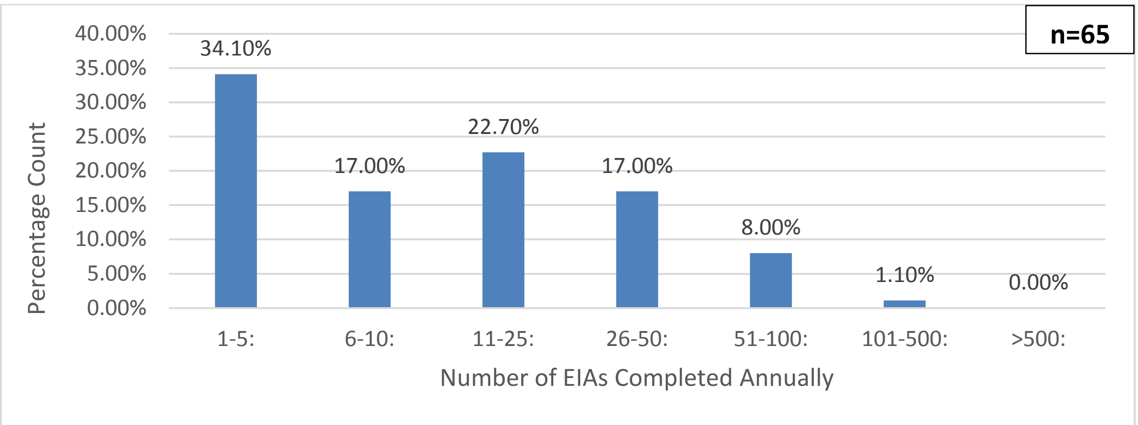



*Figure 4.8: Average number of EIAs carried out annually*

***Annual Turnover from EIA***

31.80% (28) of the surveyed organisations reported to generate between 20 million to 50 million Nigerian Naira as their annual turnover from EIAs. 28.40% (25) reported to amass below 20 million Nigerian Naira annually. 2.30% (2) of the organisations claimed to generate above 400 million Nigerian Naira annually while 1.1% (1) claimed to amass between 300 – 400 million Nigerian Naira annually (see Figure4.9).

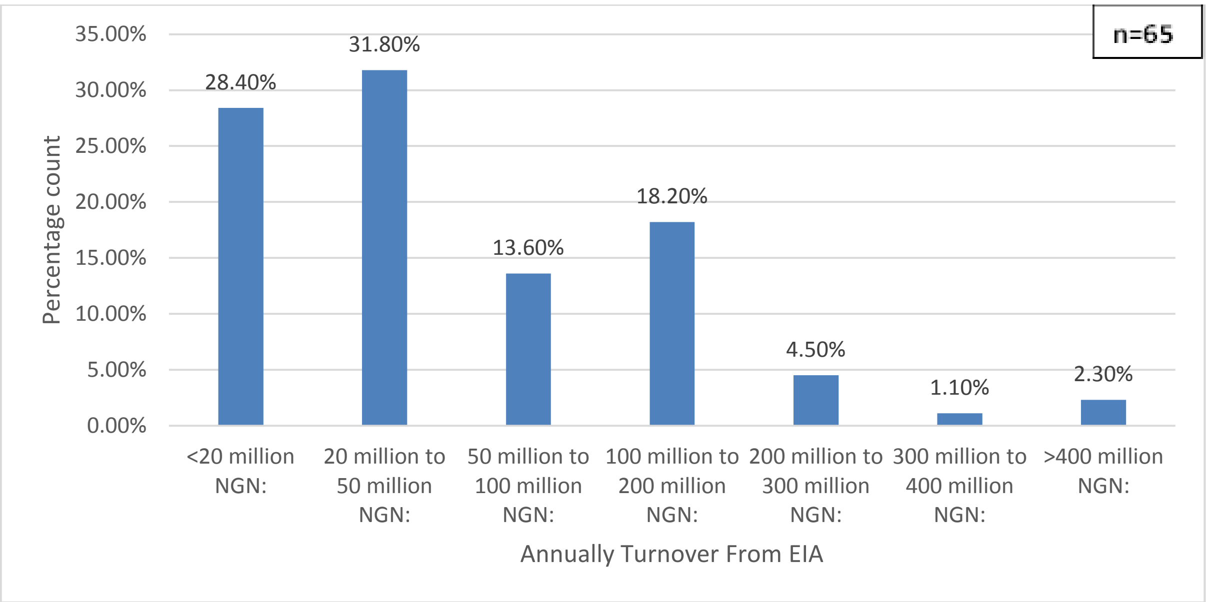



*Figure 4.9: Annual turnover from EIA*

***Experience with Cross-border EIAs***

Figure 4.10 illustrates the experience of the surveyed population with cross-border EIA preparation. 48.9% of the surveyed population claimed to have experience with cross border EIA while 51.10% indicated they had no experience with cross border EIAs.

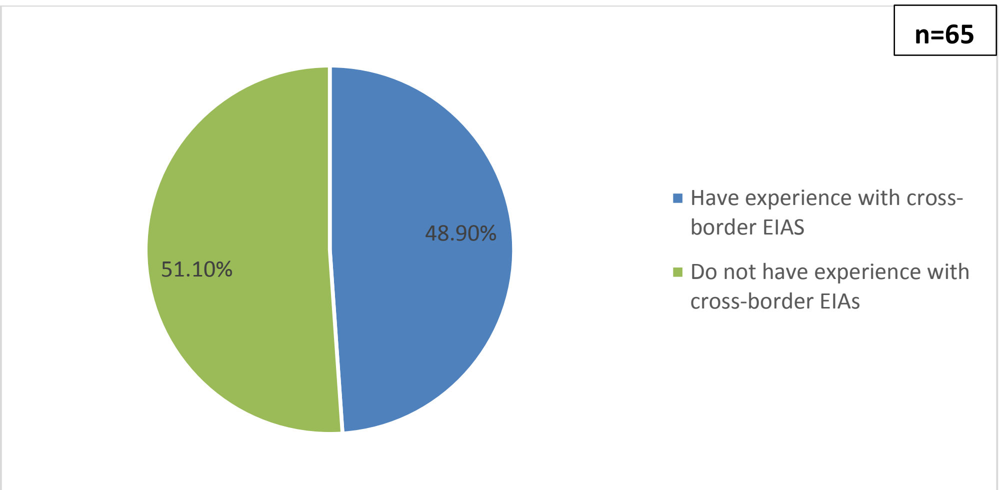



*Figure 4.10: Experience with Cross-border EIA*

### 4.2.2 EXPERIENCE OF EIA PREPARERS WITH SPATIAL DATA

This section explored the experience of the EIA preparer with the use of spatial data when preparing EIA reports. It also highlighted the types and sources of spatial data utilized by EIA preparers, as well as the difficulties associated with spatial data use.

#### 4.2.2.1 *SPATIAL DATA*

Figure 4.11 shows the types of spatial data frequently used by the surveyed organisations to prepare EIAs in Nigeria's oil and gas sector. The responses were ranked in order of their frequency count. Data on population distribution – demography ranked as the most utilised by practitioners followed by land cover data, data on human health and safety, coordinate reference systems, atmospheric conditions, habitats and biotopes, environmental monitoring systems and protected sites.

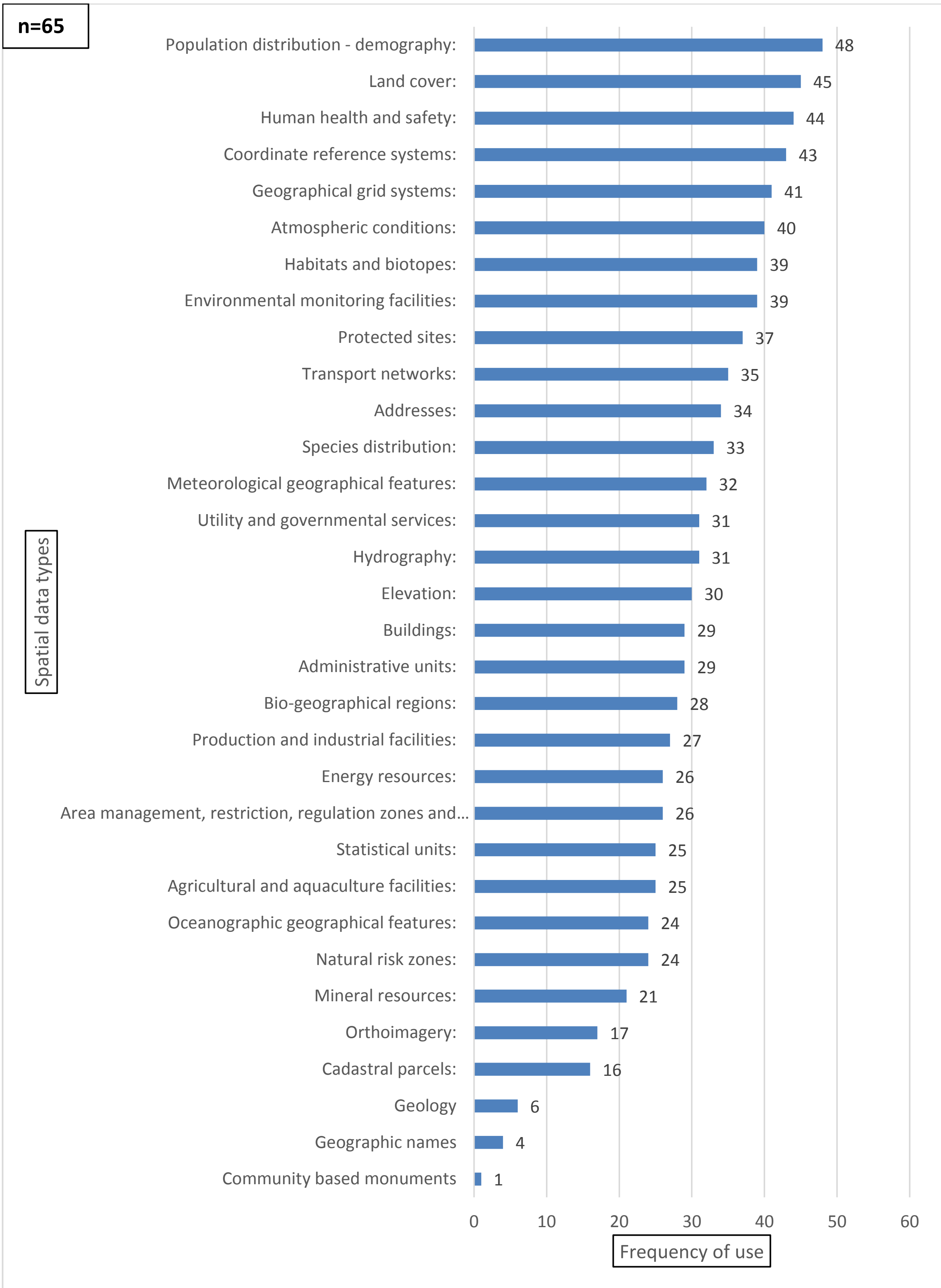



*Figure 4.11: Frequently used spatial data types*

Spatial data on geographic names, geology, cadastral parcels, orthoimagery, mineral resources, production and industrial facilities, natural risk zones, energy resources and oceanographic features are observed to be used less frequently than necessary as they are considerably very useful elements for impact prediction. Ascertaining the cause of the reduced usage and improving the access of EIA preparers to these spatial datasets is considered essential to the improvement of EIA quality.

#### 4.2.2.2 *Sources of Spatial Data*

Figure 4.12 shows that the most common sources of the spatial data for EIA preparation in Nigeria's oil and gas sector were environmental protection agencies, geological surveys and personally produced spatial data for EIAs. The ranking also shows that sourcing of data from mapping agencies and private data producers is also common among these organisations.

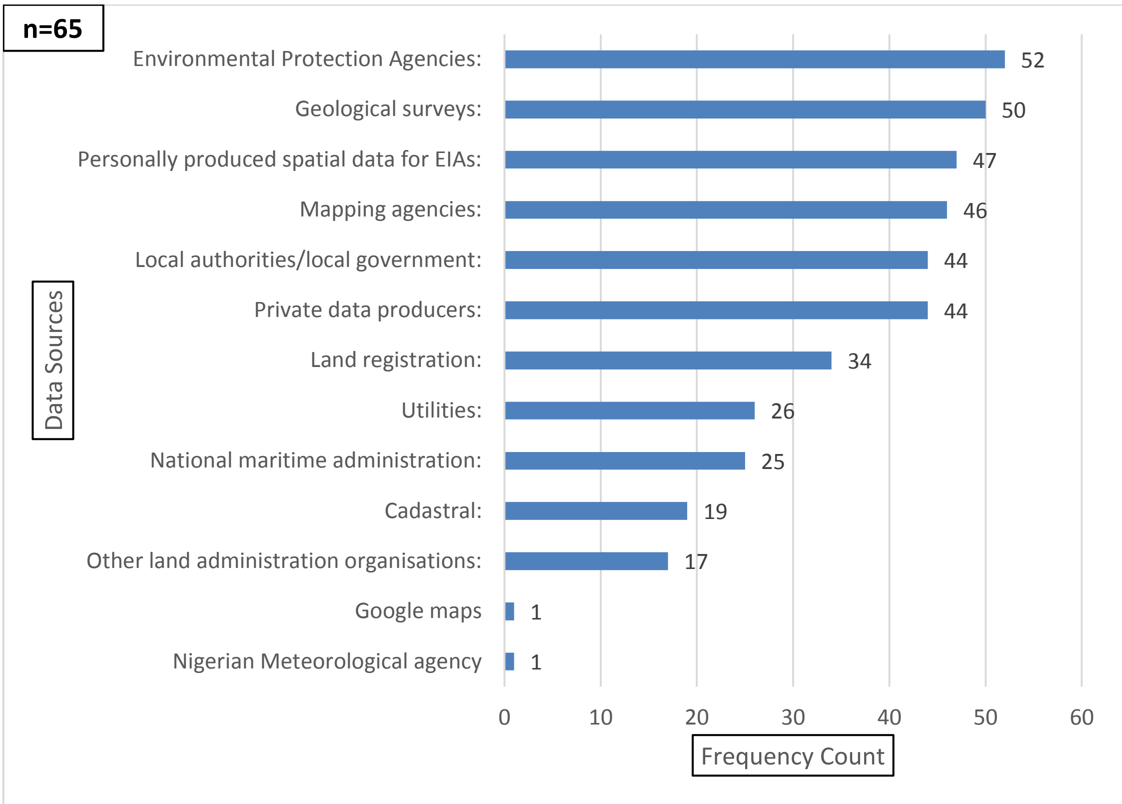



*Figure 4.12: Sources of spatial data*

It is interesting to note that while geological survey was mentioned as the second most common source of data, Figure 4.11 shows that geology as a category of spatial data was comparatively low terms of frequency of use. The data most frequently used in the surveyed organisations are data more associated with human and environmental factors like population, land cover, as well as human health and safety. Though these datasets are useful for EIA preparation, geological data from geological surveys are also very essential. They are important for conducting a comprehensive investigation, mapping and appraisal of the soil and rock components of the surveyed environment as it affects the land use, ground water, mineral soil, among other components. The low use however reflects poorly on the quality of EIA conducted as it suggests that the preparers are not extracting the highest possible benefit from geographic data by under-using important available information. This also suggests that that the EIA conducted are not thoroughly conducted line with industry best practices and thus it puts to question the quality of EIAs conducted in Nigeria. On the other hand, the variation in the frequency of use of the different sources of spatial data reflects the presence of challenges facing organisations in obtaining the relevant data needed for EIA preparation hence they obtain bits of what is needed from various sources. This also brings to question the sufficiency of the current sources of data for EIA reporting.

63% (46) of the respondents asserted that the current sources of spatial data was insufficient for EIA reporting while 37% (27) claimed the sources were sufficient for EIA reporting (See Figure 4.13).

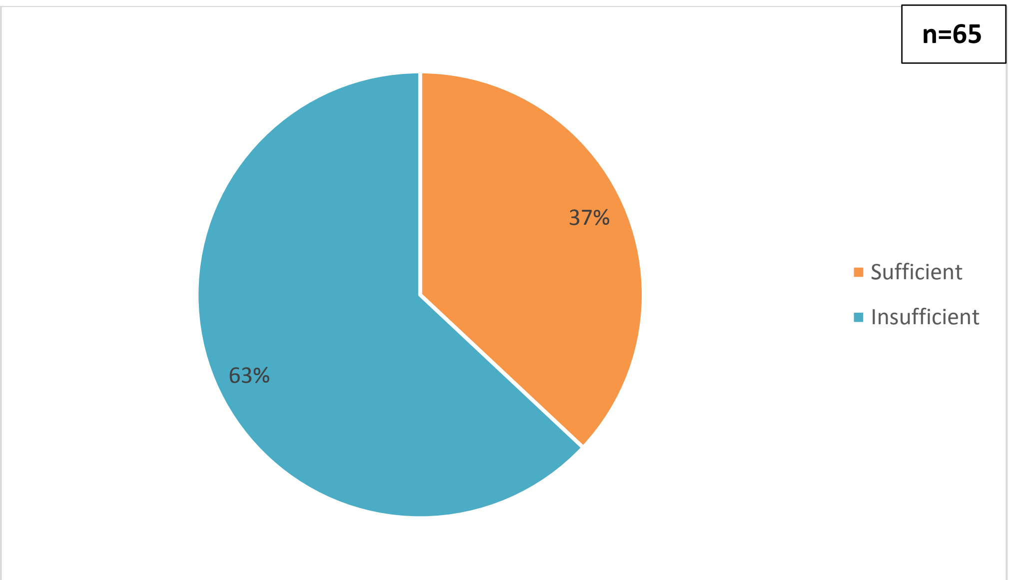



*Figure 4.13: Sufficiency of current spatial data sources for EIA reporting*

The percentage of preparers that asserted the insufficiency of the data sources is significantly higher than those that claimed it is sufficient, hence we can infer that on the average, the current state of the sources of spatial data for EIA preparation is not sufficient for EIA preparation. From the results, it can also be purported that, in completing EIA in Nigeria's oil and gas sector, EIA preparers will have to obtain data from multiple sources as well as produce or manipulate data to complement for the unobtainable units. This is a fundamental challenge to EIA preparation in Nigeria.

#### 4.2.2.3 *Spatial Data Utilization*

Spatial data was reportedly used for a number of EIA activities including; the identification of impacts, the visualisation of impacts and the presentation of impacts. Results also reflect that spatial data was utilized in conducting simple analysis and complex analysis for forecasting of impacts using modelling, scenario analysis and other relevant analysis. The variation in the frequency of usage is small as shown in Figure 4.14 thus emphasising the relevance of all four activities represented in the chart. To this end, ensuring the easy and accurate conduct of these activities with regards to its use of spatial data is fundamental to overcoming the challenges often obstructing EIA reporting.

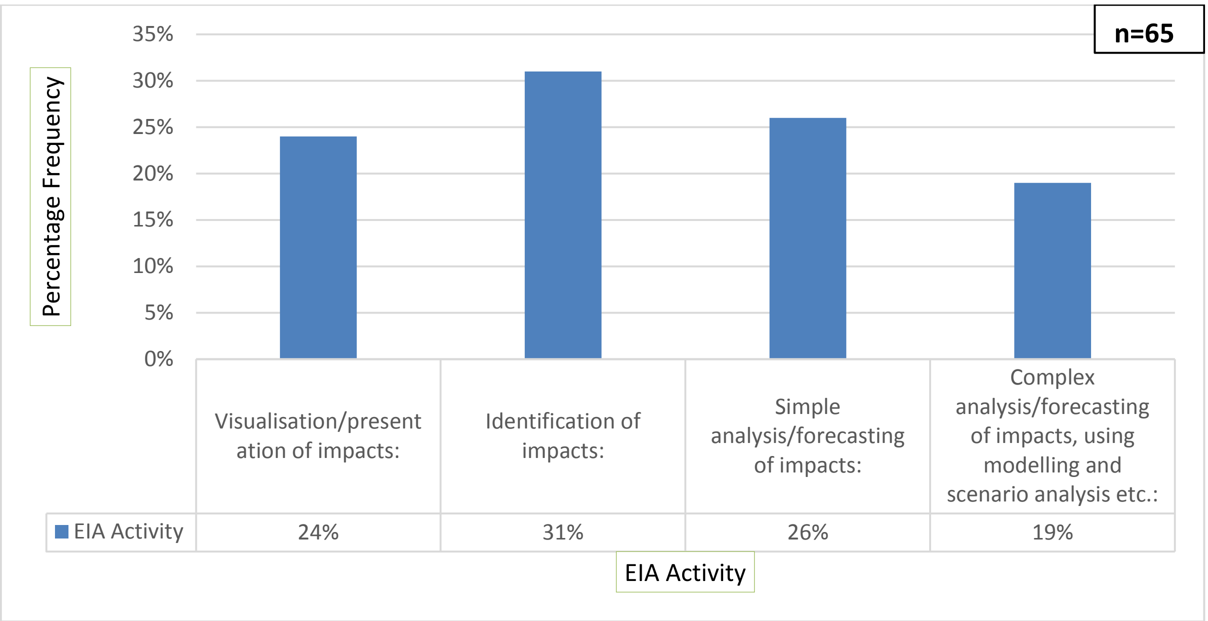



*Figure 4.14: Type of EIA activity spatial data is used for*

The study further sought to ascertain the quality and accuracy of impact predictions in the reporting of EIAs in Nigeria's oil and gas sector as this provides an overview of the quality of EIAs reported. To this end, respondents were quizzed on their engagement in predictive modelling of impacts. Predictive modelling enables the estimation of possible impending and unknown impacts by making prognosis and projecting from known data, relationships, patterns and impacts (Gontier, Mörtberg and Balfors 2010). It combines existent data with ecological and environmental variables to create a model of the requirements for the examined variables. The prediction of environmental impacts, the development of predictive models from the use of various computer and simulation models provides a more reliable set of impact predictions. It makes use of computer systems like GIS to digitize the necessary map data, and apply probabilistic-based predictive models like regression and other validity tests. A significantly higher number

(84.62%) of the organisations claim to engage in predictive modelling of impacts than do not (15.38%). See Figure 4.15 below.

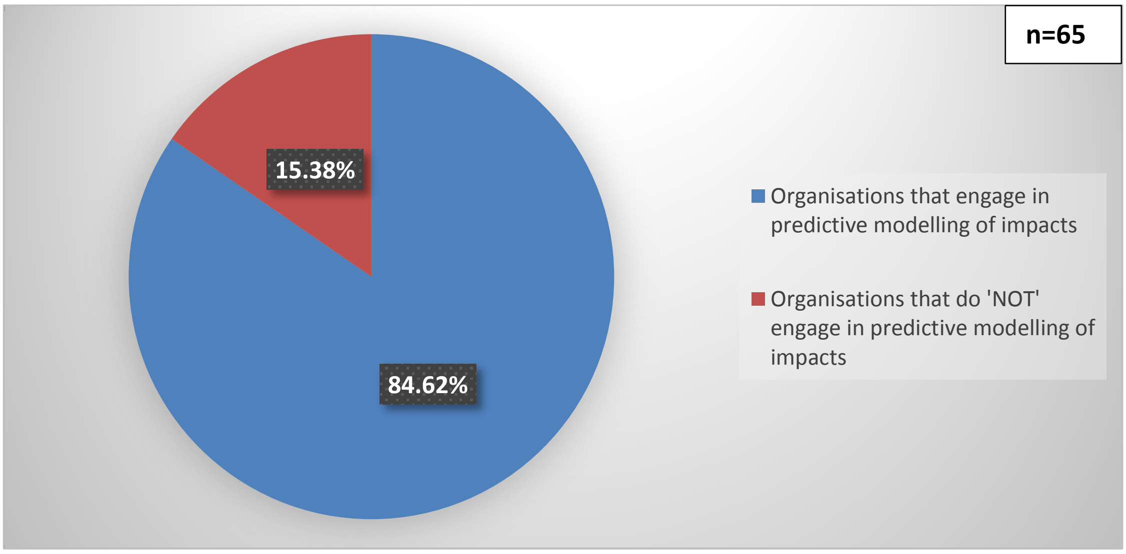



*Figure 4.15: Engagement in predictive modelling of impacts*

Respondents established that engaging predictive modelling does not only help to identify the full worth of the effects of project activities long in advance, but it also enables a more effective forecasting, planning and management decision making. One of the respondent who stated that their organisation does not engage in predictive modelling of impacts blamed this on the “inaccessibility of data” to conduct predictive modelling. None of the respondents expressed ignorance to the use of predictive modelling for impact assessment and this contradicts the assertion by Ogunba (2004), that ‘most EIA consultant firms operating from FEPA and the DPR are aware of predictive modelling but do not employ them’. Arguably, this change in their awareness and use of predictive modelling for impact analysis could be attributed to possible advancements and maturity the EIA organisations in Nigeria over the past decade.

The respondents however noted that in the engagement of predictive modelling of impacts, they tend to improvise some of the needed data by summing up data from several sources to cover the inconsistencies with the sourcing and use of spatial data. Arguably, this can reduce the level of accuracy of describing impacts, increase the uncertainty of impact prediction, increase the cost of conducting EIA studies, increase the time taken complete an EIA and cumulatively reduce the quality and credibility of the EIA report. This is because the reported EIA will be packed with assumptions, approximations and less fact. An EIA report that is produced using the accurate baseline data will be more credible than that produced from the summation of bits of data from different sources that may not be very reliable. To this end, this research goes on to explore the current challenges facing EIA preparers with the use of spatial data.

#### 4.2.2.4 *Difficulties with the Use of Spatial Data*

Figure 4.16 shows the assertions of the respondents on the difficulties with the use of spatial data. 58.50% of the respondents asserted that spatial data is ‘not’ difficult to use while 41.50% of the respondents claimed that spatial data was difficult to use.

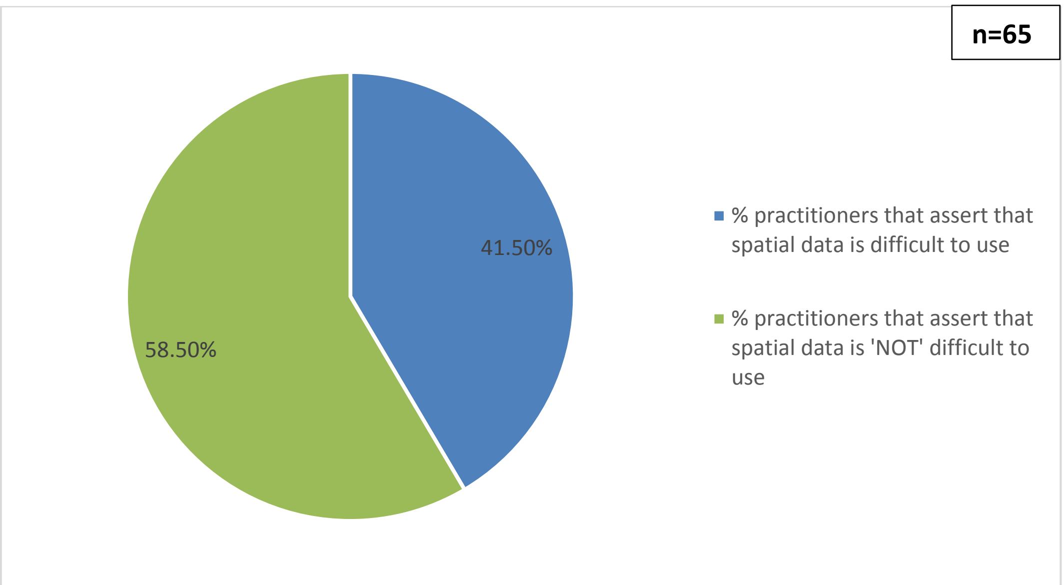



*Figure 4.16: Difficulties with the use of spatial data*

Some of the causal factors of the purported difficulties were identified to include difficulties in finding it, accessing it, integrating it with other data, its quality and its cost (See Figure 4.17 and 4.18).

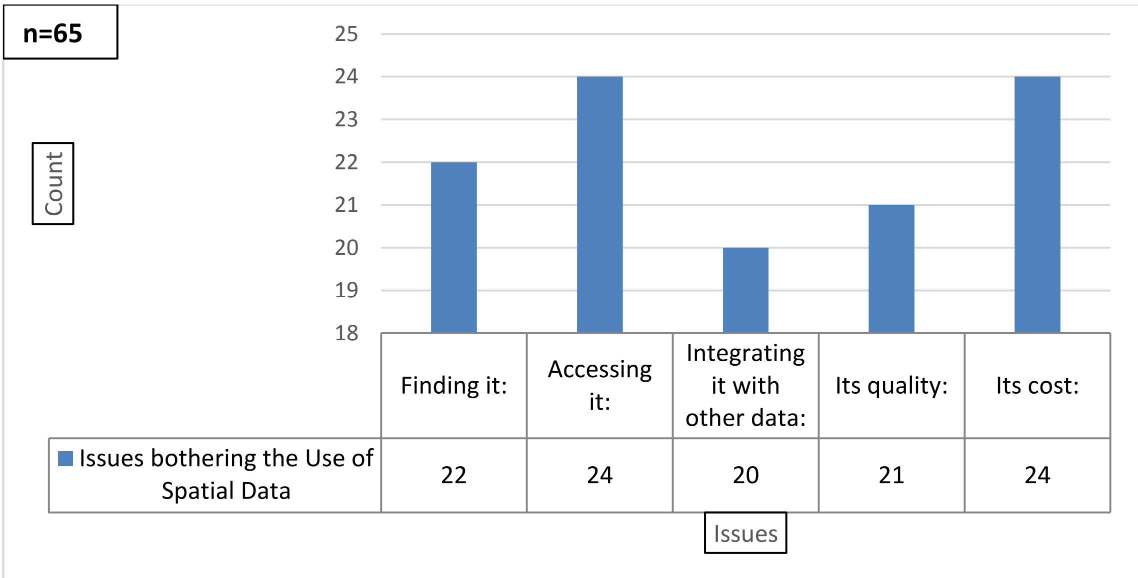



*Figure 4.17: Factors hindering spatial data use*

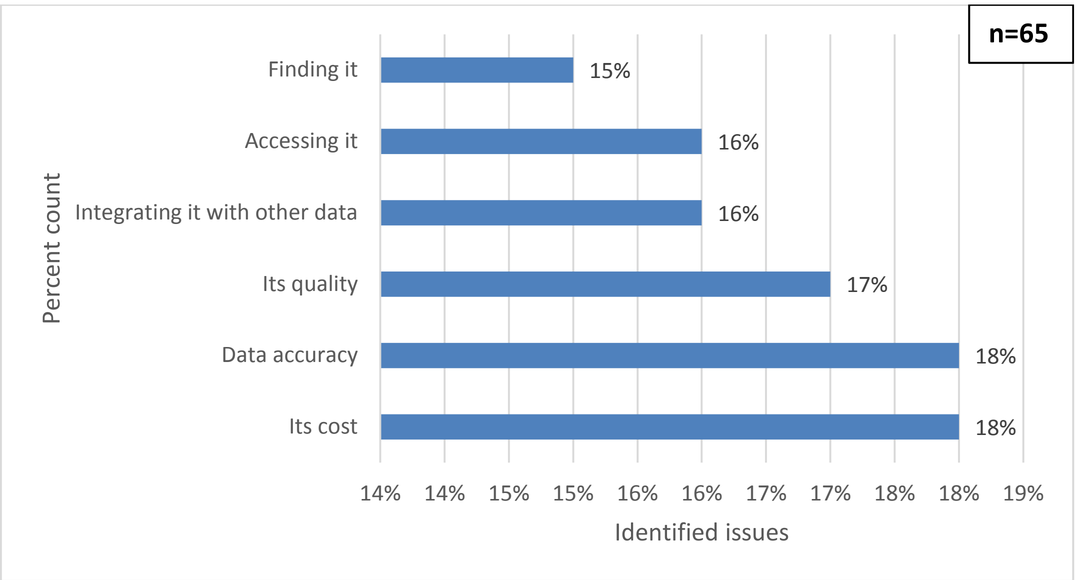



*Figure 4.18: Factors hindering spatial data use in percent count*

The variation between frequency counts of the highlighted issues is seen to be small, thus giving an averagely equal importance to all stated issues. That is, in order to overcome the factors hindering spatial data use in EIA reporting, viable frameworks need to be put in place to improve data sourcing, access, integration, quality and cost effectiveness. 73.80% of the surveyed organisations claimed to reuse spatial data that was acquired for one EIA report to produce other EIA reports while 26.20% of the surveyed population asserted that they do not reuse spatial data (see Figure 4.19). The reuse of spatial data reduces the duplication of efforts that often follows the repeated collection and reproduction of spatial data. It also highlights the possibilities of data sharing through instituted sharing partnerships and the subsequent storage and dissemination of spatial data.

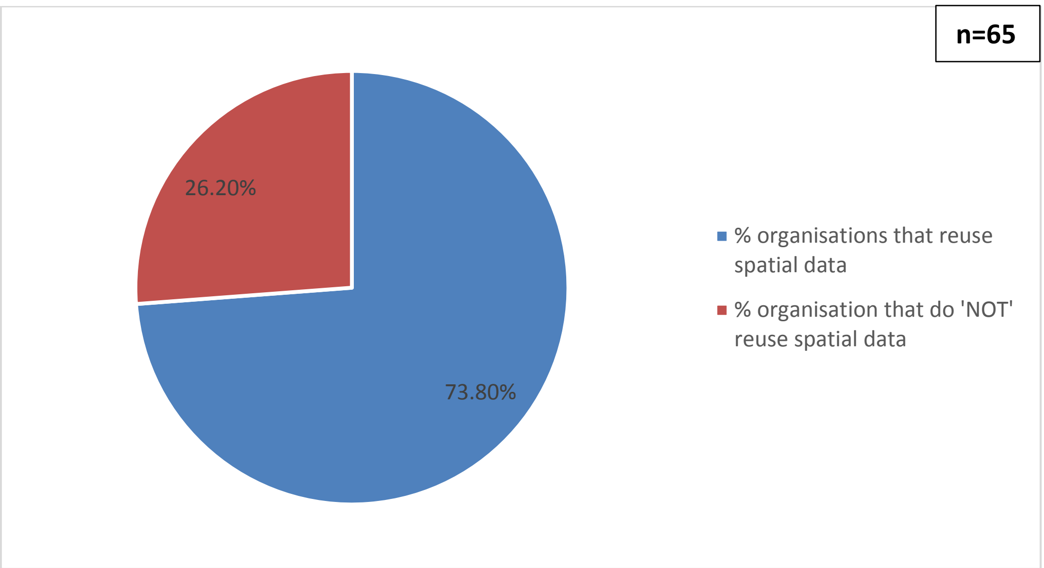



*Figure 4.19: Participants' reuse of spatial data*

The consequences of these issues on EIA reporting were also assessed. Participants highlighted that these issues with spatial data result in a lower level of accuracy when describing impacts, higher uncertainty of impacts, higher costs of studies and also increases the time taken to complete an EIA. These key effects were ranked according to the respective frequency counts and are presented Figure 4.20. The ability of the spatial data issues to lower the accuracy of impacts has the highest frequency count (31.29%) among the EIA preparers as shown. The variation between the frequency counts is considered small. Thus it can be inferred that the effect of all four categories as shown in Figure 4.20 is averagely equivalent.

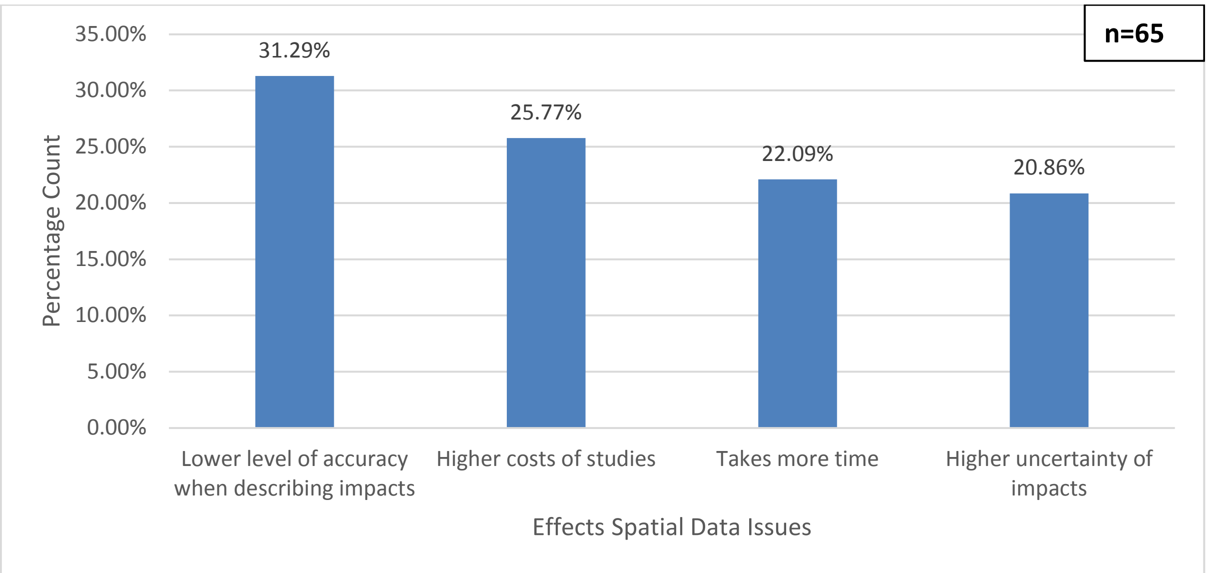



*Figure 4.20: Effects of spatial data issues on EIA reporting*

This was further assessed in relation to its effect in addressing the problem of non-testable and non-auditable predictions. EIA preparation in Nigeria has been classified as a rather qualitative prediction and analysis of potential impacts as against the standard rigorous quantitative and computational predictions, analyses, modelling and forecasting of impacts (Ogunba 2004). This is further underscored by the position of Anifowose et al. (2014) in their evaluation of pipeline interdiction using EIAs. They purported that majority of the EIAs reported in Nigeria's oil and gas sector showed 'no evident of rigorous analyses', thus suggesting that the predictions are mostly non-testable and non-auditable. The scientific testability and auditability of impact predictions is considered fundamental to the accuracy of the predicted impact and subsequently the EIA report (Anifowose et al. 2014, Briggs and Hudson 2013). The predictive technique employed, the scoping and baseline conditions, and the accuracy of data utilised has been highlighted as fundamental determinants of the testability and auditability of predicted impacts (Anifowoseet al. 2014, Noble and Storey 2005). Thus predictions generated from non-factual data or in cases where a majority of the data has been manipulated, estimated or over-approximated will likely be non-testable and non-auditable and this could hinder other follow up programs and environmental management plans.

Figure 4.21 shows that 6.2% of the surveyed EIA preparers did not agree that the access to spatial data will help address the problem of non-testable and non-auditable predictions while a greater number of 93.80% agreed that the access to spatial data will help address the problem.

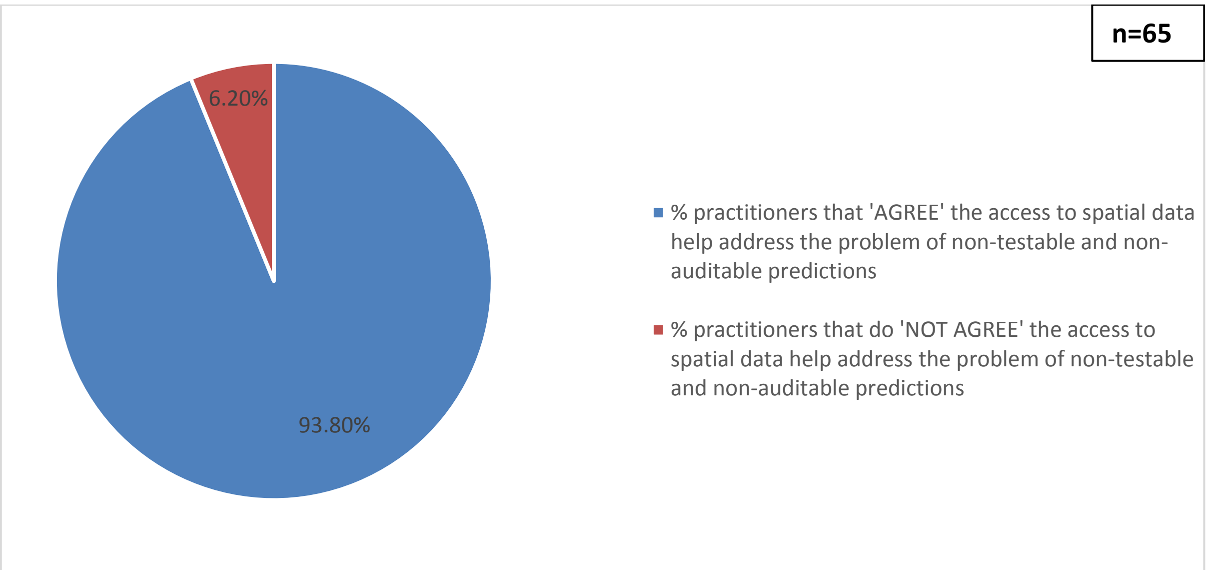



*Figure 4.21: Effect of spatial data access on addressing problem of non-testable and non-auditable*

### 4.2.3 THE EMERGENT NGDI AND CONSTRAININGFACTORS

This section emphasises the inherent factors that constrain the use of geospatial data for EIA preparation in Nigeria's oil and gas sector. It highlights the role of the regulators, preparers and oil companies, as well as their contributions to the issues currently being experienced. It also emphasises the role of the emerging NGDI in alleviating the problems of spatial data use. Emphasis was placed on the effectiveness of the current spatial data infrastructure and suggestions for possible improvements.

#### 4.2.3.1 *FAMILIARITY WITH THE NGDI*

61.5% of the surveyed population claimed to be familiar with the NGDI while 25% purported they were not familiar with the NGDI. However, a smaller percentage of the practitioners (13.8%) acknowledged having adequate access to the NGDI while the majority of the practitioners (86.2%) admitted that they do not have adequate access to the NGDI (see Figure 4.22). They maintained that the NGDI protocols appear not to be properly institutionalised and communicated to the relevant stakeholders as there are arguably limited or no partnership arrangements for data access through the clearinghouse of the NGDI. The NGDI was said to be inadequately developed with serious augmentations needed in the development of its clearinghouses to make it more accessible. Several inadequacies of the management agencies were highlighted and the need for proper coordination was put forward.

In the bid to validate the response of the EIA preparers on their access to the NGDI, the results were cross tabulated with their familiarity with the NGDI. The results as shown in the chart below confirmed that some EIA practitioners that were not familiar with the NGDI claimed to have access to the NGDI.

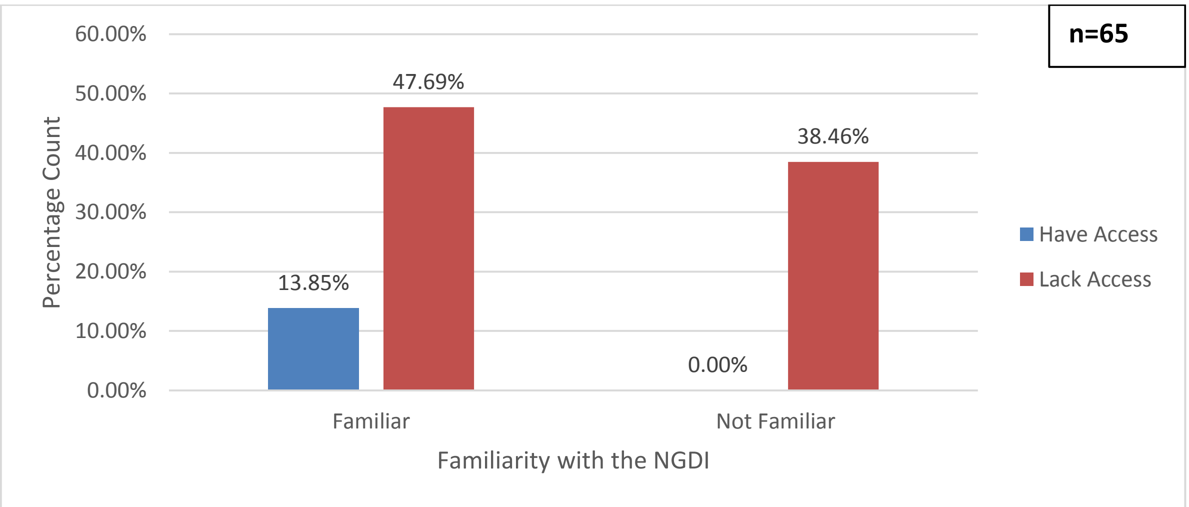



*Figure 4.22: Comparing the familiarity of EIA preparers with their access to NGDI*

#### 4.2.3.2 *EFFECT OF THE NGDI STATE ON THE QUALITY OF DATA USED FOR EIA*

90.8% of the population admitted to the insufficiency of the current protocols and procedures in the Nigerian NGDI to support the geospatial data needs of EIA practitioners in the oil and gas sector while 9.2% claimed the NGDI was sufficient (see Figure 4.23)

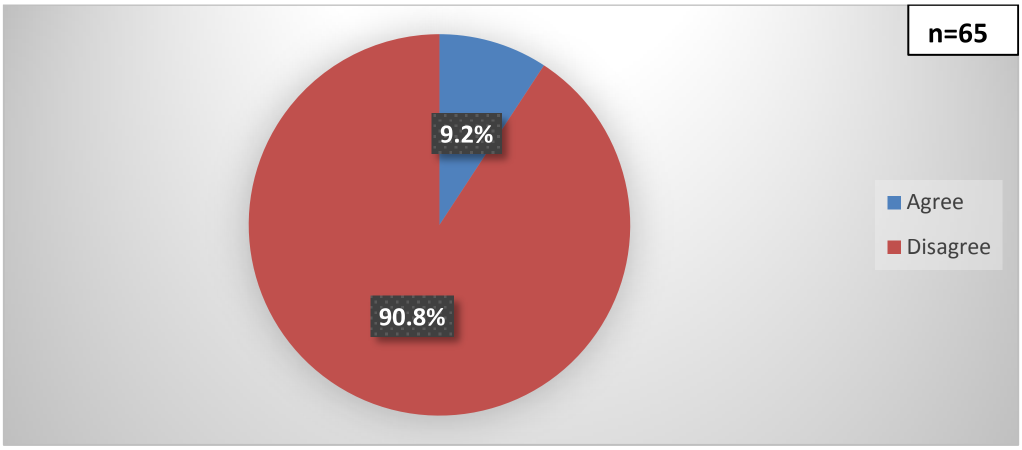



*Figure 4.23: Agree the NGDI is sufficient*

Similarly, 80% of the EIA organisations agreed that the state of the NGDI affects the quality of data used for EIA and subsequently the effectiveness of EIA reports in the oil and gas sector while a minimal number of practitioners (20%) disagreed (see Figure 4.24).

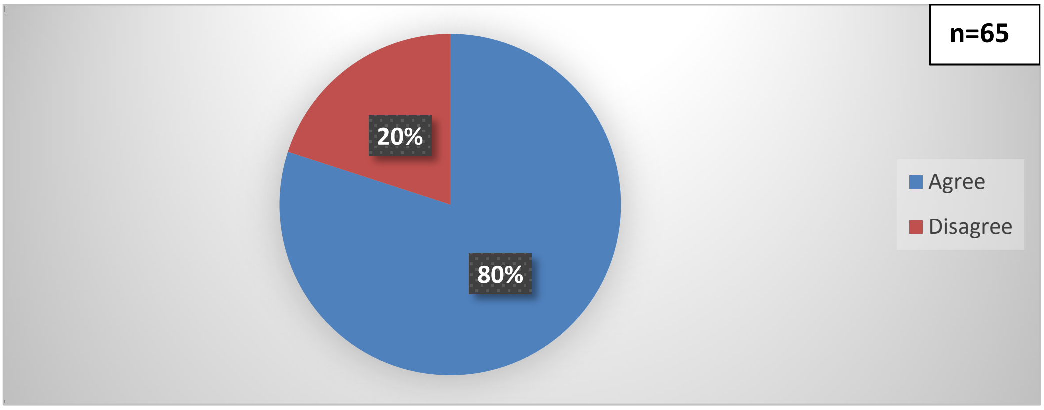
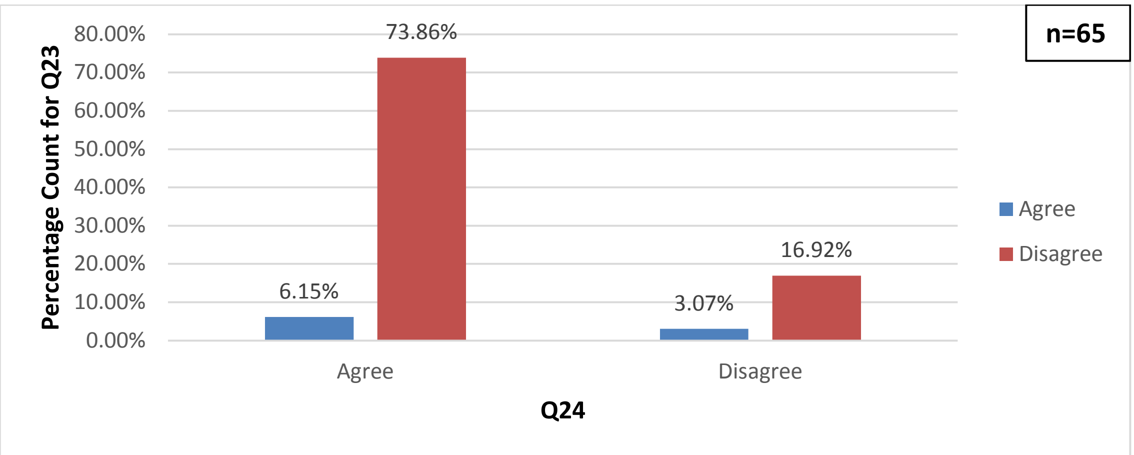



*Figure 4.24: State of the NGDI affects the Quality of Data used for EIA*

The results were cross tabulated in Figure 4.25 to show variation in the responses of the EIA preparers to these two key issues as it is an indicator to the relevance of NGDI to EIA preparation as well as the state of the NGDI.




**Keys:**
**Q23** = Agree the state of the NGDI affects the quality of data used for EIA and subsequently the effectiveness of EIA reports in the oil and gas sector
**Q24 =** Agree the current protocols and procedures in the NGDI is sufficient to support the geospatial data needs of EIA practitioners in the oil and gas sector

*Figure 4.25: Chart showing results of the cross tabulation of Q23 and Q24*

Further to this, the respondents were asked to rate the effectiveness of the current NGDI protocols. The results show that 36.90% (24) of the populated rated the current NGDI as ineffective, 30.80% (20) rated it to be less effective while 24.60% (16) claimed it was moderately effective. None (0) of the respondents rated the NGDI to be very effective but a minimal number of preparers 7.7% (5) claimed it was effective (see Figure 4.26).

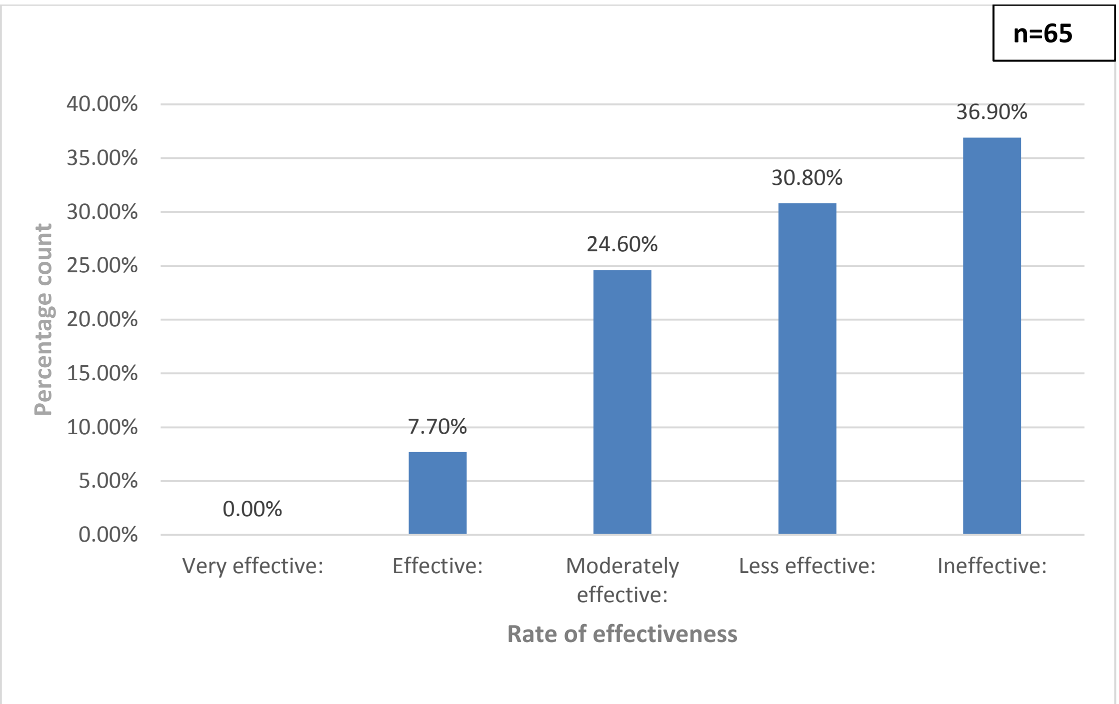



*Figure 4.26: Rate of effectiveness of the current NGDI protocols*

On checking the results with the EIA preparers that are familiar with the NGDI, it was discovered that preparers that are unfamiliar with the NGDI rated the NGDI poorer than those with access to the NGDI (see Figure 4.27).

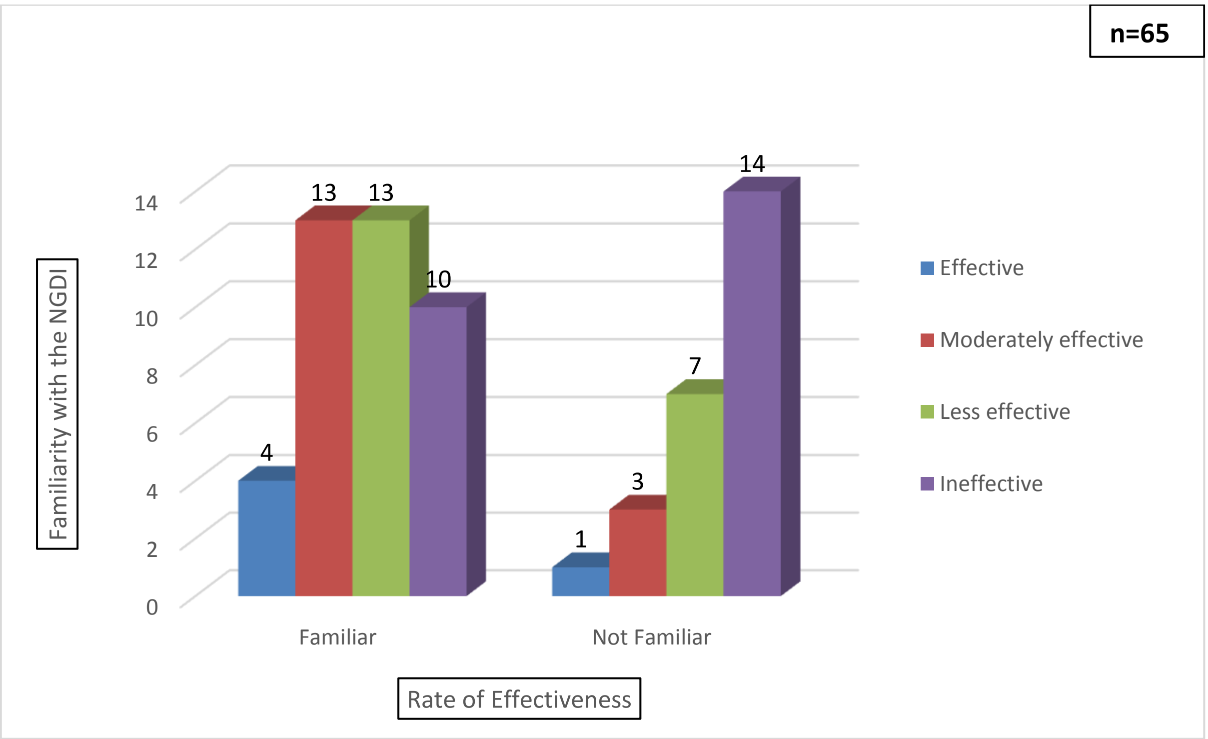



*Figure 4.27: Chart showing cross tabulation of preparers rating of the NGDI effectiveness with their familiarity to the NGDI*

The results presented in Figure 4.27 above further reiterates the need to improve level of awareness and subsequent access so as to achieve the overall goal of an NGDI which is to enable the effective dissemination of standardized spatial datasets. It was also observed that one of the EIA preparers that stated unfamiliarity with the NGDI rated the NGDI as effective while three others rated it to be moderately effective on the grounds that the NGDI was still in its implementation stage with a lot of prospects for augmentation (see Figure 4.27).

On further exploration of the data to assess participant's affirmation of the NGDI effectiveness with their access to the NGDI, it was observed that majority of the participants who claimed to have access to the NGDI rated the NGDI higher than those who lacked access (see Figure 4.28).

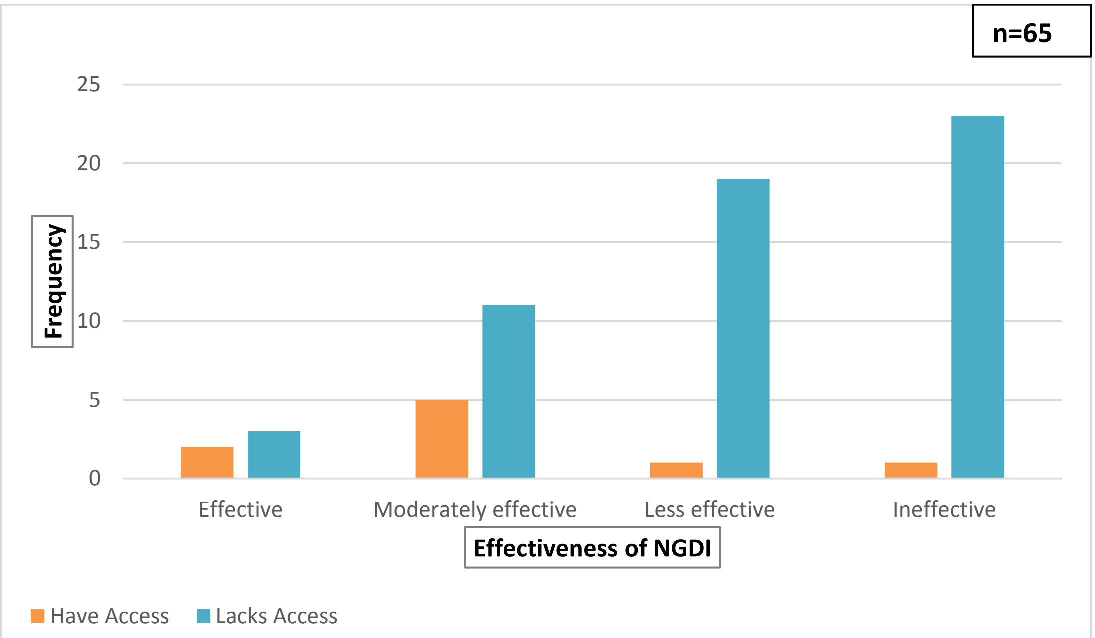



*Figure 4.28: Chart showing cross tabulation of preparers rating of the NGDI effectiveness with their access to the NGDI*

### 4.2.4 EFFECT OF NGDI ON EIA

This section focuses on assessing the effect of the emerging NGDI on EIA preparation and the quality of EIAs prepared in Nigeria. It also presents the suggestions proffered by the participants to facilitate a better implementation of the NGDI to benefit EIA preparation.

#### 4.2.4.1 *QUALITY OF EIA REPORTING*

47% of the EIA preparers surveyed claimed the EIA carried out in the Nigerian oil and gas sector are done in strict adherence to industry best practices while 52.30% disagreed with this position (See Figure 4.29 below).


*Figure 4.29: Perception of the Quality of EIA in accordance with industry best practices*

#### 4.2.4.2 *EFFECTIVENESS OF EIA REGULATION*

Analysis of the responses revealed that that 56.90% of the practitioners affirmed that the dual jurisdiction of EIA regulation is an effective approach while 43.1% disagreed (see Figure 4.30). The consultants in support of the dual jurisdiction of EIA regulation allege that the dual jurisdiction allows for validation of EIA claims and predictions. They also claimed that the harmonisation of the recommendations from both regulators enables a more detailed environmental management plan. They further stated that it enables the required checks and balances to aid a more accurate EIA report on the grounds that the high scrutiny enhances the quality of the EIAs reported.

On the other hand, the consultants that disagreed with the existence of the dual jurisdiction of EIA regulation in Nigeria's oil and gas sector stated that the current protocol results in numerous conflicts of interest and unhelpful bureaucracies that leads to different interpretations and recommendations from regulatory bodies which hinder the development of an environmental management plan. They further reiterated that the multiple EIA jurisdictions increases the time and cost of completing EIAs.

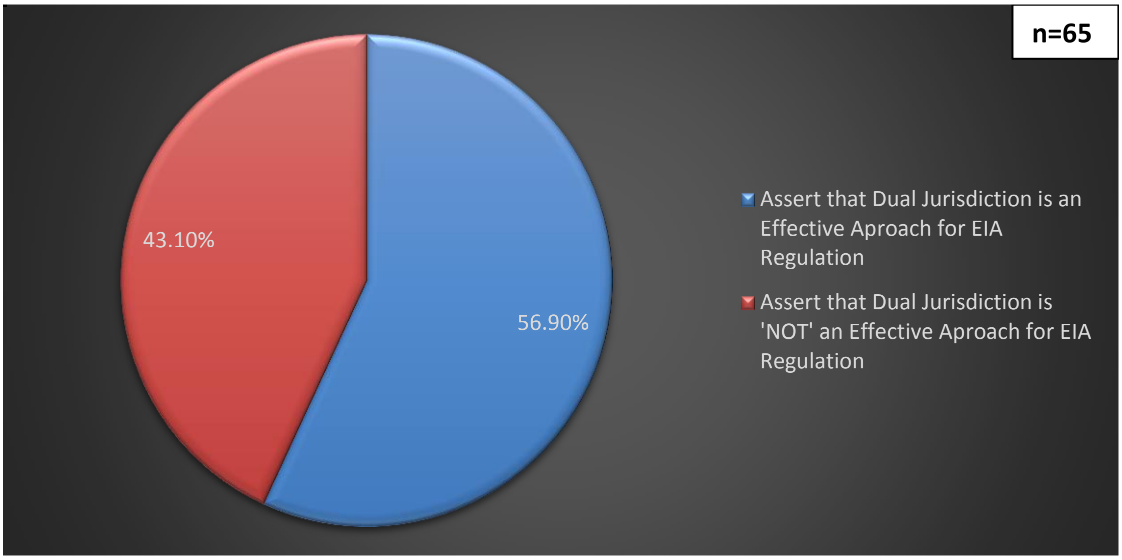



*Figure 4.30: Perception of the effectiveness of the dual jurisdiction of EIA regulation in Nigeria*

In consideration of the highlighted issues, it can be argued that the current jurisdictional arrangement has its benefits but requires a more adequate management to be more effective. Thus it may not be right to say that the dual jurisdiction in itself results in the poor quality of EIA reporting in Nigeria but contributes to the problem, alongside other cogent cumulative factors. However, it can be argued that the deployment of a unified system with a more effective institutional arrangement with clearly defined focus and roles of the respective regulators should improve the process.

Issues of data quality and effective utilization have been recorded to affect the quality of EIA in literature (González et al. 2011, Heinma and Põder 2010). An effective approach to EIA reporting and implementation therefore will be the development of an effective regulatory system that will not only deal with the economic benefits from the oil and gas sector as queried by the surveyed practitioners, but one that will consciously reinforce and monitor the spatial data inputs in the EIA process. To this end, this research went further to analyse the issues surrounding the spatial data sourcing and utilization for EIA in Nigeria's oil and gas sector in the bid to characterize the current effectiveness of the NGDI and its ability to augment the EIA process.

### 4.2.5 PRIMARY SOURCE OF THE EIA REPORTING ISSUES

31.91% of the preparers claimed the government (regulators) were the primary source of the issues limiting the effective and accurate reporting of EIA in Nigeria's oil and gas sector, 18.09% attributed these issues to the oil and gas operators, 14.89% attributed it to the EIA practitioners while 35.11% attributed the issues to have emanated from all the stakeholders involved (see Figure 4.31).

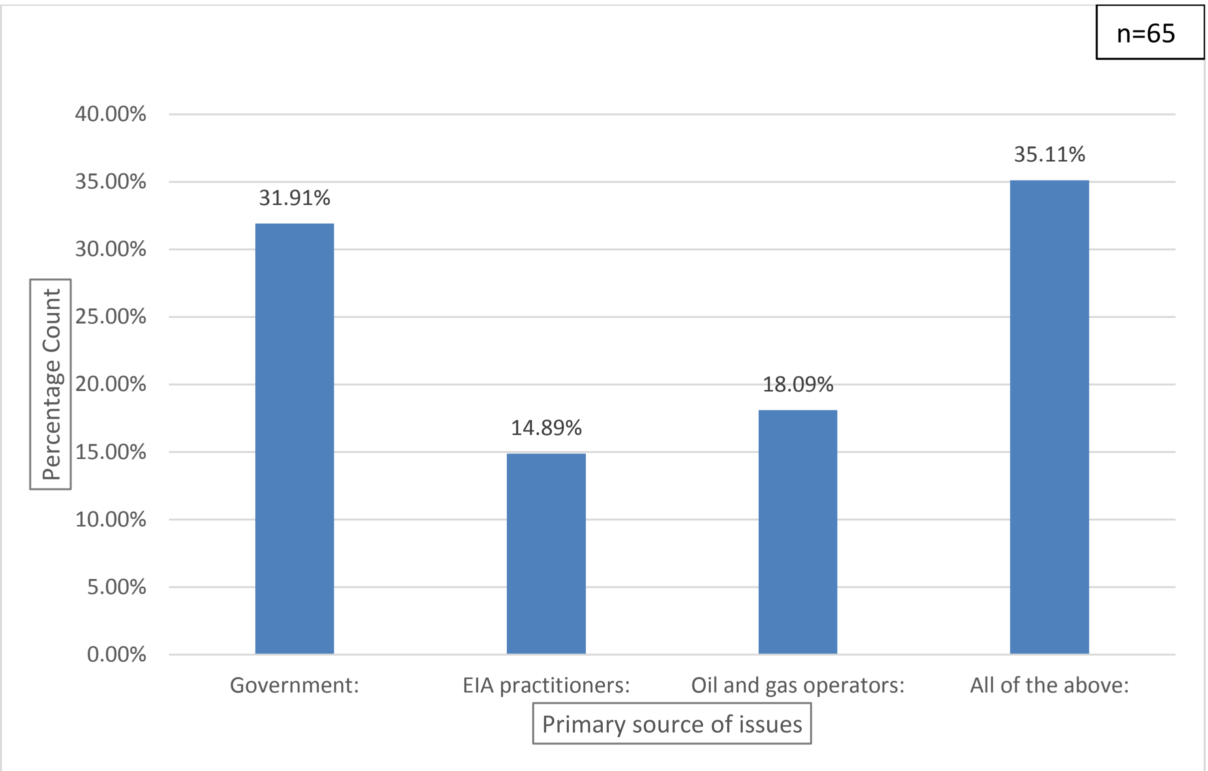



*Figure 4.31: Primary source of issues*

From the results, it can be deduced that all stakeholders (government, EIA practitioners, as well as the oil and gas operators) have their specific roles to play for the EIA to be effective, with the government having more responsibility than all other stakeholders. Thus it can be argued that the effectiveness of the EIA can be achieved through coordination of the collective efforts of all stakeholders by the government. This further reiterates the relevance of partnership arrangements and collaboration between EIA stakeholders that the implementation of the NGDI entails. To this end, respondents were quizzed on the significance of NGDI to EIA preparation.

### 4.2.6 EFFECT OF AN ADEQUATELY UPDATED NGDI ON EIA REPORTING

78.50% of the EIA preparers disagreed with the notion that an adequately updated NGDI will have no significant influence on the way EIA is being carried out while 21.50% agreed as shown in Figure 4.32below.

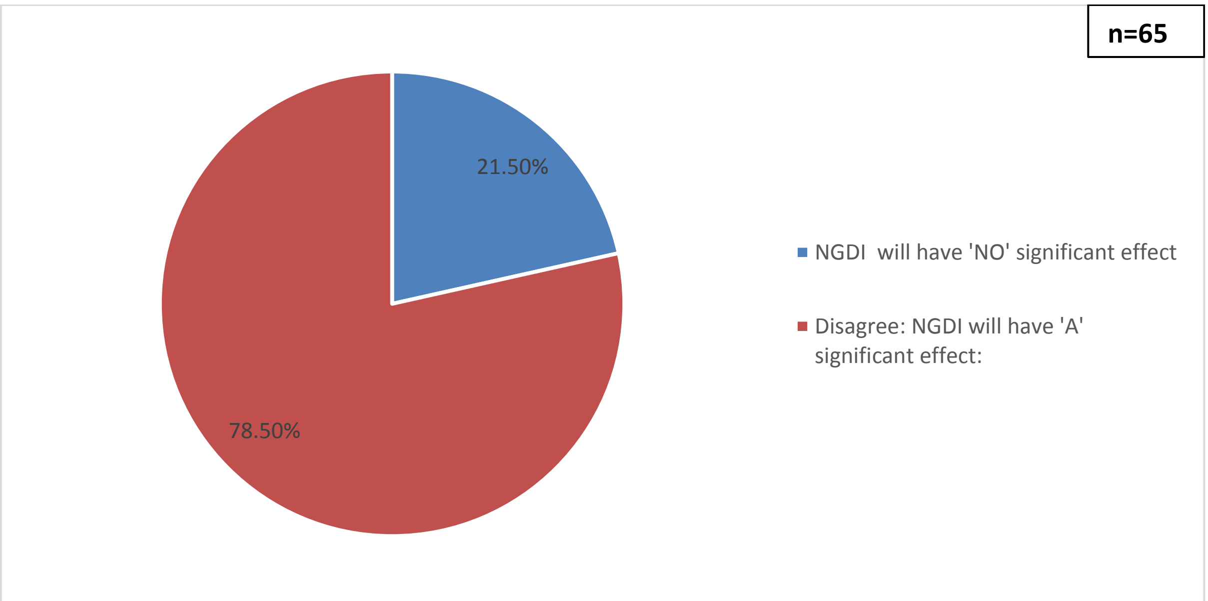



*Figure 4.32: Effect of an adequately updated NGDI on EIA preparation*

In the implementation and effective adoption of SDI, the communication and subsequent partnership between the various stakeholders creates a platform where organisations can work together to achieve common goals, share the implementation responsibility as well as the eventual benefits (Giuliani et al. 2011, Paudyal, McDougall and Apan 2011). This enables the collective agreement and implementation of protocols defining the fundamental datasets and standards required to meet the common interests of the stakeholders as well as the legislative, jurisdictional, technical, organisational, financial issues limiting EIA preparation.

### 4.2.7 EXTENT TO WHICH ISSUES LIMITING EIA AFFECT ITS QUALITY

Half (50.80%) of the EIA preparers acknowledged that the aforementioned issues affect the quality of EIA reporting to a great extent, 38.50% claimed it affected it to a considerable extent, 9.20% claimed it affected it to a moderate extent, 1.50% claimed it affected it to a slight extent and none of the preparers considered that it has no effect on the quality of EIAs reported (see Figure 4.33 below).

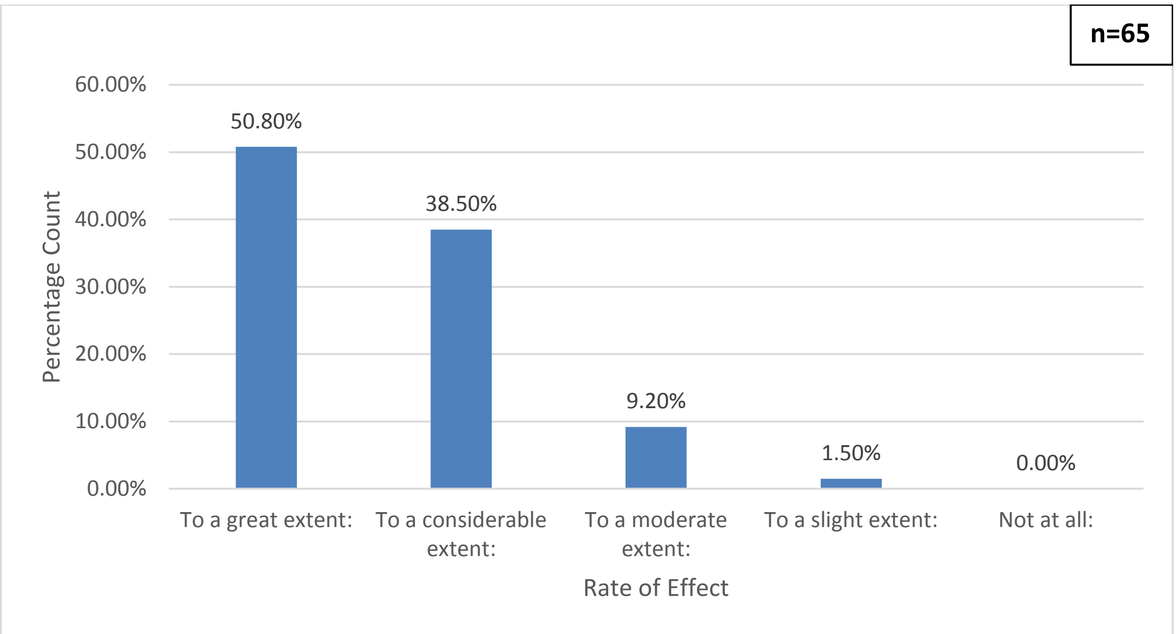



*Figure 4.33: Extent to which the issues hindering EIA affect its quality*

## 4.3 INFERENTIAL ANALYSIS

This section seeks to analyse the key findings from the descriptive analysis presented in Section 4.2 to examine the relationship between the issues assessed in the survey to ascertain if there are statistically explainable significances. From the descriptive statistics, it was evident that the current sources of spatial data were perceived as insufficient for EIA preparation and a number of inherent factors that constrain the use of geospatial data for EIA preparation in Nigeria's oil and gas sector were highlighted. It highlighted the role of the regulators, preparers and oil companies, as well as their contributions to the issues currently being experienced. It also highlighted the role of the emerging geospatial data infrastructure in alleviating the problems of spatial data use.

### 4.3.1 CORRELATION ANALYSIS

Correlation analysis was conducted to assess relationships between the assessment factors and identify the variables with statistically significant relationships. The results of the correlation analysis are presented in Table 4.2 below.

*Table 4.2: EIA-SDI survey correlation analysis*

| | Agree that the current sources of spatial data for EIA is sufficient | Agree that access to spatial data helps address the problem of non-testable and non-auditable predictions | Familiar with NGDI | Agree that the state of NGDI affects the quality of data used, subsequently the effectiveness of EIA report | Rate of effectiveness of the current NGDI procedures and protocols | Agree that an updated NGDI has no significant influence on EIA protocol |
|---|---|---|---|---|---|---|
| Agree that the current sources of spatial data for EIA is sufficient | 1 | | | | | |
| Agree that access to spatial data helps address the problem of non-testable and non-auditable predictions | -.358** | 1 | | | | |
| Familiar with NGDI | -.103 | -.071 | 1 | | | |
| Agree that the state of NGDI affects the quality of data used, subsequently the effectiveness of EIA report | -.374** | -.128 | .395** | 1 | | |
| Rate of effectiveness of the current NGDI procedures and protocols | .045 | -.058 | .322** | .336** | 1 | |
| Agree that an updated NGDI has no significant influence on EIA protocol | .100 | .134 | -.124 | -.112 | -.095 | 1 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | | | | |
| **n=65** | | | | | | |

Significant with *p<0.001* were observed between participants assessment of the sufficiency of the current sources of spatial data for EIA and their level of agreement to the statements that: (a) the state of NGDI affects the quality of data used, subsequently the effectiveness of EIA report; and (b) the access to spatial data helps address the problem of non-testable and non-auditable predictions. They both reported a low negative correlation thus indicating that the more they agree with the statement the current sources of spatial data for EIA was sufficient, the more they would disagree with statements (a) and (b) above, and vice versa.

#### 4.3.1.1 *EFFECTIVENESS OF THE NGDI*

From the descriptive statistics, it was observed that majority affirmed to the poor and ineffective state of the NGDI as shown in Figure 4.24. Participants largely disagreed with the argument that the current NGDI protocols were sufficient to support geospatial data needs for EIA (see Figure 4.23). They also largely supported the argument that the state of the NGDI affects the quality of data used, and subsequently the effectiveness of EIA reported in Nigeria. As presented in Figure 4.24, 73.86% of the participants that disagreed with the argument that the NGDI protocols were sufficient to support geospatial data needs for EIA also agreed with the argument that the state of the NGDI affects the quality of data used and subsequently the effectiveness of EIA reported. This supports the assertion of the current state of the NGDI in literature. Researchers assert that the NGDI is yet to be fully implemented (Okuku, Bregt and Grus 2014, Crompvoets et al. 2004), and as such the NGDI is currently incapable of supporting the geospatial data needs for EIA reporting in Nigeria.

They however collectively agreed on the need for improvements and the need to overcome the current challenges burdening EIA reporting. A number of issues were identified and they include;

- Issues with accessing accurate spatial data
- Interoperability and compatibility issues for data integration
- Little or no training for EIA consultants on data handling and up to date industry best practices.
- Little or no public participation
- Poor jurisdictional arrangements
- Non-conformity to regulatory guidelines
- Poor stakeholders' partnership arrangements

Arguably, the lack of access to accurate spatial data to conduct EIA can be attributed to the inaccessibility of the current NGDI, thus reiterating the initial argument that the lack of accurate spatial data results in several unethical data estimations and manipulations to suffice for the missing data is thus hampering the quality of the reported EIA. It was also highlighted that the absence of regular training workshops for consultants on up-to-date best practice EIA protocols limits the use of industry best practices and the adherence of stipulated standards for EIA preparation.

The majority (35.11%) of the EIA prepares agreed all stakeholders share a part in the generation of the current issues but acknowledged the government (31.91%) to have more responsibility than other stakeholders (see Figure 4.31). It was argued that that the government is responsible for enacting regulatory laws, as well as regulating and monitoring the EIA system and that the adherence of the oil and gas operators and EIA practitioners to these laws depends greatly on the effectiveness of the regulatory system. The dual EIA regulatory jurisdiction was identified as a contributory factor (see Figure 4.30). They highlighted the presence of unnecessary bureaucracies that increases the cost and time to complete an EIA, conflicts of interest, as well as unethical practices where EIA regulatory agencies being financed by the oil and gas companies while supervising this process. This flaws the process and reduces the conformity to stipulated guidelines.

#### 4.3.1.2 *PROSPECTS OF AN UPDATED NGDI ON EIA PREPARATION*

A chi-square goodness of fit was conducted to test the hypothesis $H_2$ shown below:

- ***$H_2$:*** *An adequately updated NGDI will have significant influence on the way EIA is being carried out in the Nigerian oil and gas sector.*

A null hypothesis was established and evaluated as follows:

***$H_0$:*** An adequately updated NGDI will have no significant influence on the way EIA is being carried out in the Nigerian oil and gas sector.

As shown in Table 4.3, $X^2(2) = 42.754$, $p = 0.000$

*Table 4.3: Test Statistics: Prospects of an adequately updated NGDI on EIA*

| | Prospects of an adequately updated NGDI on EIA |
|---|---|
| Chi-Square | 42.754[a] |
| Df | 3 |
| Asymp. Sig. | .000 |
| a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 16.3. | |

The null hypothesis was rejected. It can be concluded that an adequately updated NGDI will have significant influence on the way EIA is being carried out in the Nigerian oil and gas sector. 78.50% of the EIA preparers disagreed with the notion that an adequately updated NGDI will have no significant influence on the way EIA is being carried out while 21.50% agreed as shown in Figure 4.30. They further suggested the need for the augmentation of the current NGDI protocols to aid EIA preparation. Emphasis was placed on increasing the communication of NGDI protocols and procedures to stakeholders, improving data accessibility, data accuracy, data integration as well as the introduction of regular training of consultants on the access, integration and analysis of the SDI datasets and protocols for optimum results. They also suggested the restructuring of the current regulatory system to allow for a more effective regulatory process. Issues of funding were also raised and the need for the prioritization of environmental issues by the government, as well as other stakeholders.

## 4.4 CHAPTER SUMMARY

From the results of the survey, we can conclude that the Nigerian SDI, the NGDI, is yet to achieve its goal of supporting the spatial data needs for EIA preparation. Though there is an emerging NGDI, majority of the intending users of this infrastructure in Nigeria's oil and gas sector are yet to access the SDI and as such, are still burdened with issues of spatial data accessibility, accuracy, compatibility and interoperability which consequently affects the quality of the EIA reported. In addition, the current regulatory framework for EIA reporting in Nigeria's oil and gas sector is seen to contribute to the current limitations. Efforts are yet to be made to establish stakeholder partnerships that will be beneficial to EIA reporting. Further research is necessary to address these issues and propose valuable solutions to the identified problem.

# 5 CHAPTER FIVE: DATA ACCESS PROTOCOL AND PROTOTYPE DEVELOPMENT

## 5.1 INTRODUCTION

Results from the EIA-SDI survey highlighted significant issues that are currently affecting the effective use of spatial data in Nigeria. They include;

- Issues with accessing accurate spatial data
- Interoperability and compatibility issues for data integration
- Little or no training for EIA consultants on data handling and up to date industry best practices.
- Little or no public participation
- Poor jurisdictional arrangements
- Non-conformity to regulatory guidelines
- Poor stakeholders' partnership arrangements

A critical assessment of the identified problems exposed gaps in the current development and implementation of the NGDI. The inaccessibility to the NGDI owing to the absence of a working NGDI access network and clearinghouse was emphasised. Furtherance to this, an SDI data access protocol was proposed. This chapter presents the development, implementation and evaluation of the proposed SDI data access protocol.

Nigeria, like most developing countries have been battling consistently with power unavailability and failure (Mas'ud et al. 2015), poor to no internet connectivity

(Apulu, Latham and Moreton 2011), limited to no infrastructure for programs to thrive (Solomon, Opawole and Olusegun 2012), among other challenges. Overcoming these challenges, in addition to an effective management of the intended technological, operational and cultural changes is fundamental to the successful implementation and adoption of technological infrastructures in Nigeria. To this end, the prototype development took into account these identified challenges and sought to develop an easily adoptable technology that requires minimal physical infrastructure. It also considered the way technology is adopted in Nigeria and the corresponding acceptance or resistance exhibited by Nigerians towards technological changes. Thus, the prototype development focused on creating a seamless SDI system implemented using cloud based web services and GIS protocols to enable data access and sharing over the web.

Cloud based services enables a convenient network access to distributed networks, servers, databases, storage protocols, applications and services, that can be easily configured and utilised with minimal management effort or service provider interaction (Bhardwaj, Jain and Jain 2010). This allows the deployment of systems where some or all of its application software and data resides in remote servers; which can be owned by the deploying organisation, publicly owned by other organisations and in some hybrid cases, part of it might be privately owned while the other part publicly owned. Cloud computing presents a number of limitations (e.g. centralisation, scalability, timeliness, control, performance and security) hence the system has been proposed as a distributed system instead of the single centralised system to limit the failure of each component within the collective system to its distributed component, and also reduce the workload on the entire system by distributing the responsibilities (Botta et al. 2016, Sarma et al. 2015, Rafique et al. 2011). This is important for developments in Nigeria and other developing economies with limited resources and underlying infrastructure as it allows faster deployment and greater flexibility with reduced implementation cost (Marston et al. 2011).

The distribution of some or all of its application components to the cloud (especially with the use of free and open source software) cushions the cost of deployment emanating from the purchase and management of software and hardware, reduces operational costs as well as provides larger data storage units at minimal cost. Of course using the cloud approach incurs hosting fees and migration costs which can be very expensive but cloud computing allows access to resources without large capital expenditure, upfront costs and carbon footprint (Whaiduzzaman et al. 2014, Oliveira, Thomas and Espadanal 2014, Misra and Mondal 2011), which can be beneficial to small and medium sized organisations. Economic viability of cloud computing resources have been deduced in research by demonstrating its feasibility and proof of concept (Sarma et al. 2015), as well as by assessing its ability to better fulfil the set objectives for the development using a more flexible method and cost structure (Sultan 2011). An important aspect of an SDI is data sharing and cloud technology facilitates this efficiently and effectively. Other researchers have financially estimated economic viability of cloud computing by calculating the return on investment (Mehmi et al. 2016, De Alfonso et al. 2013, Brender and Markov 2013), as well as the cost benefit analysis of its implementation (Gupta, Saxena and Saini 2016, Maurer et al. 2012, de Assunção, di Costanzo and Buyya 2010).

The return on investment (ROI) or cost benefit analysis was not calculated in this research, we argue that the solution is economically viable due to the benefits it presents and its prospects of augmenting SDI implementation in Nigeria where there are little or no physical infrastructure to aid the process (Dahunsi and Owoseni 2015). If the solution advocated in this thesis is taken up in Nigeria or any other country, policy makers and stakeholders will need to decide on whether private in-house cloud or commercial cloud is more cost effective. Since a bottom-up approach is proposed, individual groups of users can start with a local cloud solution which in time can be combined with regional and national solutions as the solution gains momentum, and higher-level policy makers become involved. At each stage and in each location a cost-benefit analysis should be undertaken regarding the underlying infrastructure design to ensure economic viability.

Nigerians are reported to be more inclined to mobile devices as against desktop devices, with documented statistics of tremendous increase in the number of mobile technology users recorded in Nigeria annually (Dogo, Salami and Salman 2013). Thus, it can be argued that Nigerians would pose less resistance to technological infrastructures that can be operated on their mobile phones and tablets above those that are only limited to desk-top computers. These facts, in addition to other highlighted factors above, helped define the main objective of the prototype development, which was to *provide a lightweight and flexible SDI data access protocol that can be accessed using mobile devices as well as computers*. The deployment of this system does not undermine the current challenges with the use of mobile devices to complete GIS tasks as most geospatial work requires large screens, large storage spaces, as well as devices with very high performance to effectively complete its tasks. In consideration of these challenges, the system has been deployed to work effectively on both mobile devices to serve field and on-demand operations as well as on computers for very detailed review and analysis of the data. This is supplemented with OpenLayers, an open source JavaScript library that supports the display of map data for mobile and desktop web GIS applications. This is capable of rendering vector and raster data from a variety of formats including GeoJSON, OGC-KML, OGC-GML, and OGC web services, thus making it more flexible for the Nigerian market. It also utilises distributed cloud based services to divide the operational load and databases between these systems thus making it lightweight and optimise the system's performance. The following sections of this chapter present the prototype development, implementation and evaluation process. They highlight the specific software engineering methods adopted for the prototype development. The chapter is arranged into sections showing the iterative and incremental stages of defining the system requirements, requirement analysis, prototype design architectures, prototype implementation and testing. The EAI-SDI survey, as well as the review of literature, informed the development of the use cases and the conceptual framework for the model development. The use cases provided a better understanding and definition of the research problem to effectively address the identified research gaps as presented in the following sections.

## 5.2 SYSTEM REQUIREMENTS AND PROTOTYPE CAPABILITIES

Requirements engineering is a fundamental aspect of prototype design and implementation. It determines the suitability of the prototype to address the needs of the users or stakeholders in the environment where it is deployed and subsequently, the success of the model (Pandey, Suman and Ramani 2010). The requirements formulate the properties the system must exhibit in order to address the established research problem within the research context. In this instance, the requirements engineering took into account the initial research findings and research problem established from the evaluation of aspects by the users (selected stakeholders) and system interactions at different levels within the research context (Teixeira, Ferreira and Santos 2012, Cheng and Atlee 2007). Thus, it incorporates “user requirements” and “system requirements”.

The waterfall prototype development process was initially adopted to define and analyse the requirements, as well as design, code and test the prototype but the iterative development process was later adopted to better accommodate changes and uncertainties in a timelier fashion (Balaji and Murugaiyan 2012, Qureshi and Hussain 2008). The iterative development process involved the development and evaluation of the prototype in incremental stages. Unlike the waterfall process where the evaluation is done at the end of the entire development, the iterative process involves the evaluation of each phase of the development proceeding to the next phase (Andrews, Pritchett and Woolcock 2013, Jacobson 1999:7). Identified errors are debugged and additional features are designed into the system to create a system that fully satisfies the defined, as well as the updated user and system requirements.

Use cases were utilized for the definition of both user and system requirements. A use case is a combination of related interactions between a user (categorized as the actor) and the system (Savic et al. 2012, Sinha and Paradkar 2010, Jacobson 2003). It is fundamental to requirements engineering as it demonstrates the functions, attributes and scope of the prototype in relation to the user requirements (Cruz, Machado and Santos 2014, Bolloju, Schneider and Sugumaran 2012, Drira, Warin and Laroussi 2011). As established in the review of literature, SDIs are anticipated to aid environmental management activities by enabling and coordinating the interoperable discovery, access, dissemination, visualization, retrieval and update of seamless geospatial, environmental, socio-economic and institutional data across various unified platforms(Giuliani et al. 2016, Latre et al. 2013, Sutanta, Rajabifard and Bishop 2010, Masser, Rajabifard and Williamson 2008, Rajabifard, Williamson and Feeney 2003). As stated earlier, the objective of the prototype was to provide a lightweight and flexible SDI data access protocol that can be accessed using mobile devices as well as computers. This will enable the interoperable access and utilization of OGC compliant spatial datasets for environmental management protocols like environmental impact prediction and EIA reporting. This is anticipated to address the documented issues of standardization and data inconsistencies that burdens environmental protocols like EIA, and overcome the challenges faced in the acquisition of accurate spatial data to support their operations. The construction of use cases detailing how a user would interact with the system aided the identification and subsequent definition of the system entities as well as its attributes.

SDIs are anticipated to help reduce duplication of effort among environmental consultants and managers by enabling the access to quality of data utilized for environmental activities at a reduced cost, thus obtaining optimal benefit from the data. A fundamental determinant of the effectiveness of an SDI is hinged on the established partnerships and data dissemination outlets between the stakeholders in the various private organisations, government agencies (local, state and federal) and academia (Elwood 2008, Rajabifard et al. 2006, Maguire and Longley 2005). Arguably, the SDI initiatives in developing countries like Nigeria are observed to have focused on developing the needed technology, standards, and policies without ample emphasis on how the people and institutional aspects would be integrated with the technology. The effect of this is seen in the existence of attempted SDIs that can only serve as storage systems for data without effectively supporting accurate data access, data update to overcome redundancy, and data sharing among users. This puts forward the need to develop architectures that will translate available technologies as well us update the needed technologies, standards and policies to allow easy access, use and sharing of spatial data by users, in this case, environmental practitioners. Open standards frameworks and the use web applications are anticipated to promote technical interoperability, as well as improve the access and dissemination of SDI data as it would enable the standardization and dissemination of its data and its cumulative benefits from the SDI to the users (Steiniger and Hunter 2012, Giuliani, Ray and Lehmann 2011). To this end the prototype development included the implementation of an open source web service to support interoperable machine-to-machine interaction and spatial data access over the web (Buyya, Ranjan and Calheiros 2010). The interface is anticipated to enable web interactions following web services standards. This is because cloud based systems make sharing of data much easier and still allow suitable privacy settings to be made.

An analysis of the requirements of both the system and the users was conducted to inform the prototype development and the outcome is presented below.

## 5.3 REQUIREMENTS ANALYSIS

This prototype development aims *to provide a lightweight and flexible SDI data access protocol that can be accessed using mobile devices as well as computers*. Use cases were developed to assess the interaction of environmental practitioners with the intention of conducting an EIA. The use cases were collected by first gathering information about spatial data use for EIA from the EIA-SDI survey. This provided information on the current and regularly used spatial datasets as well as procedures employed to access spatial data for EIA reporting. To overcome informant and population bias, the informants requirements were supported with current literature on EIA, SDI and cloud based GIS systems to develop the initial set of system requirements. Based on the assessment of the user requirements obtained through the EIA-SDI survey and literature review, the development considered the inclusion of a graphical user interface (GUI) that allows the users discover data, access the data, add data to the prototype, share the data, explore the data. It also anticipated the possibility of querying and processing the data within the prototype, as well as downloading the data in compatible formats for processing in other GIS platforms. These user requirements have been grouped together to show the intended service request as well as the questions the development process may need to answer to build a prototype that will sufficiently respond to the identified requests. This is presented in Table 5.1.

*Table 5.1: Prototype user requirements*

| User Requirement | Intended Service Request | Questions to Address |
|---|---|---|
| **Find or discover data** | • Locate the data and service<br>• Get help and access links to relevant resources | • Is the data access function achievable? And how?<br>• What protocol, software and hardware is required?<br>• Are there existing protocols to build on?<br>• Where is the data stored? |
| **Acquire data** | • Download the data | • Are there protocols to allow data download?<br>• What are the possible methods to employ? |
| **Share data** | • Upload data<br>• Share data files and links | • What methods can we use to achieve this?<br>• Are there accessible, cost effective software and hardware we can use? |
| **Process data** | • Analyse data<br>• Delete data<br>• Update standards | • Does the dataset and protocols employed allow for interoperable exploration and processing of datasets? |

These scenarios were carefully examined based on the questions raised and the system responsibility and user intentions were defined using a responsibility matrix as shown in Table 5.2. The responsibility matrix was essential in the prototype development as it clearly differentiates the role of the system from those of the users. It is important in the pre-development stages as the clear identification of the system requirements would clearly guide the choice of protocols employed as well as the corresponding software and hardware materials to be utilised. This is because the choice of the materials and process for building the prototype would be selected to achieve the system and user requirements. As such, it saves the time wasted in building systems before testing to see that the materials used do not support the need of the user or the proposed prototype.

*Table 5.2: Prototype responsibility matrix*

| S/N | Task | Party Responsible | |
|---|---|---|---|
| | | User | System |
| 1. | Request search | | X |
| 2. | Enter search criteria | | X |
| 3. | Start search | X | X |
| 4. | Review results | | X |
| 5. | View data | | X |
| 6. | Download data | | X |
| 7. | Download literature (information on analysis) | | X |
| 8. | Upload data | X | X |
| 9. | Conduct relevant analysis | | X |
| 10. | Provide relevant information (on datasets and analysis) to the users | X | |
| 11. | Allow the maintenance of the system | X | |
| 12. | Update data (to avert redundancy) | X | X |
| 13. | Validate users | X | |
| 14. | Respond to requests | X | X |
| 15. | Generate data for download | X | |
| 16. | Update user details | X | X |
| 17. | Maintain data | X | X |
| 18. | Display results of analysis | X | |

## 5.4 PROTOTYPE DEVELOPMENT: DESIGN AND IMPLEMENTATION

### 5.4.1 CONSTITUTING COMPONENTS

The expectations from an SDI to enable discovery and delivery of spatial data from a data repository via a service provider to a client were taken into account in the development of the prototype. The possibility of enabling the spatial data provider, regulator or developer to update the spatial data stored in a repository was also experimented. The overall aim of the selection was to utilise resources (software and hardware) that will enable the deployment of a system that addresses the user requirements as well as fulfil the aim of this research. This is because there is the constraint of time and resource limitation in this research, and this was taken into consideration to ensure the proposed solution is deployed using the most cost effective and economically viable approach. A number of proprietary (ESRI ArcGIS Server and the Hexagon Geospatial Geomedia) and open source software (Mapserver and GRASS GIS) have been documented in literature to aid geospatial researches. However a fundamental criterion for this research is to ensure interoperability, scalability, cost effectiveness and long-term economic sustainability, thus this narrowed the selection to OGC compliant software and data components that have been documented to using free and open source technologies.

Given the criteria of free, open source and OGC compliancy there are some alternative software that can be considered and that would meet the requirements of the build. Table 5.3 presents some examples of alternative software for each requirement category. For the purposes of the development, there was little to choose between the alternatives and the software considered more dominant in the field was selected. All technology selected was free, open source and, where applicable, OGC compliant except for the underlying web platform. AWS was chosen as the hosting web platform as it was not possible to find a free platform, openly available for off-site testing which offered the resourcing and support requirements for this research. Alternative commercial platforms were also available which might have been used, but in this category the choice was not relevant to the outcome of the development of the prototype. Should the framework produced in this research be taken-up in Nigeria or any other country, cost evaluations would need to be undertaken by stakeholders to decide on the best hosting solutions which may involve public or private Cloud (see section 5.1).

*Table 5.3: Software selection process*

| **CATEGORY** | **CRITERIA** | **PRODUCTS CONSIDERED** | | |
|---|---|---|---|---|
| | | | | |
| UML Tool | | **Argo UML** | **Dia** | **Comments** |
| | Required Functionality | Yes | Yes | There are a number of open source diagramming tools available. The main criteria were that the product should be open source and follow UML standard closely ArgoUML fitted the bill well and was selected |
| | Open Source | Yes | Yes | |
| | OGC Compliant | n/a | n/a | |
| | | | | |
| Map Client | | **OpenLayers** | **Leaflet** | **Comments** |
| | Required Functionality | Yes | Yes (but may be limitations when extending to new functionality) | Openlayers is a very popular proven mapping client and was selected over Leaflet because of its maturity, features and community support |
| | Open Source | Yes | Yes | |
| | OGC Compliant | Yes | Yes | |

| | | | | |
|---|---|---|---|---|
| | | | | |
| Geospatial Data Server | | **Geoserver** | **Mapserver** | **Comments** |
| | Required Functionality | Yes | Yes | Geoserver was selected because it is a widely used and accepted technology |
| | Open Source | Yes | Yes | |
| | OGC Compliant | Yes | Yes | |
| | | | | |
| Data Repository | | **Postgres/ PostGIS** | **H2 Database Engine/ H2GIS** | **Comments** |
| | Required Functionality | Yes | Yes | Postgres/PostGIS was chosen because of its wide use, user community and proven technology |
| | Open Source | Yes | Yes | |
| | OGC Compliant | n/a | n/a | |
| | | | | |
| Java Application Server | | **Apache Tomcat** | **JBoss** | **Comments** |
| | Required Functionality | Yes | Yes | There are some alternative servers for Java applications but Apache Tomcat is by far the dominant software and was chosen without consideration of others as it is a proven technology |
| | Open Source | Yes | Yes | |
| | OGC Compliant | n/a | n/a | |
| | | | | |
| GIS Desktop Client | | **QGIS** | **uDig** | **Comments** |
| | Required Functionality | Yes | Yes | QGIS was selected for its high usability and robustness. It required very minimal training due to its similarities with proprietary ArcGIS and the availability of relevant documentation online. It was considered best for sorting, editing and updating the data to ensure completeness and normalisation. |
| | Open Source | Yes | Yes | |
| | OGC Compliant | Yes | Yes | |

| | | | | |
|---|---|---|---|---|
| Web Platform | | **Amazon Web Services** | **Google Cloud** | **Comments** |
| | Required Functionality | Yes | Yes | Any reliable web platform host could be chosen. AWS was selected because of its known reliability and availability but other hosts might also be equally reliable. |
| | Open Source | No | No | |
| | OGC Compliant | Yes | Yes | |

The final selection of the constituting components includes the following:

I. ArgoUML and Eclipse EE were used for the design of the prototype structure and the implementation of the back end. The classes and activity diagrams were created in ArgoUML were imported into Eclipse EE for the implementation of the Java perspectives for the web application development.

II. OpenLayers map client was used for the display, query, and analyse spatial data. It also implements Java perspectives. GeoExt2 and EXT.js java script files were also used for the definition of the layers and navigation functions of the user interface.

III. Geoserver web service served as the catalog service to enable the discovery, browsing, and querying of metadata or spatial services, spatial datasets and other resources

IV. Apache Tomcat7 hosted the spatial data service - allowing the delivery of the data via the Internet. Initial experimentation was done using Apache Tomcat 6 but the final prototype was assembled using Apache Tomcat7 on AWS instance on port 8080; http://52.18.169.105:8080

V. OGC compliant and open source web service, Geoserver, provided the GML, KML, ISO 19115, WMS, WCS and WFS capabilities for the delivery of maps, vector and raster but also data format and internet transfer standards by W3C consortium.

VI. PostgreSQL served as the spatial data repository for the prototype. PostGIS served as the spatial database extender for PostgreSQL. They are both OGC compliant, free and open source software that for spatial database management system.

VII. Open source QGIS desktop client was used to prepare, create and update spatial data.

VIII. Amazon web service (AWS) was used to deploy the Ubuntu 14.04 virtual machine and operating system provided the base layer support for the prototype system and also provided the web access to the deployed prototype through the IP allocated to the virtual machine by AWS.

These different software components were layered together to create a flexible web-based system to store, process and transfer spatial data to enable easy access and sharing of the data, thus increasing the usability of the prototype to prospective users.

### 5.4.2 PROTOTYPE DESIGN

In order to build a prototype to demonstrate spatial data infrastructure (SDI) data access, the fundamental components of an SDI was developed on the AWS operating system. The architecture was designed to allow the integration of spatial data prepared according to defined standards and its metadata, stored in an IT infrastructure that allows access, dissemination, exploration and processing. To achieve this, the constituting components identified above were integrated. The development was guided by the defined user requirements so as to stay within the scope of the research. Use cases were designed to conceptualize the design of the system prototype following the requirements analysis. The use case analysis is presented below.

#### 5.4.2.1 *Use Case Development and Analysis*

Use cases were plotted and implemented using ArgoUML, an open source software with a general public licence (GPL). It aided in the virtual development, testing and validation of the use cases. The ability to virtually develop, test and validate the use cases was very important as it saved a reasonable amount of time and resources that would have been expended into developing trial cases and models on actual systems before verifying the validity of the proposed model (Ali, Hosking and Grundy 2013), and thus stay within the scope and time appropriated for the research. The virtual implementation of the use cases for this research also enabled the creation and testing of these use cases in three iterations. Each iteration included significant incremental changes that would have been time-consuming and expensive for this research if the prototype use case development were not done virtually. In the design, the key findings from the questionnaire survey were aligned with current research to define the system requirements. These requirements were defined to highlight the needed tools and datasets for the design of the conceptual framework for the prototype development. The development of the use cases was formalised and validated by repeat iterations to improve the representation of the use case scenarios and methods.

The use cases were developed to exemplify what the users of the unified spatial data infrastructure would require from such system. It represented the process of users accessing, exploring, sharing and updating fundamental spatial datasets suitable for conducting environmental impact assessment, among other management protocols that require spatial data. The user roles, as well as the system roles, were included in the use case mapping as shown in Figure 5.1.

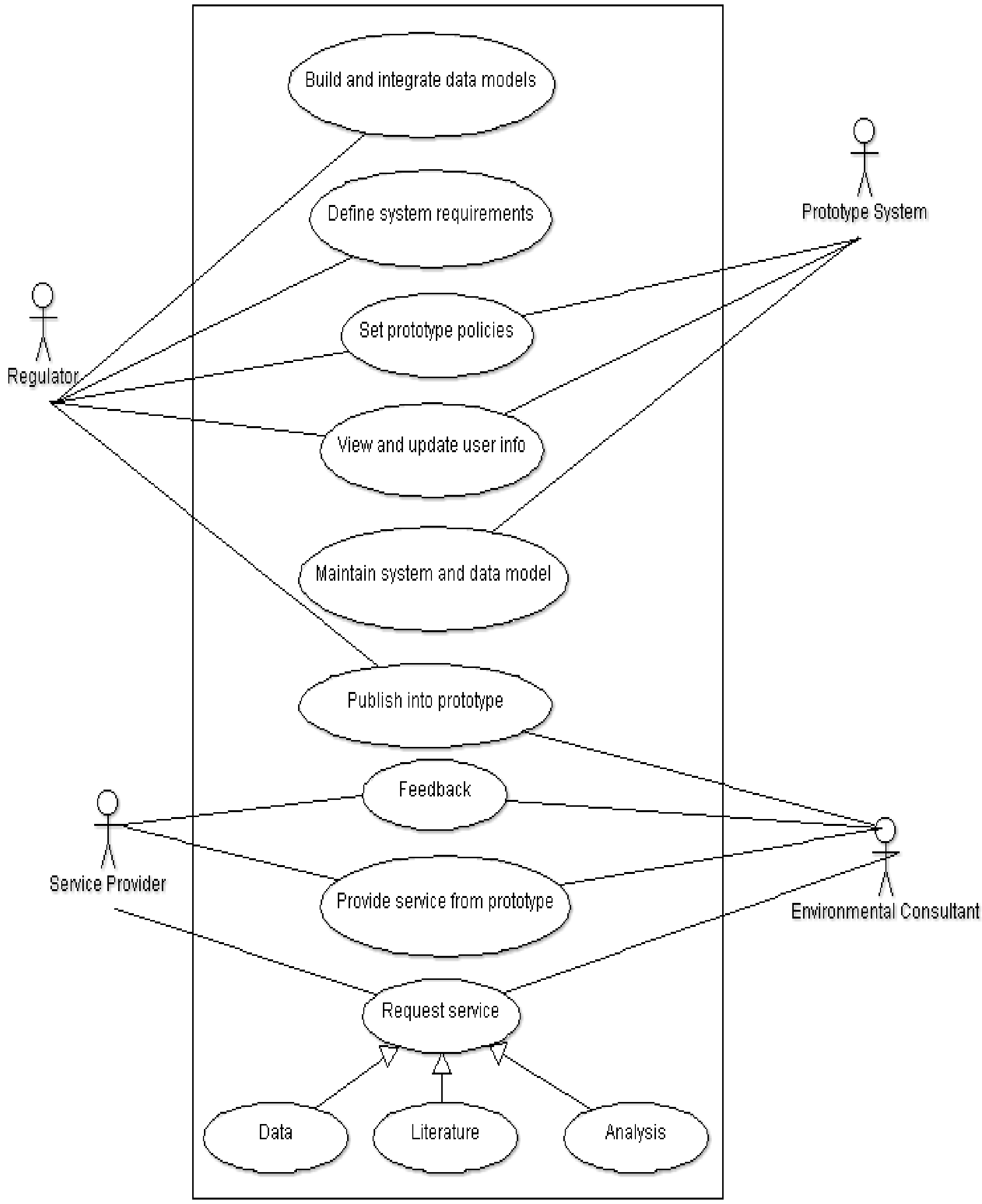



*Figure 5.1: Initial use case diagram*

As shown in Figure 5.1 above, the roles initially represented were the service provider (Serv_Prov), environmental consultant (EnvCon), regulators (Reg) and Server (Server) which represents the system. The interrelationships between each use case as well as their corresponding responsibilities were mapped to enable a better analysis of the cases for the design of the prototype. Further analysis of the use cases in alignment to current research in SDI development and the requirements of the environmental consultants gathered from the previous survey, a second and a third iteration of the use cases were achieved. Figures 5.2 and 5.3 present the final iteration of the prototype use case diagram. Figure 5.2 shows the simplified use case diagram while 5.3 shows the detailed diagram. Within the use case, the requirements are grouped into four fundamental functions; discover data, collect data, share data files and process data. .

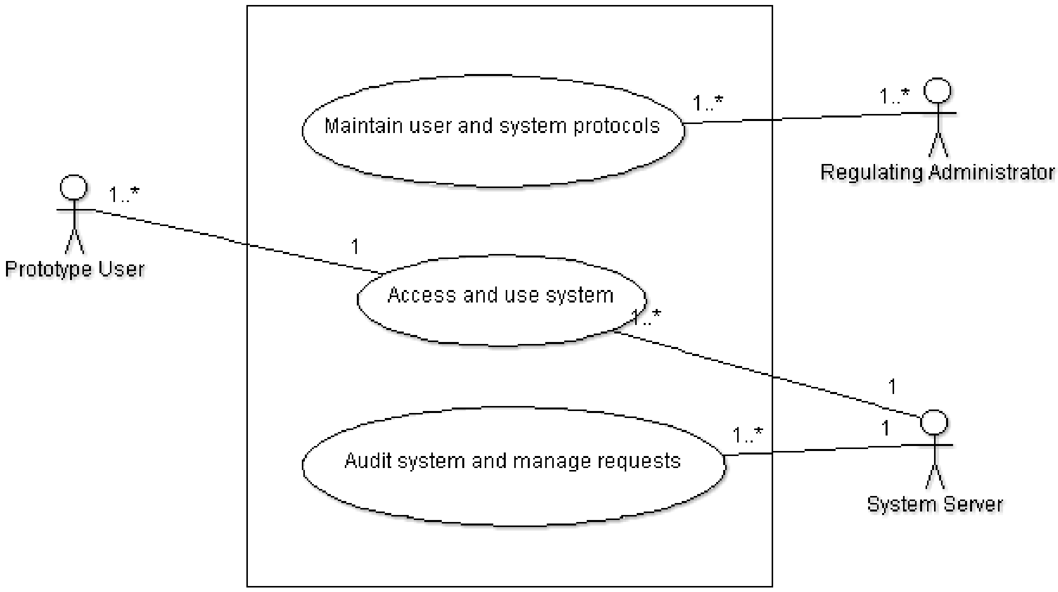



*Figure 5.2: Simplified use case diagram*

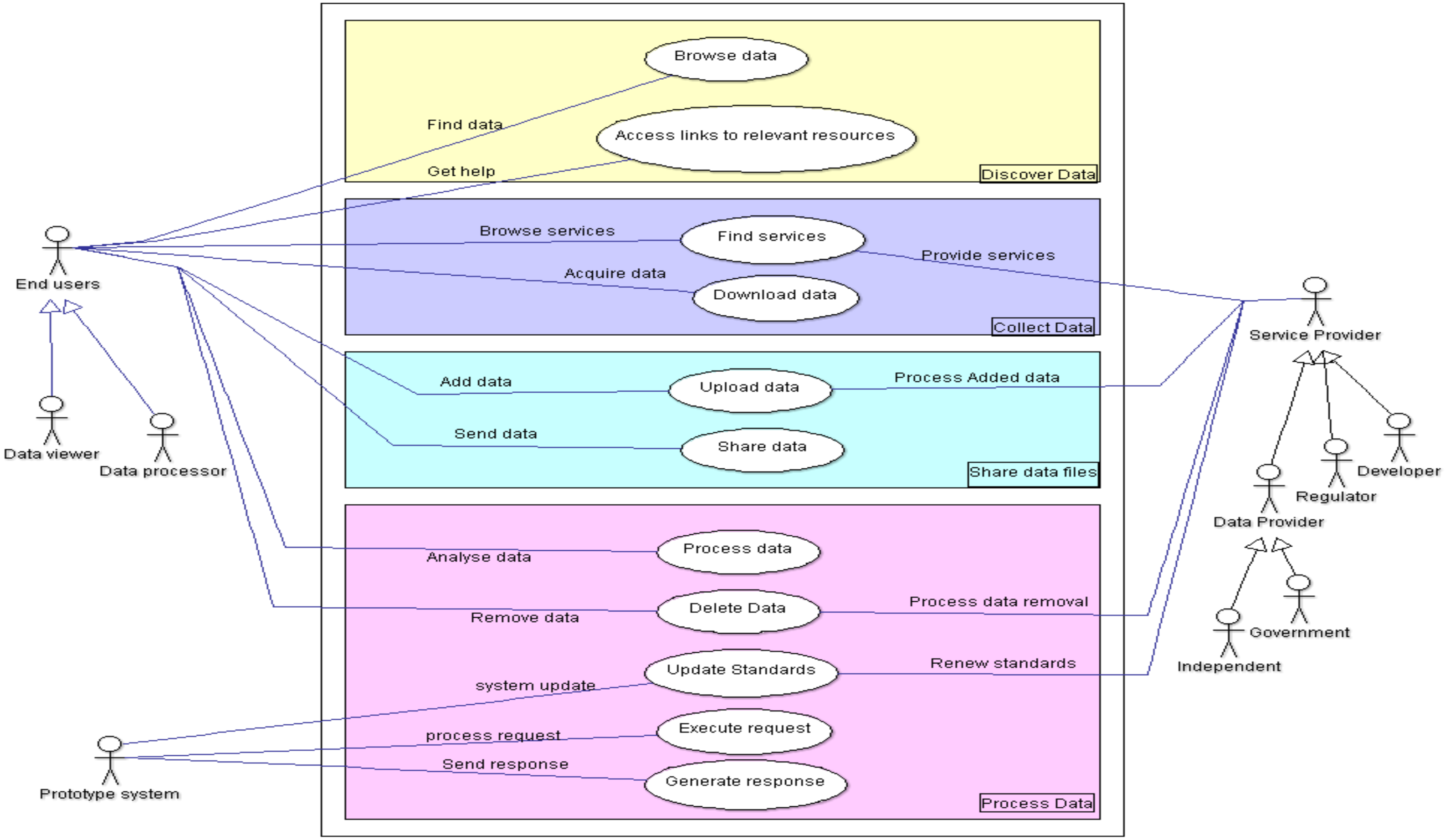



*Figure 5.3: Prototype use case diagram*

### 5.4.3 ACTIVITY DIAGRAM

This activity diagram shows the paths and actions the system follows once a request is made by a user. The system takes into account, three basic needs of EIA preparers: accurate spatial data; sufficient knowledge of relevant environmental analysis; and a guide to the relevant platform for the conduct of the analysis. The arrows indicate the direction of flow of the system and each case is defined in the system to perform a particular action. The normal action is modelled together with other abstract or incorrect actions. In the case where the user inputs an incorrect or invalid request, they are allowed to retry for a specified number of times before the request is aborted. The system has been designed to request for login information and partnership codes so as to encourage the users to engage with the partnership. It also enables the regulators to monitor the actions of the users. The activity diagram is shown in Figure 5.4.

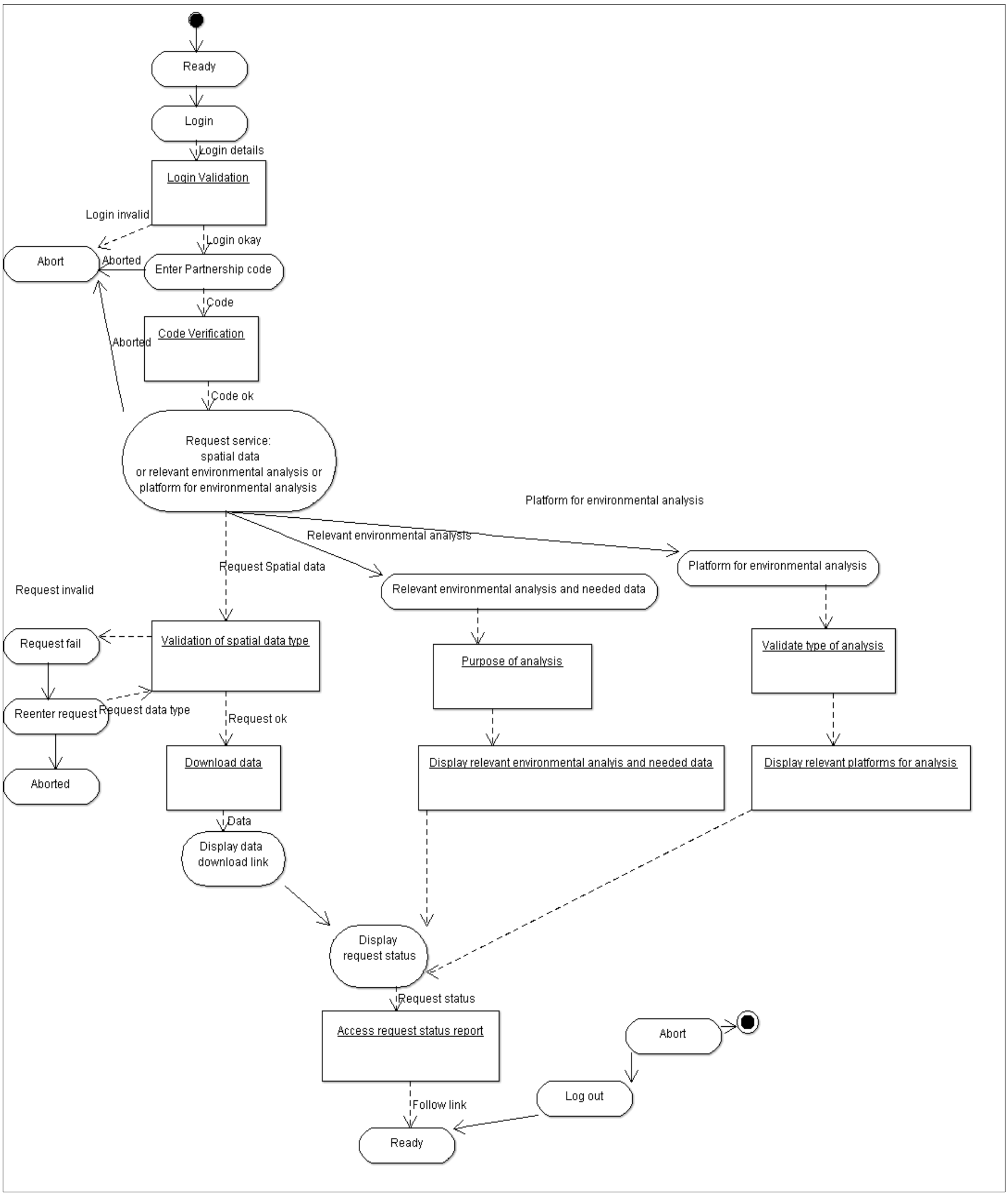



*Figure 5.4: Prototype activity diagram*

For the prototype implementation, certain steps in the activity diagram were removed so as to remain focused on demonstrating the necessary SDI data access protocol to augment SDI implementation in cases where SDIs are struggling to achieve effectiveness. The different actions and processes in the activity diagram were critically analysed to identify the primary actions and processes, as well as those that were secondary to the demonstration. The aspects that were primary and fundamental to demonstrating SDI data access to augment SDI and enhance partnership arrangements were prioritised while other aspects like the login protocol, and display of access links to resources, were considered secondary to SDI data access demonstration and so, were not prioritised. This does not imply that these aspects were irrelevant, as they are considered important to improving the usability of any SDI as well as improving the awareness, knowledge and technical proficiency of users. Thus, this activity diagram was included as part of the recommendations of this research for the deployment of the data access protocol in practice. Limiting the development to certain aspects was necessary as the aim of the development was for demonstration purposes to trigger fundamental debates on the factors currently limiting the NGDI and to assess the developed data access protocol as a protocol that can significantly contribute to the augmentation of SDIs, in combination with other factors like policy, standards, people and accurate data.

## 5.5 PROTOTYPE IMPLEMENTATION

The main components of the system architecture are the web server, the spatial database and the web interface with Java capabilities that connects the system interface to the user interface. Open layers and GeoEXT were used to design the functionalities and navigations of the user interface. Free and open source OGC compliant software was utilized for this purpose as shown in Figure 5.5 below. *Apache Tomcat 7* served as the web service through which the Geoserver was deployed and the web application was implemented. The implementation of the prototype was done on an Amazon Web Services Ubuntu 14.04 system.

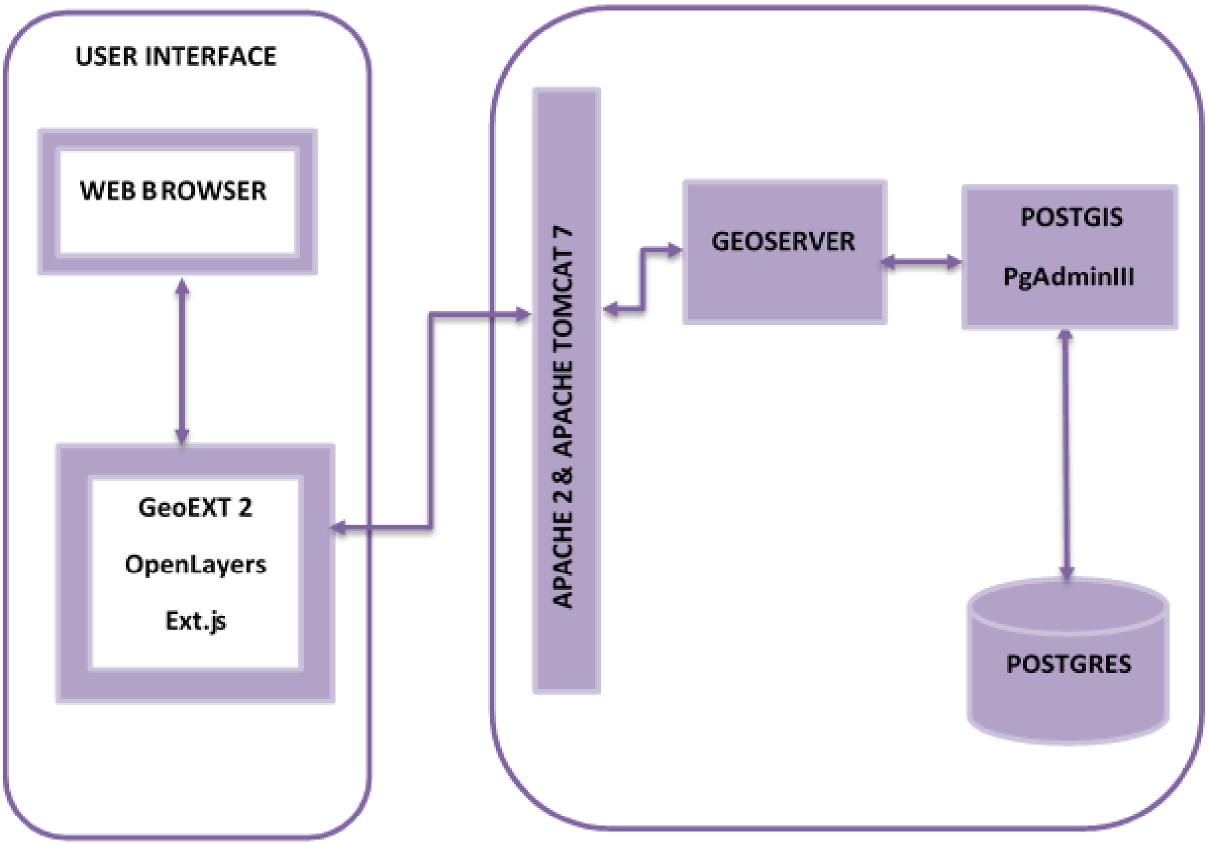



*Figure 5.5: System architecture*

### 5.5.1 ASSEMBLY OF SYSTEM COMPONENTS

#### 5.5.1.1 *DATABASE*

Due to the absence of SDI in Nigeria and the restrictions to the limited sources of data in Nigeria, the data used to create the database for the prototype was gathered from different sources. The majority of the sources available for accessing Nigerian datasets were at a cost which was unaffordable for this research and as such, free and open sources databases were explored to gather the data. Though the quality of free and open source data can be questionable in many cases, it remains a cost effective source of data for conducting academic research. Known issues with free and open source datasets range from the completeness of the data, its validity, consistency, accuracy, to its reusability (Ray et al. 2016, Xia 2012). This is because, significant amounts of the spatial data accessed, especially from volunteered and open sources, either lacks the metadata or has a metadata that has not been completely and correctly updated (Giuliani, Dubois and Lacroix 2013, Mohammadi, Rajabifard and Williamson 2010, Coleman 2010). The high cost of acquiring quality data, together with the issues surrounding the use of free and open source data can be argued as a major obstruction to spatial data use in Nigeria and consequently, NGDI implementation. This research puts forward a provenance model to address the issue of data quality and if the provenance model is correctly applied, it will enable the inclusion of standardised spatial datasets in SDIs with sufficient information to enable an easier evaluation of data quality and thus the correct use of the data.

For the creation of the database for the prototype, the anticipated data quality errors emanating from the use of free and open source spatial datasets were checked by including a data preparation step where the data was cleaned up in QGIS. The data tables were also updated for completeness and consistency. This is a time and resource consuming process and the access the quality spatial data will allow a more effective use of spatial data.

The updated datasets were then imported into the PostgreSQL server created in the AWS RDF instance. The data is imported into PostgreSQL with their corresponding spatial layers and tables using the PostGIS extension. This was to ensure that they were in the right projections and formats for easy integration with other datasets. Concerted efforts were made to ensure the created database represented the most recent, complete and accurate datasets retrievable under the current circumstances and challenges. The data was collected to cover the frequently used fundamental datasets identified in the EIA-SDI survey (see Figure 4.11). This was to ensure that the created database and consequently the demo data access protocol represented and provided access to spatial datasets that are widely used by environmental consultants as well as other users of spatial data in Nigeria, thus satisfying the user requirements. The data utilized were sourced from OGC compliant WMS and WFS servers. The Terrestris web service was used to fetch the Open Street Map used as the base map for the user interface. Data on the transport services and administrative areas were downloaded from Open Street Map using QGIS 2.82. Open source services that provide OGC compliant spatial data like the United States geological survey were also utilized (see Figure 5.6).

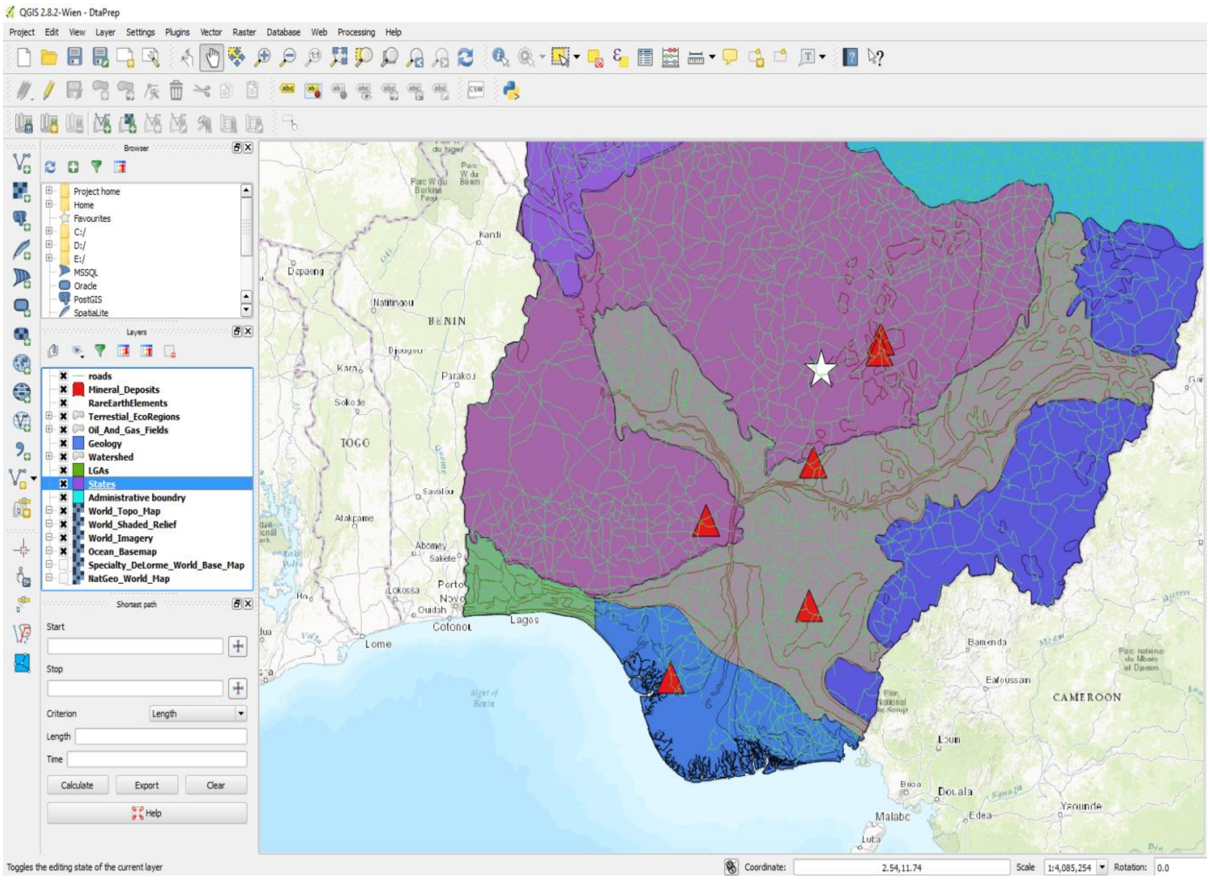


*Figure 5.6: Data preparation in QGIS*

Free and open source databases and software were used for the creation of the database to ensure that the development as well as access to the infrastructure was cost effective. That is, users would be able to access the infrastructure, explore and retrieve data at no cost, except for the cost of acquiring internet service. The infrastructure and its database was developed in AWS cloud service so as to ensure easy access from anywhere and avert restrictions to the use and dissemination of the datasets. This is to allow easy discovery of the available datasets and its metadata so the users can be well informed of the conditions under which the data was acquired so the data can be used rightly and properly. The data is maintained in the PostgreSQL instance within the AWS relational data base service (RDS) and harvested into the Geoserver web service.

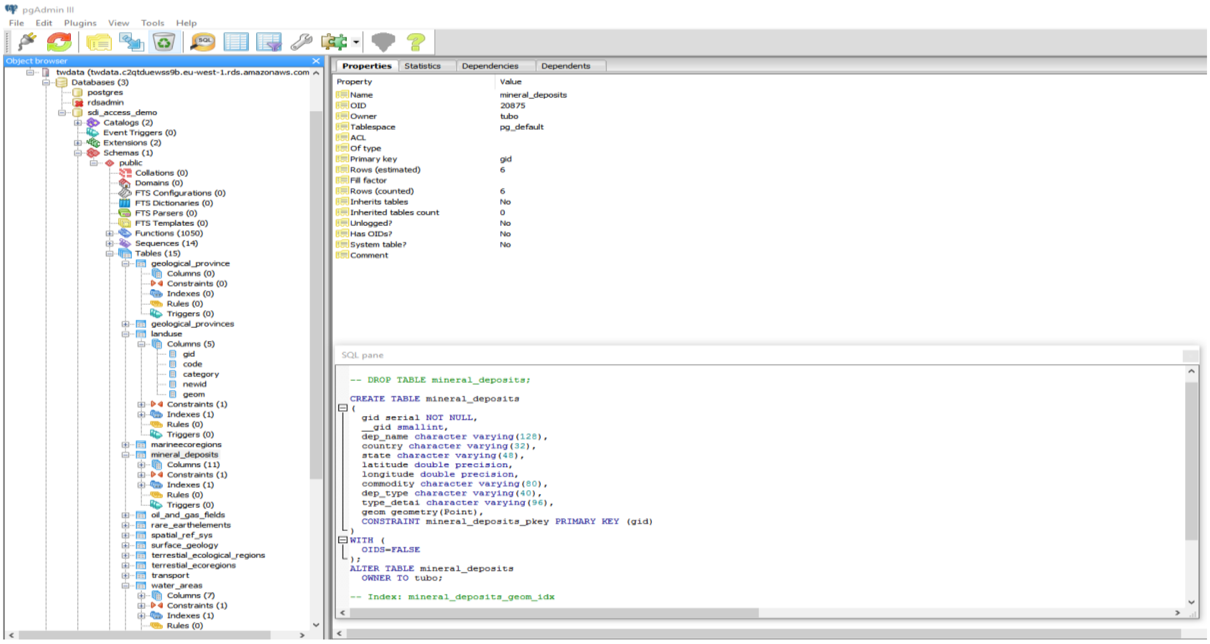



*Figure 5.7: PgAdminIII showing AWS RDS Postgres database*

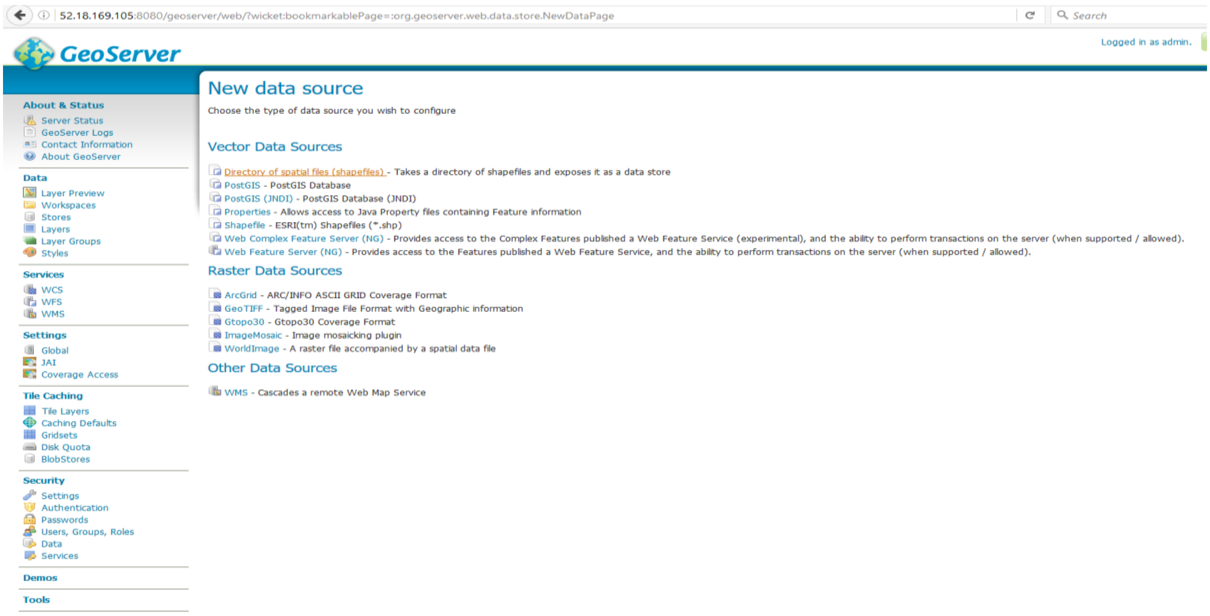



*Figure 5.8: Geoserver Instance*

To allow for participation and cooperation, roles and responsibilities were defined in the Geoserver instance to enable users, or participants within specific nodes (sector) or across different sectors (depending on the permissions set up) to contribute to the database. Geoserver was very important in this development because it allowed the seamless flow and combination of spatial data from multiple sources: Postgres server, from user's directory, from other web services and geoportals, among others. It also allows the sharing of data between many users at various levels for various applications.

The metadata catalog for the SDI data access prototype was deployed to conform to ISO19115, an international metadata catalog standard to ensure data accuracy, compatibility and interoperability. It provided a structure for describing the characteristics of the inputted spatial datasets to be accessed via the SDI data access demonstrator prototype. As established earlier, open source Geoserver was selected as the OGC compliant geospatial webservice that served the spatial data to the users. It included a library or catalog with a user interface through which the datasets can be accessed, published and updated online, either directly within the Geoserver or via other webservices. This library or catalog within the Geoserver was then adapted to implement ISO19115 metadata standard by configuring the Catalog Service for the Web (CSW) OGC service into the Geoserver data directory using the ISO Metadata Profile Mapping file MD_Metadata; thus providing the CSW 2.0.2, the metadata Catalog Service for the Web, which implements ISO19115:2003 within the Geoserver (see Figure 5.9).

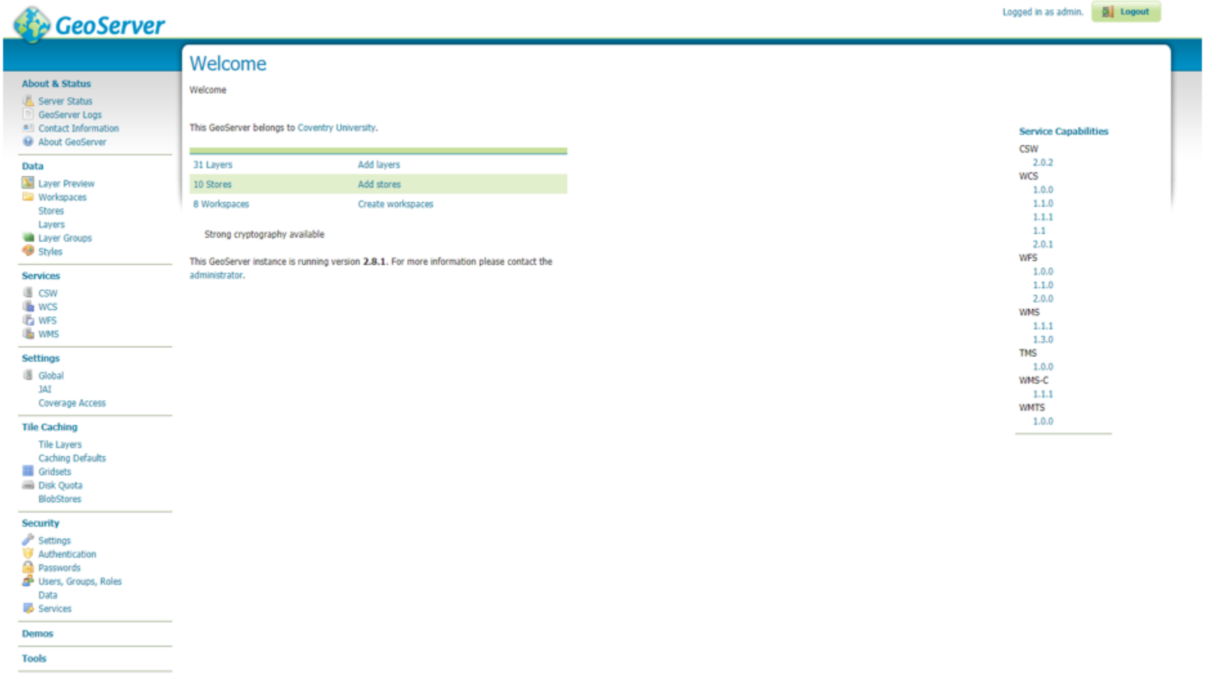



*Figure 5.9: Geoserver Instance showing service capabilities*

The Geoserver import system also allows the definition of the data standards following specified ISO standards and formats specified by the legislature in Nigeria. See Figure 5.10.

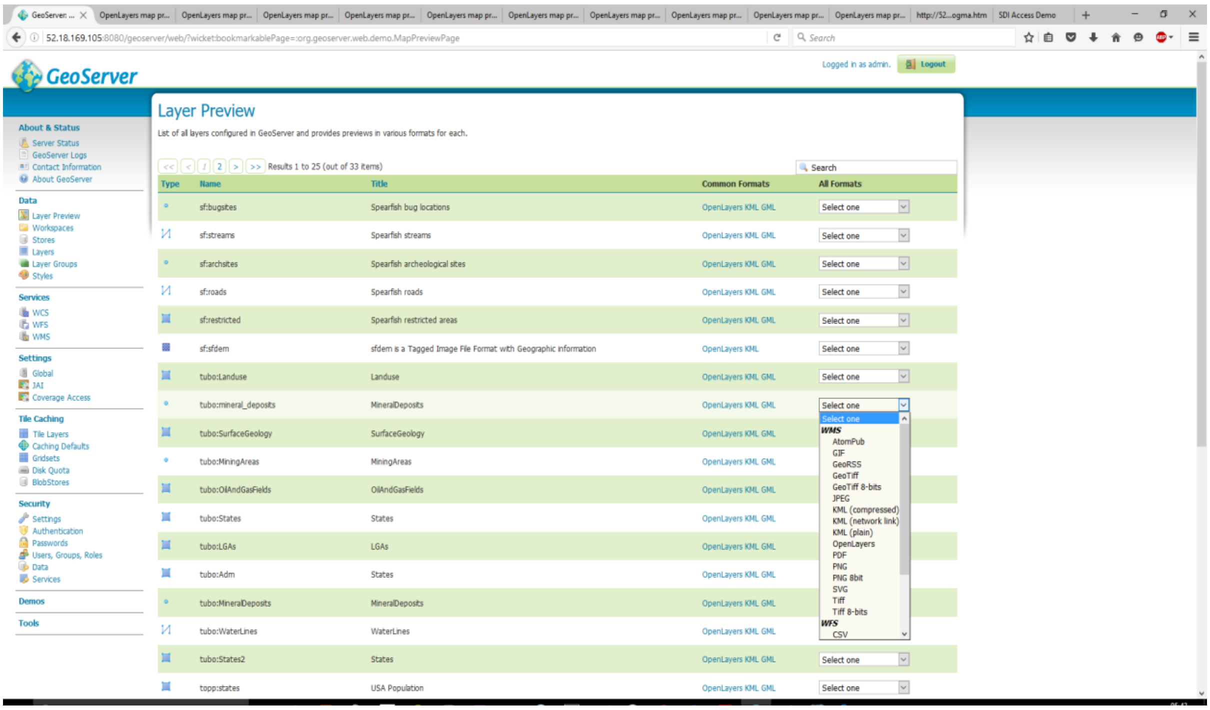
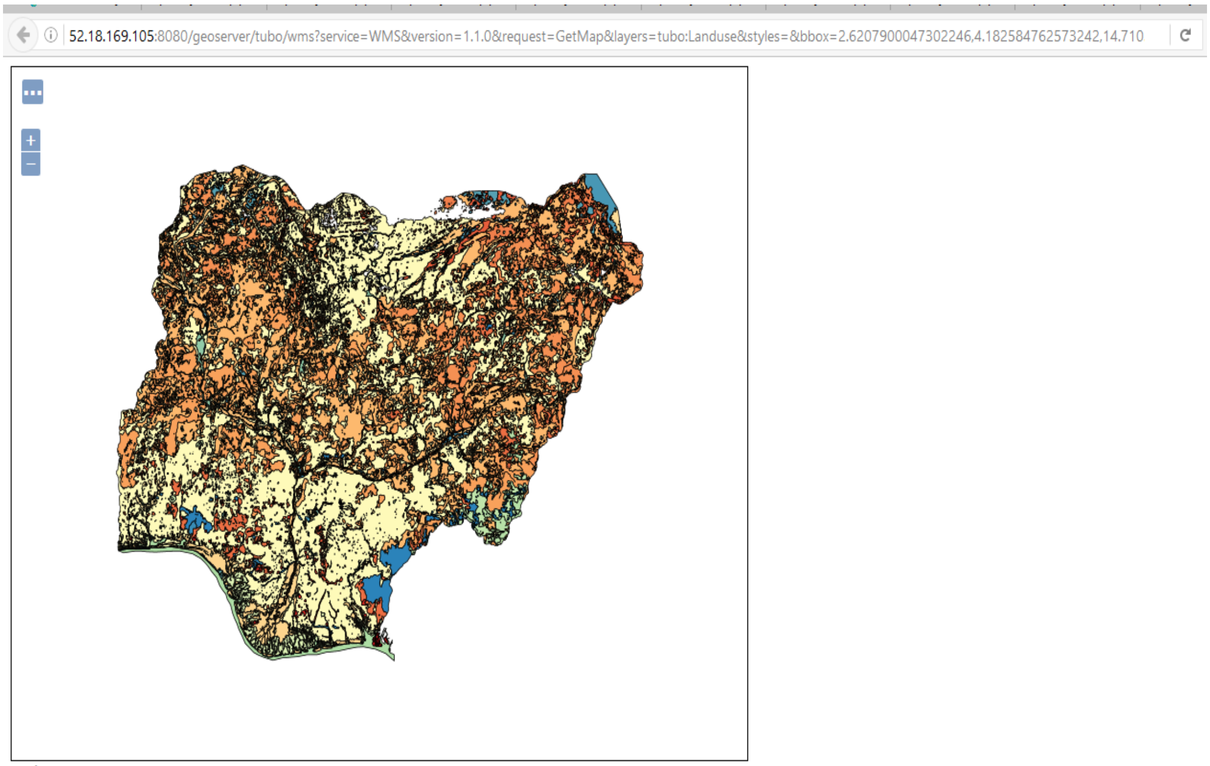



*Figure 5.10: Geoserver instance showing data formats*

This decentralization of the system, where data are stored in the Postgres database and harvested into the Geoserver in specified format, managed and retrievable over the web, optimises the processing speed for data download and access requests as the platform is not burdened with the storage of datasets. It also enhances data sharing and partnerships as the SDIs can be connected to standardized databases in different locations thus aiding collaborations between the local, state and federal agencies. It also creates a valuable avenue for private sector partnerships and collaboration with governments, private sector investments, job creation and in consequence the maximization of spatial data potentials. This is so because the private sector can partner with the government to produce standardized datasets from any location thus providing its benefits to augmenting the SDI. It is achievable in an environment where there is an effective government and stakeholder partnership arrangement.

To download the data, selecting shapefile, CSV or any of the available formats downloads the data in the format stipulated. For instance, selecting Open Layers format for the Land Use data, presents the data in a WMS web map as shown below.




**Landuse**

| fid | CODE | CATEGORY | NEWID |
|---|---|---|---|
| Landuse.14229 | 211 | Intensive(row crops, minor grazing) small Holder Rainfed Agricu | 2 |
| Landuse.14376 | 52 | Undisturbed forest | 2 |

*Figure 5.11: Accessing data via OpenLayers in Geoserver*

### 5.5.1.2 *METADATA CATALOG: ISO19115*

The Metadata Catalog enables the storage of metadata. It performs this task by arranging the metadata in defined standards and schemas to enable the easy discovery of distributed and heterogeneous assets such as datasets, software, computing resources, sensors and users within a database. It enables the correct definition of metadata and in turn, the datasets to avoid misuse and misrepresentation of the data. A number of metadata standards and schemas have been defined and are being adopted in practice. They include the Dublin Core Metadata Element Set, the PREMIS (Preservation Metadata Implementation Strategies), e-Government Metadata Standard, the ISO (the International Organization for Standardization) Metadata Standards, among others. This research however adopts the ISO 19115 Geographic Information - Metadata standard, prepared by ISO Technical Committee 211 (ISO TC211) for the definition of the metadata catalog deployed within the Geoserver. The ISO 19115 Metadata Standard defines the metadata elements needed to document the spatial dataset by providing a structure for describing and discovering the metadata elements See Figure 5.12 below. These elements are encoded using XML (Extensible Mark-up Language) Meta Language and they are structured to adhere to the relevant schemas and structures.


```xml
<?xml version="1.0" encoding="UTF-8"?>
<csw:DescribeRecordResponse xsi:schemaLocation="http://www.opengis.net/cat/csw/2.0.2 http://ec2-34-240-248-132.eu-
west-1.compute.amazonaws.com:8080/geoserver/schemas/csw/2.0.2/CSW-discovery.xsd" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:csw="http://www.opengis.net/cat/csw/2.0.2">
 - <csw:SchemaComponent schemaLanguage="http://www.w3.org/XML/Schema" targetNamespace="http://www.opengis.net/cat/csw/2.0.2">
   - <xs:schema version="2012-07-13" xmlns:xs="http://www.w3.org/2001/XMLSchema" xmlns:xlink="http://www.w3.org/1999/xlink"
     xmlns:gmd="http://www.isotc211.org/2005/gmd" targetNamespace="http://www.isotc211.org/2005/gmd" elementFormDefault="qualified"
     xmlns:gco="http://www.isotc211.org/2005/gco">
         <!-- ================================== Annotation ================================== -->
     - <xs:annotation>
         <xs:documentation>Geographic MetaData (GMD) extensible markup language is a component of the XML Schema Implementation of Geographic
           Information Metadata documented in ISO/TS 19139:2007. GMD includes all the definitions of http://www.isotc211.org/2005/gmd namespace
           The root document of this namespace is the file gmd.xsd. This identification.xsd schema implements the UML conceptual schema defined in
           A.2.2 of ISO 19115:2003. It contains the implementation of the following classes: MD_Identification, MD_BrowseGraphic,
           MD_DataIdentification, MD_ServiceIdentification, MD_RepresentativeFraction, MD_Usage, MD_Keywords, DS_Association,
           MD_AggregateInformation, MD_CharacterSetCode, MD_SpatialRepresentationTypeCode, MD_TopicCategoryCode, MD_ProgressCode,
           MD_KeywordTypeCode, DS_AssociationTypeCode, DS_InitiativeTypeCode, MD_ResolutionType.</xs:documentation>
       </xs:annotation>
         <!-- ================================== Imports ================================== -->
       <xs:import schemaLocation="http://schemas.opengis.net/iso/19139/20070417/gco/gco.xsd" namespace="http://www.isotc211.org/2005/gco"/>
       <xs:include schemaLocation="gmd.xsd"/>
       <xs:include schemaLocation="constraints.xsd"/>
       <xs:include schemaLocation="distribution.xsd"/>
       <xs:include schemaLocation="maintenance.xsd"/>
         <!-- ######################################################################### -->
         <!-- ######################################################################### -->
         <!-- ================================== Classes ================================== -->
```


*Figure 5.12: XML Showing the definition of the metadata catalog within the Geoserver*

ISO19115 was adopted to create the metadata catalog to enable the documentation of the metadata information within the prototype. ISO19115 is used to describe digital information that has geographic extent. It can in fact be used to describe various types of resources including textual documents, initiatives, software, non-geographic information, product specifications and repositories, that is, it can be used to describe information resources that do not have geographic extent. This is important because, the availability of complete datasets with its corresponding metadata information were highlighted as a major challenge in Nigeria as well as in other climes.

The CSW configured in the Geoserver was achieved using MD_Metadata configuration file that utilises four packages as documented in the ISO19115 metadata standard. They are Citation and responsible party information, Language-characterset localisation information, Extent information, and Metadata application information. This was used to provide the metadata.

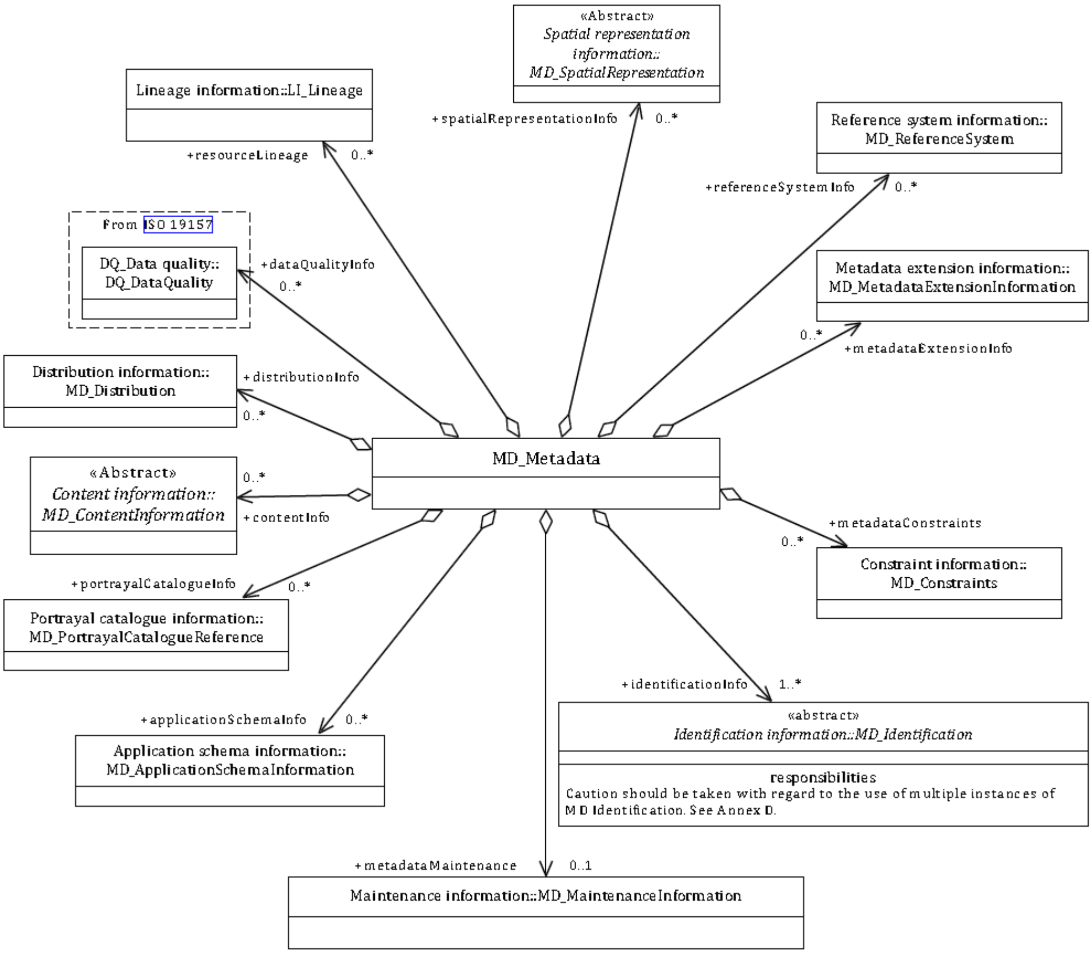



*Figure 5.13: ISO19115 schema showing the MD_Metadata classes*

### 5.5.1.3 *USER INTERFACE*

The user interface was deployed using GeoEXT, Ext.js and OpenLayers to create a map window to access data stored in the Geoserver, as well as to create the user interface. Figure 5.14 shows the interface on a desktop computer and Figure 5.15 shows the interface on a mobile phone.

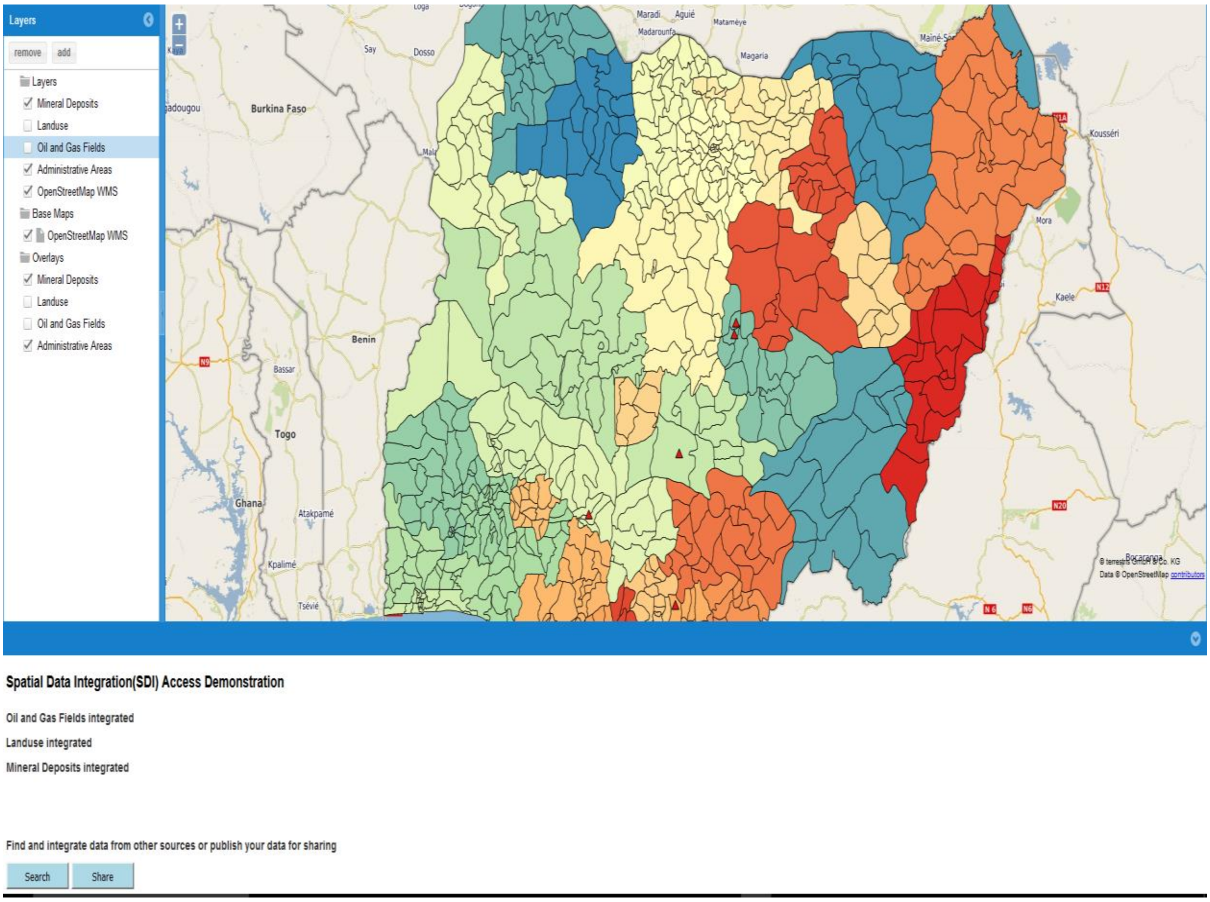



*Figure 5.14: Web application accessed via a computer*

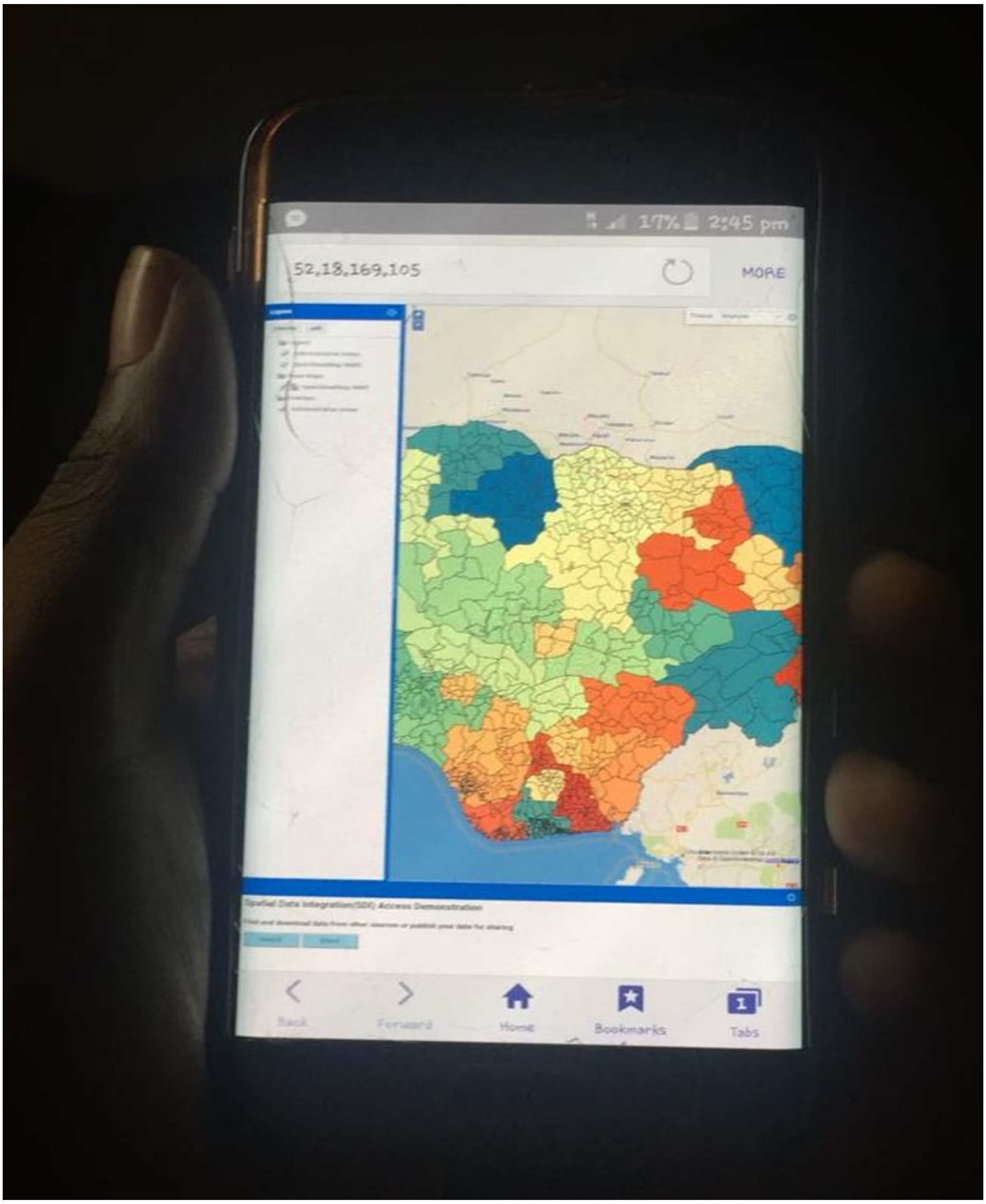



*Figure 5.15: Web application accessed via a mobile phone*

The web application was deployed in the root folder of the Apache 2 Server in the Ubuntiu14.04 instance as shown below in Figure 5.16 using Ext.js (ext-4.2.1.883), GeoEXT 2 (geoest2-2.1.0) and Open layers (OpenLayers-2.13.1) to load the web application.

/var/www/html/access

| Name | Size | Changed | Rights | Owner |
|---|---|---|---|---|
| .. | | 09/09/2016 01:35:55 | rwxrwxrwx | root |
| demo | | 09/09/2016 05:54:07 | rwxrwxr-x | ubuntu |
| ext-4.2.1.883 | | 09/09/2016 02:37:03 | rwxrwxr-x | ubuntu |
| geoext2-2.1.0 | | 09/09/2016 01:37:48 | rwxrwxr-x | ubuntu |
| OpenLayers-2.13.1 | | 09/09/2016 01:57:01 | rwxrwxr-x | ubuntu |

*Figure 5.16: Location of web application in Apache 2*

The landing page of the web app which is the first map panel opened when accessing the web application was executed using the code shown in Appendix V.

The resulting map panel is show in Figure 5.17 below;

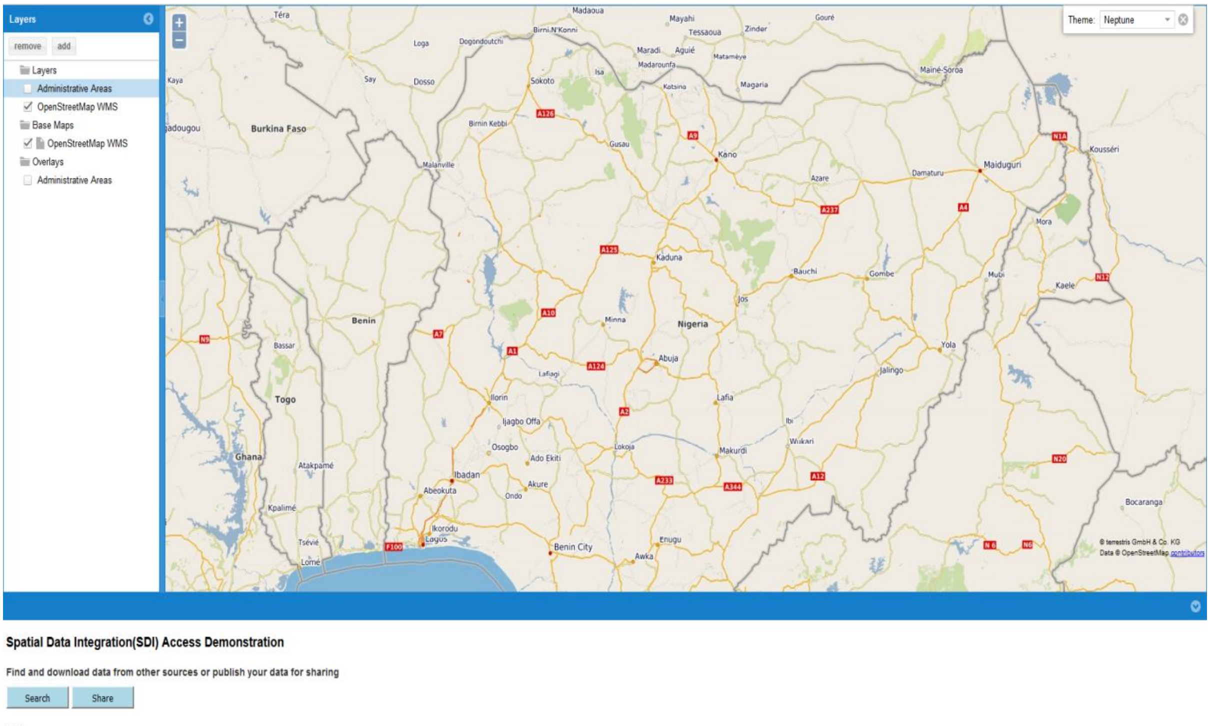



*Figure 5.17: Map panel*

The full list of codes used in the development is added to the Appendix V. However, a screenshot of the code list is presented is given in Figure 5.18.

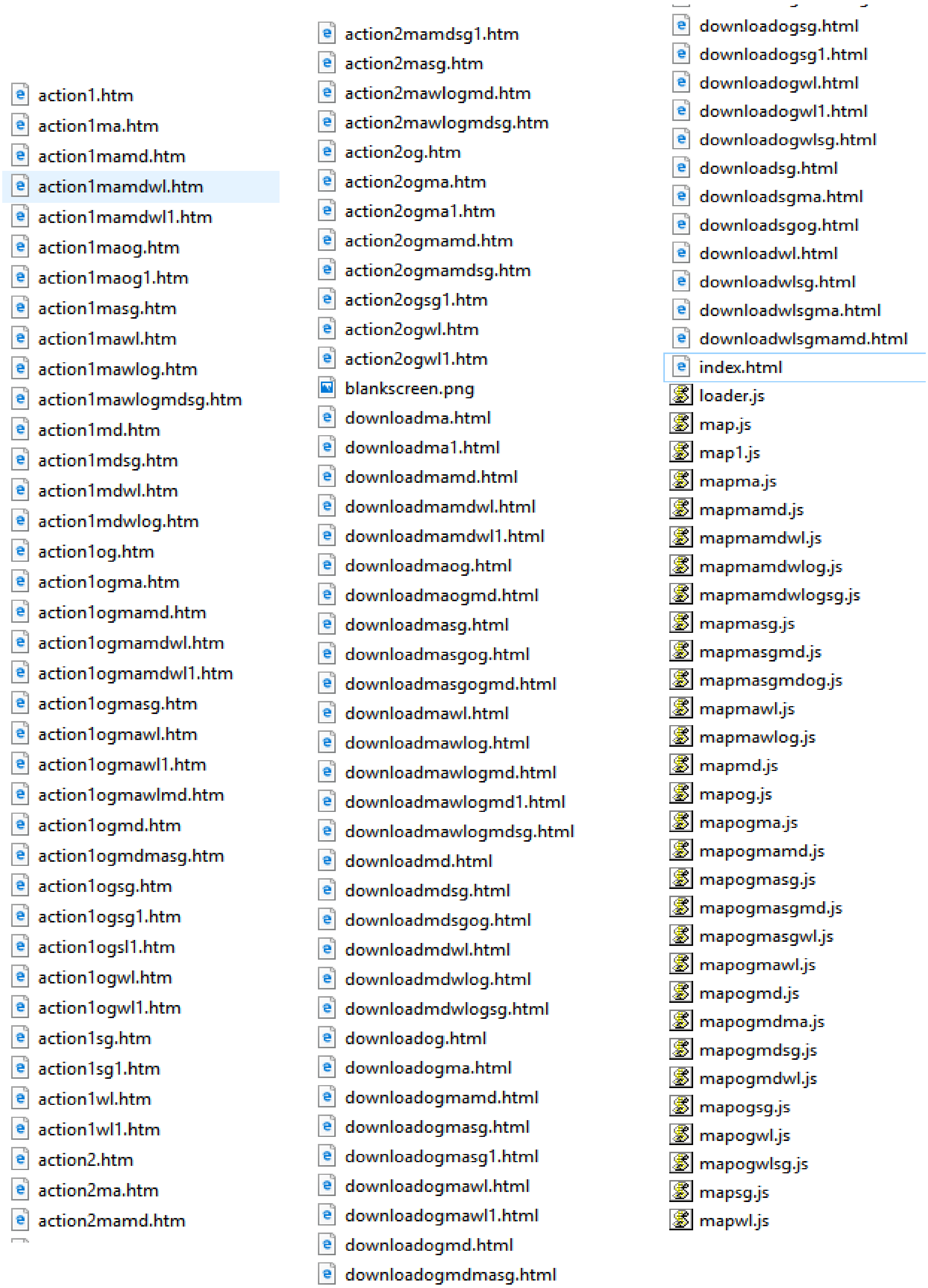



*Figure 5.18: Screenshot of the list of codes*

Each of these codes executed different functions to allow data search, integration and sharing within the system. Data can then be searched and integrated into the map by clicking on the 'search' or 'integrate' button. Figure 5.18 shows the interface for selecting spatial data to integrate. Figure 5.19 shows the application interface. There are two buttons in the bottom left hand corner of Figure 5.19 entitle 'search' and 'share'. Users can click these to start off the relevant processes for searching for or sharing data.

# Spatial Data Integration Services

Select from the following available data.

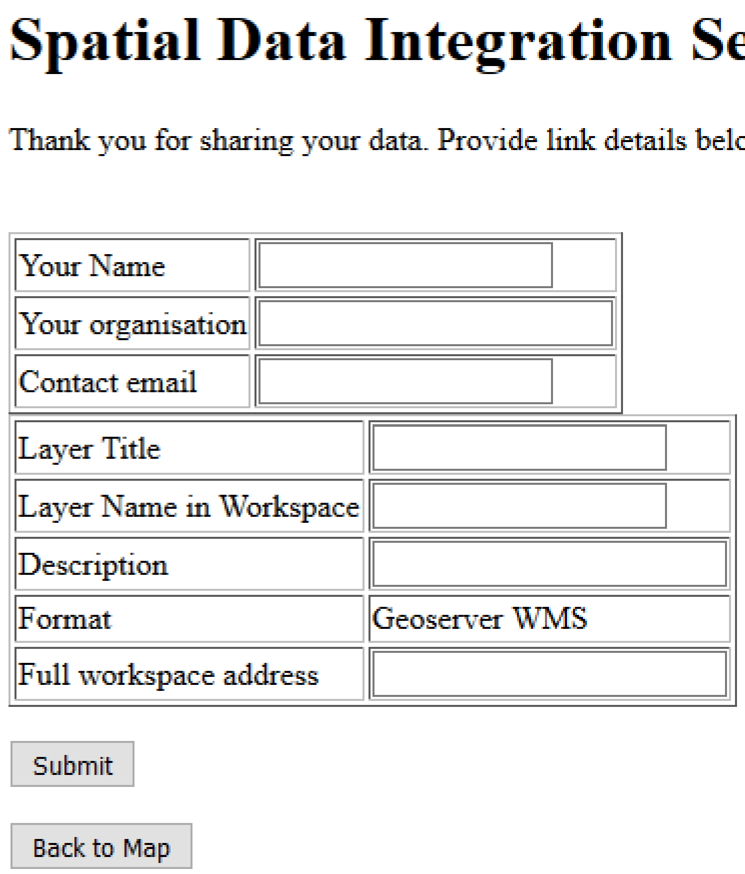
| Data Name | Description | Format | Integrate |
|---|---|---|---|
| Oil and Gas | Oil and Gas Fields in Nigeria | Geoserver WMS | Integrate |
| Landuse | Landuse in Nigeria | Geoserver WMS | Integrate |
| Mineral Deposits | Mineral Deposits in Nigeria | Geoserver WMS | Integrate |

*Figure 5.19: Integrating data into the map*

Once integrated the selected layers appear on the web application as show below


*Figure 5.20: Data access interface*

The web application provides to opportunity to share data by clicking on the 'share' button. This opens a web form where data can be shared as shown in Figure 5.21 below


# Spatial Data Integration Services

Thank you for sharing your data. Provide link details below:

| | |
|---|---|
| Your Name | |
| Your organisation | |
| Contact email | |
| Layer Title | |
| Layer Name in Workspace | |
| Description | |
| Format | Geoserver WMS |
| Full workspace address | |

Submit

Back to Map

*Figure 5.21: Data sharing interface*

## 5.6 TECHNICAL EVALUATION OF THE PROTOTYPE

A multi-criteria evaluation method was designed in this research to analyse the technical capabilities of the system against the stated system requirements and its ability to meet the stated user requirements. The technical evaluation was conducted internally by the researcher and this was done by aligning the defined or stated levels of performance based on both system and user requirements. The evaluation method employed in this research assesses the ability of the developed prototype to aid data access and exploration for the visualization and prediction of environmental impacts for EIA reporting. To this end, the criteria shown in Table 5.3 were set.

*Table 5.4: Technical evaluation of prototype*

| User Requirement | Intended service request | Questions Addressed | Method | Assessment | Comments |
|---|---|---|---|---|---|
| **Find or discover data** | Locate the data and service<br><br>Get help: Access links to relevant resources | Is the data access function achievable? And how?<br><br>What protocol, software and hardware is required?<br><br>Are there existing protocols to build on?<br>Where is the data stored? | Data discovery and access was deployed using the<br><br>The web application was designed using GeoEXT, OpenLayers and Java Script (ext) that connects to the Geoserver to allow data visualisation.<br><br>These are existing protocols that were configured and coded to allow data access.<br><br>Currently data can be accessed, viewed and explored via the platform but downloaded via the Geoserver. | Accessibility: The system is accessible over the internet.<br><br>Speed or scalability of service: The system was built using light weight open source software and thus is easily accessible without delays of loading as the weight of the system is spread across the Geoserver, Postgres and user interface. | Currently requires internet access to view the data, but once downloaded can be viewed offline. The development of an offline service that allows certain datasets to be viewed without internet access but telecom minutes would be very helpful in cases where internet service is poor or unavailable.<br><br>More coding and designing of the user interface to increase the sizes of the icons, include a search icon and simplify the user interface.<br><br>Development of downloadable web apps from the mobile app store could be useful to improve acceptance.<br><br>Developing an improved geoportal where the data can be downloaded, imputed and metadata can be stored would be very useful.<br><br>Geonetwork was explored and is recorded to be very useful open |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | source platform to create geoportals |
| **Acquire data** | Download the data<br><br>Get help and access links to relevant resources | Are there protocols to allow data download?<br><br>What are the possible methods to employ? | Geoserver was deployed with appropriate permissions to allow data sharing | Data can be downloaded via the Geoserver in an easy way thus allowing more uses with less technical proficiencies like managers to access the platform easily.<br><br>Data can be downloaded in different formats depending on its relevance to intended users. | Geoserver was deployed allow the data download, it is however limited to the type and quality of data fed into it. Thus, the SDI augmentation framework recommended as part of this research included a protocol for data development and maintenance to ensure quality is controlled and assured at all times.<br><br>In cases where additional data types are required, converters can be implemented as an extension to the system to convert the data as documented by Ryoo et al., (2017). In their research the converter extension was implemented to convert data from ISO geometry to SFCGAL and vice versa. The SFCGAL Wrapper objects invoke the corresponding native methods of SFCGAL when methods of ISO geometry are called by GeoServer. Once processing in SFCGAL is completed, the results are returned as wrapper objects. |

| | | | | | |
|---|---|---|---|---|---|
| **Share data** | Upload data<br><br>Share data files and links | What methods can we use to achieve this?<br><br>Are there accessible, cost effective software and hardware we can use? | Geoserver was deployed with appropriate permissions to allow data sharing<br><br>A file transfer protocol was deployed in the user interface to allow data sharing from pre-registered data providers (nodes or Geoserver) to allow for quality assurance and control.<br><br>Data sharing was achieved but it is largely dependent on the access control, roles and functions attributed to each of the users registered to the system. | The datasets have been defined or created using specific data standards to ensure interoperability and easy sharing. The success of this depends on the enforcement of the policy that ensures data standards are adhered to.<br><br>Downloaded datasets can be printed, emailed, or transferred using FTP or the data url from the Geoserver | The success of this function largely depends on the policy defined for the SDI as well as the permissions set within the Geoserver to allow for participation and data sharing. As a result, the SDI augmentation framework recommended as part of this research emphasises on policy implementation and included a protocol for partnership and participation. |
| **Process data** | Explore data<br><br>Analyse data<br><br>Edit data<br><br>Delete data<br><br>Update standards | Does the datasets and protocols employed allow for interoperable exploration and processing of datasets? | Data can be explored within the Geoserver using by accessing the data using one of the deployed formats for exploration. Data can be explored in form of open layer maps, either through the data access platform or the Geoserver. It can also be harvested as in different formats for analysis in external GIS systems<br><br>The map panel of the web application was deployed to enable data exploration | Metadata and data standards were and can be updated in the Geoserver thus improving the accuracy and quality of the data. It also ensures the consistency of standards and ensuring data interoperability. | The system does not currently provide the function for data analysis as it was not considered relevant for the demonstration. However, for the full implementation in practice, some analytical functions would be helpful. In order to support WPS functions, additional metadata elements would need to be added to the metadata catalog to enable the detailed data processing operations. This will both ensure data completeness and consistency as well as ensure the accuracy of WPS operations. |

From the technical analysis of the prototype, a number of issues were identified. Most of these issues were addressed and others like the ability to explore and analyse data within the data access platform were put aside as it was not considered significant to demonstrating data access through the NGDI. Participants were however quizzed on the need for that function during the PPU evaluation. Participants agreed that the developed platform was sufficient for the demonstration but cited that those extra functions would improve the usability of the system once it is being fully deployed, that is when it is being implemented in practice. As suggested, appropriate recommendations have been made so as to guide the implementation of the data access protocol in practice.

## 5.7 PROTOTYPE PERFORMANCE AND USER EVALUATION

This section presents the results of the PPU evaluation. Participants were made to go through a number of carefully designed tasks that enabled them to explore the prototype and its corresponding functions. The PPU evaluation instrument is shown in Appendix III. On completion of the prototype evaluation task, participants were quizzed on the usability and applicability of the prototype. The PPU evaluation questions were designed based on ISO 9421-210 usability standard. The questions were designed in Likert scale and participants were asked to state their level of agreement (strongly agree, agree, unsure, disagree or strongly disagree) with assertions concerning the prototype usability and applicability.

### 5.7.1 EFFECTIVENESS OF PROTOTYPE DESIGN: TECHNICAL VALIDITY

Participants were quizzed on their perception of the effectiveness of the prototype design. They were asked after the prototype demonstration, to state if they feel the prototype design is based on explicit understanding of users, tasks and environment. As shown in Figure 5.22, 54.17% of the respondents rated it as very effective while the remaining 45.83% rated it as effective. None of the respondents were unsure and none of the respondents either disagreed or strongly disagreed with the assertion.

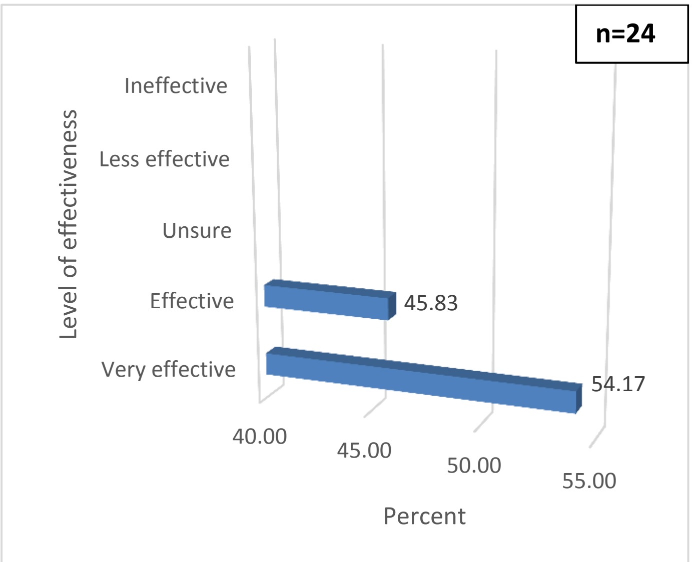



*Figure 5.22: Effectiveness of prototype design - Technical*

In furtherance to this, participants were quizzed on the effectiveness of the prototype as a demonstration of accessing spatial data from an SDI (spatial data infrastructure). 79.17% of the respondents rated the prototype as an effective demonstration for accessing spatial data from SDI while the remaining 20.83% of the respondents rated it as effective. Correspondingly, none of the respondents thought they were unsure, disagreed or strongly disagreed with the statement. Figure 5.23 shows a cross tabulation of participants' perception of the effectiveness of the prototype to demonstrate data access from an SDI with their perception of the effectiveness of the prototype design.

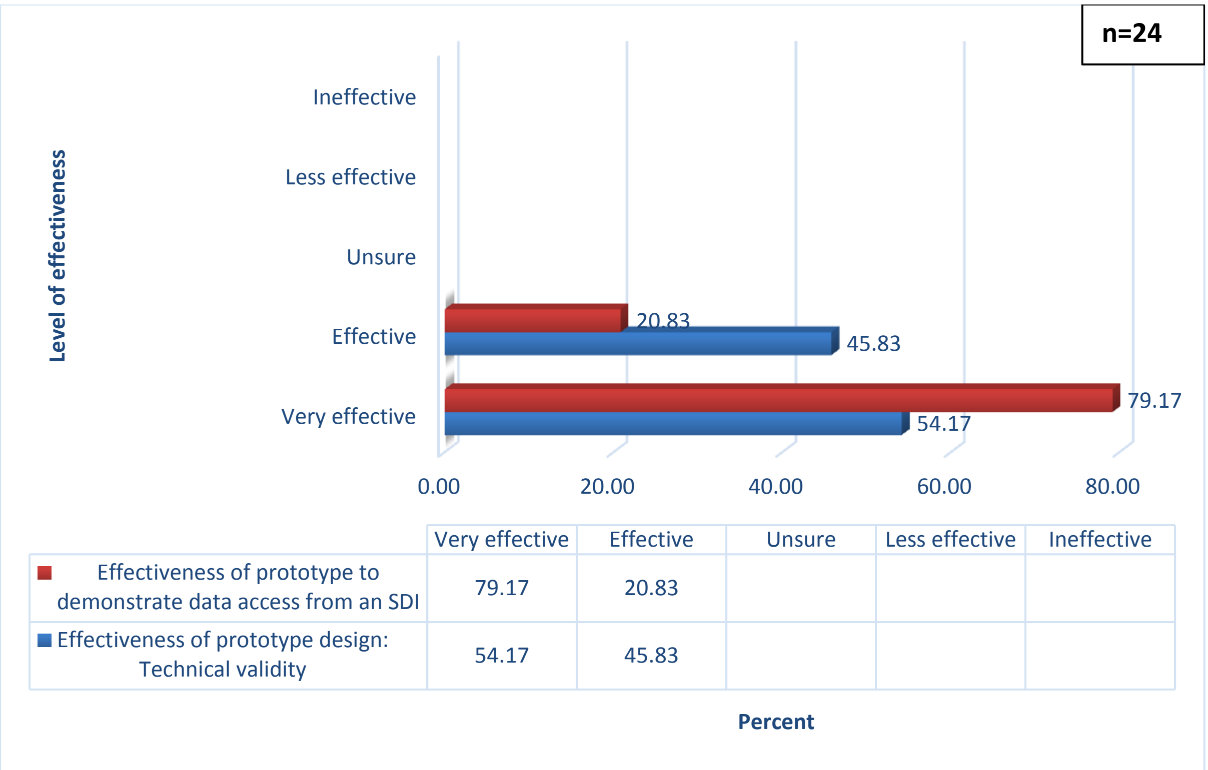



*Figure 5.23: Cross tabulation of users' perception of the effectiveness of the prototype*

## 5.7.2 COMPREHENSIBILITY OF PROTOTYPE

In order to ascertain how usable, the developed prototype was to the participants, they were asked to the comment on the helpfulness of prompts in the user interface. They were made to select from five Likert scale options (very helpful, helpful, unsure, less helpful and very unhelpful), signifying if they think that the instructions and prompts in the user-interface are helpful. 66.67% of the participants asserted that the instructions and prompts were very helpful, 29.17% asserted that it was helpful, 4.17%

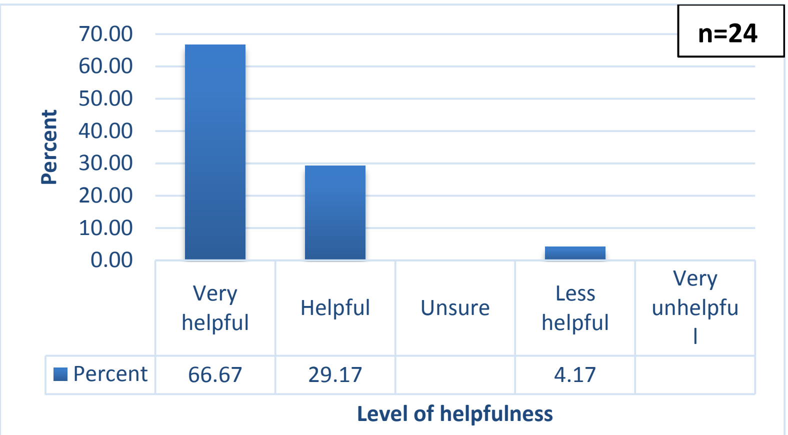



*Figure 5.24: Helpfulness of prompts and instructions in the user interface*

asserted that they were unsure, another 4.17% asserted that the instructions and prompts were less helpful, but none of the respondents attributed the instructions and prompts to be unhelpful (see Figure 5.24). It was important to find out how helpful the prompts and instructions were within the prototype while participants were carrying out the demonstration and evaluation tasks as it enables the inference of the comprehensibility of the prototype system. This was further checked by quizzing the respondents' on the clarity of the prototype system.

As show in Figure 5.25, 62.50% of the respondents strongly agreed with the statement that the system is presented in a clear and understandable manner, 29.17% agreed, 8.33% were unsure while none of the respondents disagreed or strongly disagreed with the statement.

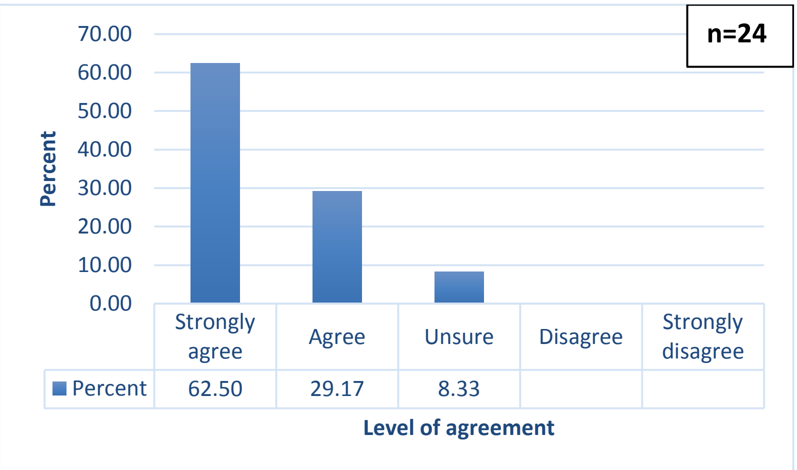



*Figure 5.25: Agree system is presented in clear and understandable manner*

In order to validate their understanding of the evaluation tasks and by implication, their rating of the prototype effectiveness, participants were quizzed on the clarity of the evaluation tasks. Participants were asked to rate the evaluation tasks on the prototype. They were required to state if it was very easy, easy, if they were unsure, if it was hard or very hard.

### 5.7.3 CLARITY OF EVALUATION TASKS

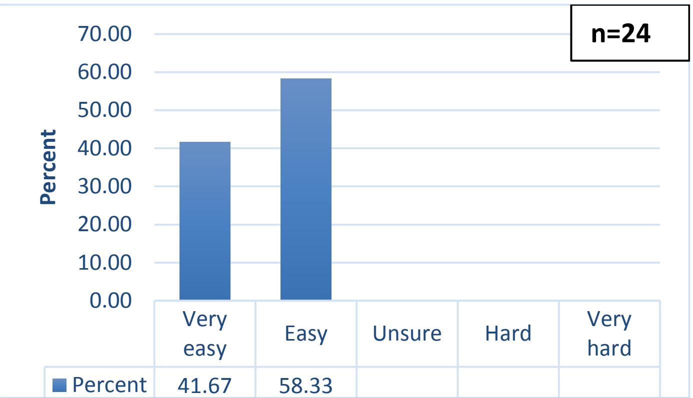



*Figure 5.26: How easy it was to go through evaluation tasks*

It was important to ascertain the clarity of the evaluation tasks.

As shown in Figure 5.26, 41.67% of the respondents asserted that it was very easy to go through the evaluation tasks while 58.33% said it was easy. None of the respondents were unsure and none of them asserted that the evaluation tasks were hard or very hard.

### 5.7.4 USER SATISFACTION WITH PROTOTYPE

It was also important to ascertain the user satisfaction with the prototype and also get valuable feedback of possible improvements and recommendations. Thus participants were quizzed on their level of satisfaction with the prototype as well as the possibility of them recommending the prototype data access protocol to their colleagues.

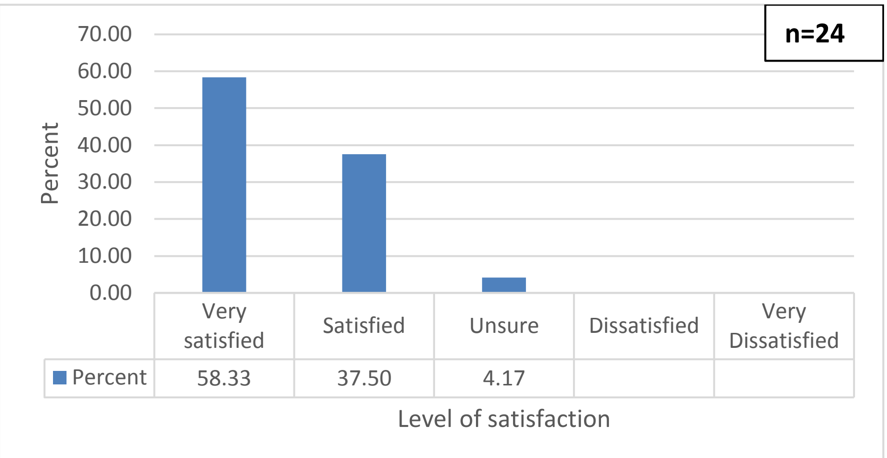



*Figure 5.27: User satisfaction with the prototype*

As shown in Figure 5.27, 58.33% of the participants noted that they were very satisfied with the prototype, 37.50% noted that they were satisfied while 4.17%

acknowledged their uncertainty as they were unsure. However, none of the participants were either dissatisfied or very dissatisfied with the prototype.

In a similar vein, all of the participants asserted that they would recommend the prototype data access protocol to their colleagues. 70.83% selected very likely while the remaining 29.17% selected likely. None of the participants were unsure and neither of them selected not likely or not at all. See Figure 5.28 below.

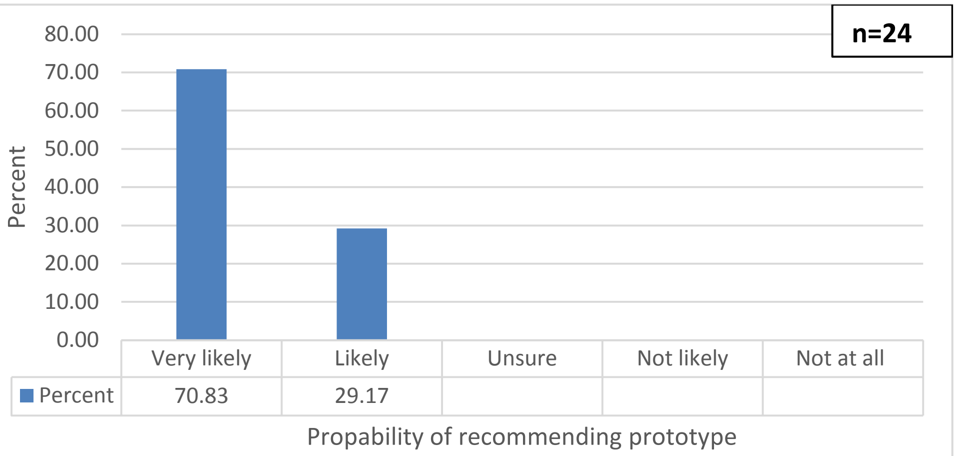



*Figure 5.28: Possibility of recommending prototype to colleagues*

## 5.7.5 ABILITY OF PROTOTYPE TO ADDRESS NGDI CHALLENGES

In order to effectively deduce the validity and usability of the implemented prototype to support environmental protocols like EIA, participants were asked to state their level of agreement to the statement that the *development of this prototype addresses the concerns of accessing NGDI data* highlighted in the EIA-SDI survey presented in Chapter 4 of this thesis.

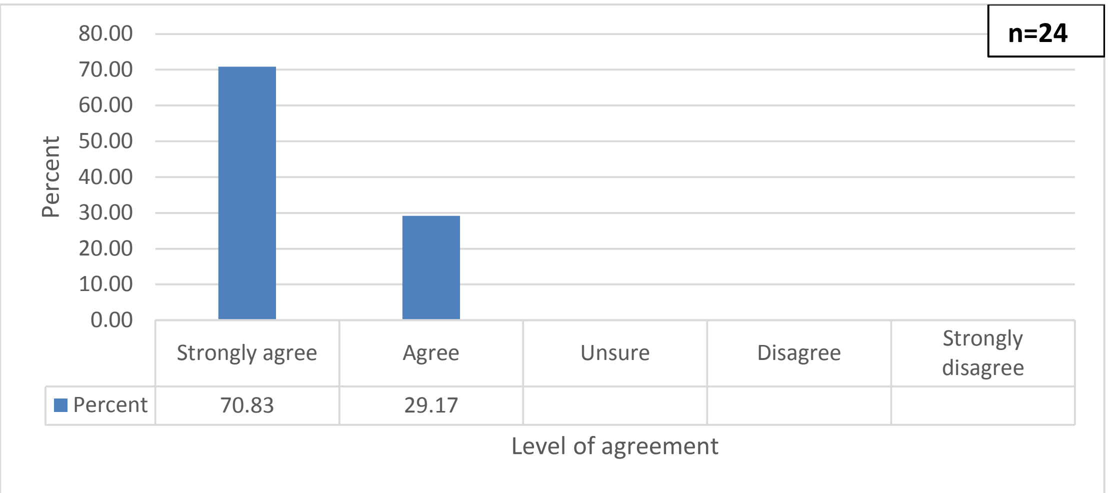



*Figure 5.29: Ability of prototype to address NGDI challenges*

70.83% of the respondents strongly agreed with the statement as shown in Figure 5.29 above. 29.17% agreed, none of the respondents were unsure and none disagreed or strongly disagreed with the statement.

### 5.7.6 ASSESSMENT OF PROTOTYPE FUNCTIONS

In the same vein, participants were asked to indicate how the use of the prototype can affect their ability to perform a number of tasks. Selected statements referencing fundamental tasks performed during the evaluation tasks were presented to the participants and participants were required to agree or disagree with the statements in various degrees (Likert scale; strongly agree, agree, unsure, disagree, strongly disagree). Cases of uncertainties were expressed by selecting ‘unsure’. These problem statements were grouped into five fundamental SDI components; standards, policy, access network, data and people. The tasks examined were the four main user requirements defined in Table 5.1 (see Section 5.3). They are; find or discover data, acquire (download) data, share data (dissemination to support partnership arrangement), and to process or explore data for analysis. This is an important part of the prototype evaluation as it confirms the validity of the prototype to fulfil the predefined user requirements. Results of the participant responses are presented in Figure 5.30 below.

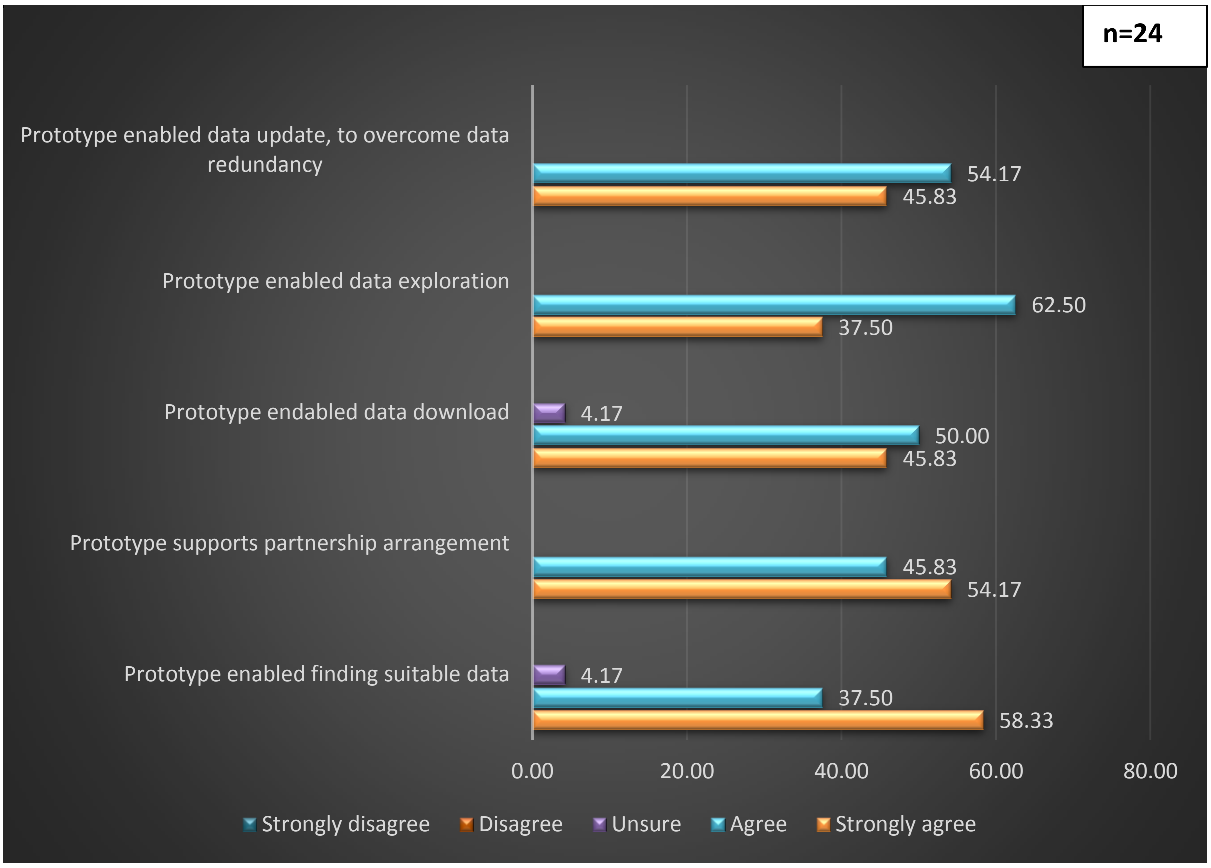



*Figure 5.30: Prototype ability to perform users' tasks and fulfil user requirements*

Participants expressed satisfaction with the prototype as mostly strongly agreed and agreed to the ability of the prototype to perform the stipulated tasks. Only 4.17% of the respondents were unsure that the suitable spatial data can be found via the prototype and that the interface provides access to download spatial data. None of the respondents disagreed or strongly disagreed with the prototype's ability to aid in the performance of the stipulated tasks. Participants however identified areas for improvements and recommended additional features that would make the prototype more effective as well as usable.

### 5.7.7 OVERALL PROTOTYPE ASSESSMENT

Participants were also requested to give an overall appraisal of the prototype. In this case participants were required to rate the prototype in a scale of 1-5 where 1 was the highest score (excellent).

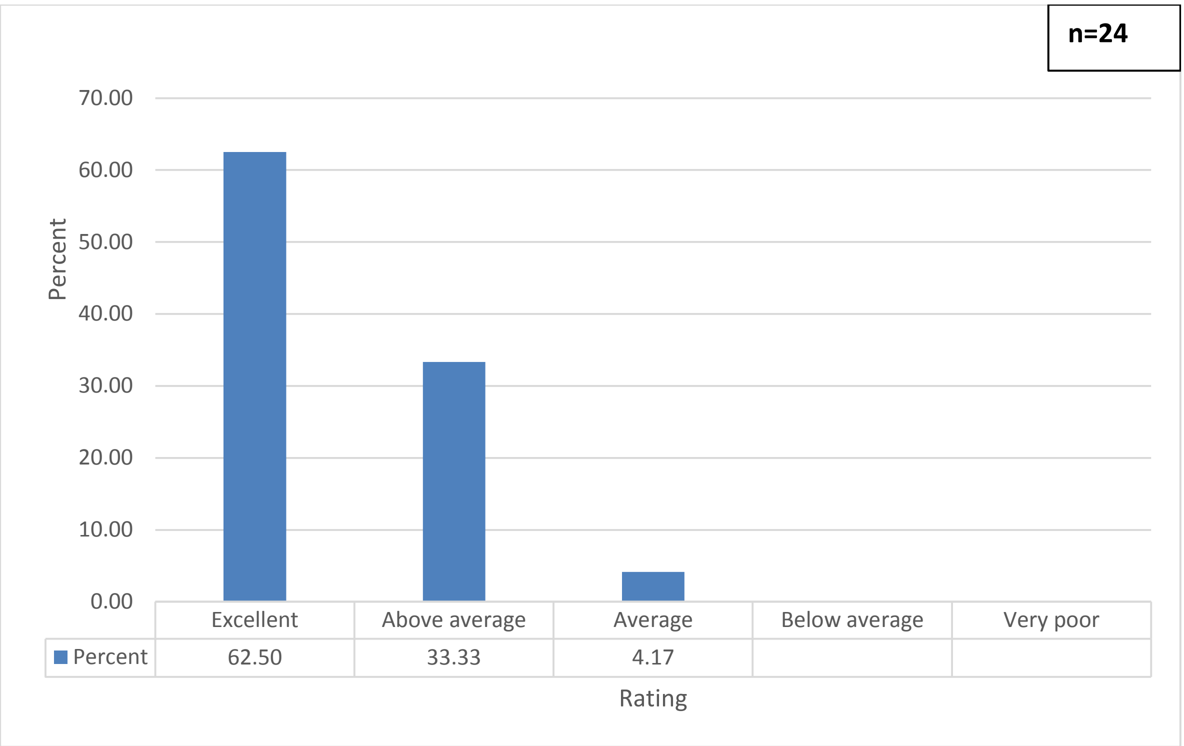



*Figure 5.31: Users' rating of the prototype*

As shown in Figure 5.31 above, 62.50% of the participants gave an excellent rating to the prototype, 33.33% rate it above average while 4.17% gave an average rating to the prototype. None of the participants rated the prototype below average or very poor.

## 5.8 INFERENTIAL ANALYSIS

Further analysis of the data is important to compare the data and check for relationships. It informs a more robust understanding of the data and survey population to make valid conclusions. Statistical tests were also conducted to verify participants' affirmation on the ability of the prototype to aid the performance of fundamental tasks identified when defining the user requirements in Table 5.1. Further statistical tests were conducted to verify the capability of the participants to make such judgements, thus validating their responses. This was possible by analysing their level of expertise as well as the category of their organisation, spatial data end user, spatial data producer or spatial data policy maker. This in addition to the type of task for which they use GIS and spatial data helps define their capabilities, thus validating their judgement of the prototype performance. Correlation and multiple regression analysis were conducted. The results are presented in the following sub-sections.

### 5.8.1 CORRELATION ANALYSIS: EFFECTIVENESS OF PROTOTYPE

Fourteen assessment factors were utilised to assess the effectiveness of the developed prototype. The factors measured the performance and user satisfaction with the developed prototype in relation to the current issues experienced with accessing NGDI data in Nigeria and its ability to address these challenges. Bivariate correlation analysis of these factors was conducted to identify the trends and associations. The results of the correlation analysis are presented in Table 5.5. A significant correlation *($p<0.01$)* with a strong positive association was recorded between participants' position on the statement that the "instructions and prompts in the user interface are helpful" with their position that the "prototype design is effectively based on explicit understanding of users, tasks and environment". A summation of 95.84% assert that the instructions and prompts were helpful; 66.67% very helpful, 29.17%

helpful and 4.17% less helpful, 0% unsure, 0% very unhelpful (See Figure 5.24) while 100% the population agrees with that the prototype design is effectively based on explicit understanding of users, tasks and environment; 54.17% strongly agree, and 45.83% agree (See Figure 5.22). Also, a significant correlation (*p<0.01)* with a strong positive association was also recorded for their position on the argument that the system is presented in a clear and understandable manner, with the argument that the instructions and prompts were helpful. The strong positive association with both assessment factors posits the argument that the helpfulness of the instructions and prompts in the user interface of the prototype influenced their decision that the prototype was designed effectively based on explicit understanding of user tasks and environment as well as their perception that the system was presented in a clear and understandable manner. 62.50% of the respondents strongly agreed that the system is presented in a clear and understandable manner, 29.17% agreed, 8.33% were unsure, 0% disagreed and 0% also strongly disagreed (See Figure 5.25).

A significant correlation (*p<0.01)* with a strong positive relationship as also recorded with the user documented satisfaction with the prototype and the argument that the "prototype is an effective demonstration of accessing spatial data access from an SDI". The positive correlation informs that user satisfaction with the prototype, in which 95.83% asserted to be satisfied (58.33% very satisfied and 37.50% satisfied - see Figure 5.27) is influenced by the effectiveness of the prototype to demonstrate accessing spatial data from an SDI (79.13% agreed it was very effective and 20.83% thought it was effective - see Figure 5.23). User satisfaction with the prototype is also observed to influence three more assessment factors: participant "likelihood of recommending the prototype data access protocol to colleagues" (see Figure 5.28); participant agreement to the statement that "the prototype addresses concern of accessing NGDI data" (see Figure 5.29); and their position on the statement "the user interface of the prototype enables data update, to overcome data redundancy" (see Figure 5.30). A significant correlation (*$p<0.05$*) with a medium positive association was recorded with the three assessment factors, thus indicating that their increased satisfaction with the prototype influences their increased agreement with the other three factors presented in Figures 5.28, 5.29 and 5.30.

*Table 5.5: Bivariate correlation of factors assessing the effectiveness of the developed prototype to address identified NGDI challenges*

| Correlations | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** | **K** | **L** | **M** | |
| Prototype design is effectively based on explicit understanding of users, tasks and environment **(A)** | 1 | | | | | | | | | | | | | |
| Prototype is an effective demonstration of accessing spatial data from an SDI **(B)** | .352 | 1 | | | | | | | | | | | | |
| Instructions and prompts in the user interface are helpful **(C)** | .526** | .280 | 1 | | | | | | | | | | | |
| The system is presented in a clear and understandable manner **(D)** | .384 | .272 | .591** | 1 | | | | | | | | | | |
| User evaluation task was easy to go through **(E)** | .269 | .434* | .261 | .077 | 1 | | | | | | | | | |
| User satisfaction with the prototype **(F)** | .284 | .661** | .146 | .332 | .232 | 1 | | | | | | | | |
| Probability of recommending prototype data access protocol to colleagues **(G)** | .330 | .348 | .141 | .397 | .356 | .444* | 1 | | | | | | | |
| Prototype addresses concern of accessing NGDI data **(H)** | .146 | .122 | .141 | .113 | .170 | .444* | .395 | 1 | | | | | | |
| Prototype enabled finding suitable data **(I)** | -.151 | .126 | -.060 | -.117 | .086 | .372 | .126 | .763** | 1 | | | | | |
| Interface provides access to download spatial data **(J)** | -.207 | .195 | -.190 | -.047 | .123 | .201 | -.013 | .468* | .580** | 1 | | | | |
| Interface supports partnership arrangement **(K)** | -.175 | -.060 | -.069 | .124 | -.240 | .284 | .146 | .514* | .575** | .232 | 1 | | | |
| Interface supports data exploration **(L)** | -.324 | -.026 | -.153 | .017 | -.131 | .168 | .118 | .308 | .467* | .339 | .540** | 1 | | |
| Interface supports data update, to overcome data redundancy **(M)** | .175 | .060 | .069 | .005 | -.099 | .442* | .038 | .590** | .442* | .207 | .343 | .151 | 1 | . |
| How would you rate the prototype **(N)** | .207 | -.195 | .398 | .613** | -.271 | .053 | .013 | .013 | -.074 | .021 | -.085 | -.188 | .085 | 1 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | | | | | | | | | | | | |
| *. Correlation is significant at the 0.05 level (2-tailed). | | | | | | | | | | | | | | |
| **n=24** | | | | | | | | | | | | | | |

The argument that the prototype addresses concerns of accessing NGDI data in Nigeria is also seen to have significant correlations with four assessment factors. A strong positive association is also recorded with these factors. A significant correlation of $p<0.01$ is observed for the association with the statement that the "prototype enabled finding suitable data" while a significant correlation of $p<0.05$ is observed for the association with the other three assessment factors; the arguments that the "interface provides access to download spatial data", that the "interface supports partnership arrangement" and that "the interface supports data update to overcome data redundancy", thus indicating that these assessment factors influence their position on the ability of the prototype to address the concerns of accessing NGDI data. The positive association depicts that an increase their agreement with these assessment factors increases their perception of the ability of the prototype to address the concerns of accessing NGDI data.

A positive association was also observed between the argument that the "prototype enabled finding suitable data" and four assessment factors. A significant correlation of $p<0.01$ was recorded with their positions on the statement that the "interface provides access to download spatial data" and the statement that "interface supports partnership arrangement". A significant correlation of $p<0.05$ was also observed with the statements that "interface supports data exploration" and that the "interface supports data update, to overcome data redundancy". The positive association indicates that these assessment factors influence their agreement with the argument that the prototype addresses concerns of *accessing* NGDI data and vice versa. Also, the position on the statement that "interface supports data exploration" is also observed to influence their position on the statement that the "interface supports partnership arrangement" and vice versa. A significant correlation of $p<0.01$ was recorded with a strong positive association thus indicating that an increase in the prototype's ability to support data exploration would improve its ability to support partnership arrangement.

Finally, a significant correlation (*$p<0.01$*) was recorded with a strong positive association between the users' rating of the prototype ("how would you rate the prototype) and the argument that "the system is presented in a clear and understandable manner". This indicates that developing the system to ensure that it is presented in a clear and understandable manner influences the users' rating of the system as it is observed in in Figure 5.31 where 62.50% gave an excellent rating to the system, 33.33% rated it to be above average and the remaining 4.17% gave it an average rating.

### 5.8.2 Multiple Regression: Prototype Effectiveness

Multiple regression analysis, using the stepwise method was also conducted to identify the predictors of the overall rating of the prototype ("how would you rate the prototype."). Two significant models were produced using this method; Model 1: $(F\ (1, 22) = 13.26, p<0.005, R^2 = 0.38, R^2_{Adjusted} = 0\ .35)$ and Model 2: $(F\ (2, 21) = 11.25, p<0.001, R^2 = 0.52, R^2_{Adjusted} = 0\ .47))$. The adjusted R Square value showed that model 1 accounted for approximately 35% of the variance level of independence of the variables while Model 2 accounted for 47% of the variance level of independence of the variables, with the amount of variance increasing by 11% between the models.

*Table 5.6: Coefficients for prototype effectiveness*

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | .623 | .238 | | 2.618 | .016 |
| | The system is presented in a clear and understandable manner | .544 | .149 | .613 | 3.642 | .001 |
| 2 | (Constant) | 1.150 | .302 | | 3.809 | .001 |
| | The system is presented in a clear and understandable manner | .638 | .140 | .719 | 4.566 | .000 |
| | Prototype is an effective demonstration of accessing spatial data from an SDI | -.549 | .222 | -.390 | -2.477 | .022 |
| a. Dependent Variable: How would you rate the prototype | | | | | | |

The level of agreement to the attestation that the system is presented in a clear and understandable manner, as well as the attestation that the prototype is an effective demonstration of accessing spatial data from an SDI were shown to have contributed significantly to the overall rating of the prototype. That is, these two assessment factors have been useful in predicting the overall rating of the prototype. As displayed in Table 5.6 above, the attestation that the system is presented in a clear and understandable manner was the first predictor selected to be entered into the analysis (Model 1), indicating that it is the most useful predictor of the overall rating of the prototype, followed by the effectiveness of the prototype to demonstrate how spatial data can be accessed from an SDI. Other variables that did not show significant contributions to the rating of the prototype were excluded from this model. In the development of the SDI–AF therefore, the implementation of ***a clear and understandable SDI data access protocol that would effectively demonstrate and allow spatial data access from an SDI*** was prioritised.

## 5.9 CHAPTER SUMMARY

This chapter presented the prototype development, implementation and evaluation. The descriptive statistics of the evaluation reflected a high rating of the prototype. The participants gave very positive feedback of the prototype and suggested ways of improvement. The inferential statistics provided further information on the associations and trends within the data. Variables that influenced their opinions were also identified using correlation analysis. These factors were not limited to the ones shown by the correlation, as the research took into account the fact that correlation analysis does not completely show cause and effect. Thus, regression analysis was conducted to determine which of the independent variables statistically predicted the value of the dependent variable.

# 6 CHAPTER SIX: THE NGDI-CF EVALUATION

## 6.1 INTRODUCTION

The previous chapter presented the analysis of the outcome of the Prototype Performance and Usability (PPU) evaluation. The prototype was deployed to serve as the foundation for the SDI Augmentation Framework (SDI-AF) deployed in this research. However, to enable the adequate development of the proposed framework, sufficient knowledge of the current state of the NGDI was important to update the knowledge gathered from the initial EIA-SDI survey. This chapter therefore, details the NGDI Critical Factors (NGDI-CF) evaluation conducted to update the knowledge gathered on the state of the NGDI from the initial EIA-SDI survey. It provided further understanding on the current state of the emerging NGDI in Nigeria. Interviews were conducted in this case. It focussed on the effectiveness of the NGDI, the factors critical to its effectiveness, as well as those impeding its successful implementation. Questionnaire survey was combined with interviews to gather sufficient information on the NGDI. The results of the NGDI-CF survey and the analysis of the findings are presented in the following sections.

## 6.2 DESCRIPTIVE STATISTICS

This section presents the descriptive statistics and summaries of the responses of the participants from the interview survey conducted. The essence of this section is to enable a clearer understanding of the participant responses and show the emerging patterns and key issues raised. It also provides initial interpretations of the datasets which will serve as a foundation for more robust analysis. Inferential statistics and thematic analysis of the responses and data summaries are presented in subsequent sections.

The sample population for the NGDI-CF comprised of surveyed environmental consultants (which includes EIA preparers), operators (oil and gas operators) and regulators. The regulators in this case were similar to those from the EIA-SDI case as they were sampled from the Department of Petroleum resources (DPR) and the Federal Ministry of Environment (FMEnv). An additional set of regulators from NASRDA, the coordinating body for the NGDI, was included in the NGDI-CF evaluation. The regional SDI regulator, ECOWAS (Economic community of West African states) was also included for a more robust data gathering.

### 6.2.1 USERS AND ORGANISATIONAL PROFILE

This section reports on the technical proficiency of the participants and the category of their organisations.

#### 6.2.1.1 *TECHNICAL PROFICIENCY OF PARTICIPANTS*

The technical proficiency of the evaluation participants was surveyed to identify their individual level of expertise with the use of computers and GIS applications. This is to validate their understanding of the evaluation tasks as well as their assessment of the prototype. The majority (71%) of the respondents were experts in computer and GIS applications, 29% of the respondents were at an intermediate level while 0% was at a starter level. See Figure 6.1.

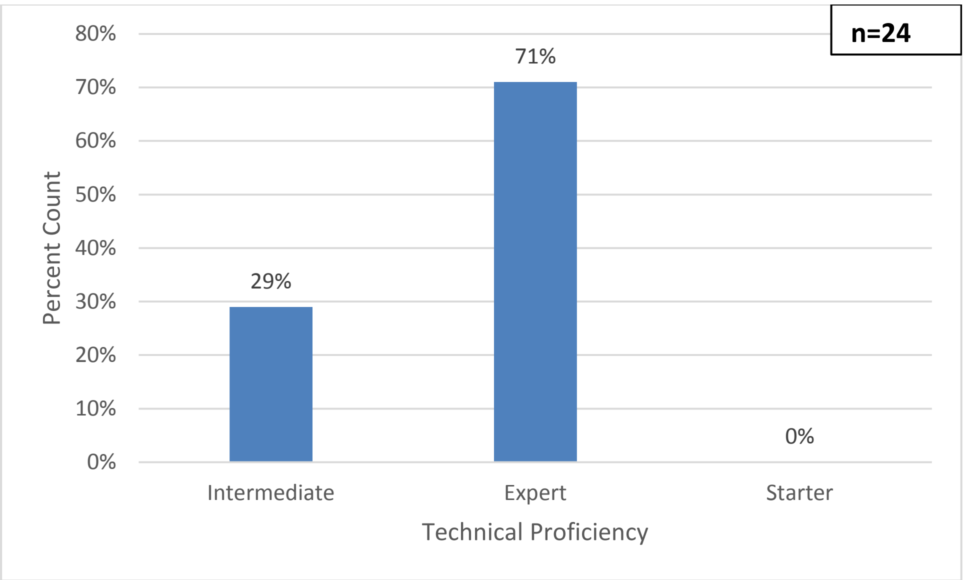



*Figure 6.1: Technical proficiency of respondents*

#### 6.2.1.2 *Category of Participant's Organisation*

The organisations of the participating respondents were also categorised to show their role in spatial data provision and policy making as well as in its use. Participants were asked to categorise their organisations based on three predefined categories; spatial data end user, spatial data provider, and spatial data policy maker. Organisations with more than one role were also reflected as shown in Figure 6.2.

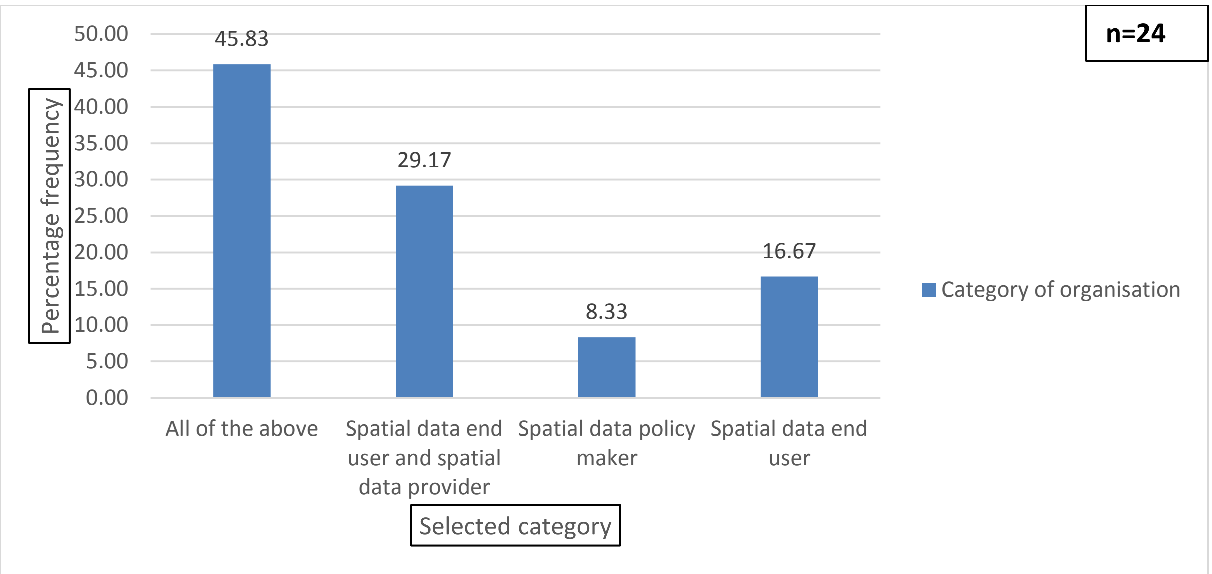



*Figure 6.2: Category of organisation*

45.83% of the participants selected ***all of the above,*** which indicates that they carry out all of the predefined roles of spatial data end user, provider and policy making. 29.17% are both spatial data end user and spatial data provider, 8.83% were only involved in spatial data policy while 16.67% were spatial data end users alone.

### 6.2.2 CURRENT CHALLENGES WITH SPATIAL DATA

Participants were also quizzed on the type of tasks for which they use GIS and spatial data. Respondents were observed to utilise GIS and spatial data for a wide range of environmental studies that included environmental impact assessments (EIA), environmental sensitivity index (ESI) mappings, oil spill contingency planning, for conducting baseline studies and sampling protocol for environmental studies, as well as for siting facilities to show the carrying capacity or robustness of selected locations. Other respondents were found to utilise GIS and spatial data for developing the boundaries of concession maps, for developing e-agricultural projects and smart city projects, among others. At a regional level, GIS and spatial data was seen to contribute to peace monitoring and for the development of public indicators for reflecting crisis or disease prone areas. It is also utilised for early warning and disease or crisis response purposes. It aids in the analysis and identification of hot spots of various events that are affecting human security (for example, Boko haram terror attacks) or health (disease outbreaks like the Ebola outbreak in 2014). From their extensive use of spatial data and GIS, participants were able to highlight a number of problems currently faced with the access and use of spatial data and GIS for their work.

*Transcript Excerpt 6.1*

*R: What problems do you currently face with the access and use of spatial data for you work?*

*"Agb": Access because there is no spatial infrastructure we depend in searching for bits in diverse places*

*Transcript Excerpt 6.2*

*R: Are there any particular problems with the use of the accessed spatial data with GIS?*

*"Nsi": Accuracy, completeness*

*Access to the right platform and proficiency in using*

*Transcript Excerpt 6.3*

*R: What problems do you currently face with the access and use of spatial data for you work?*

*"GE": Collecting spatial data. Okay. If I am to be completely honest, the major problem, because I come from a business end, so the major problem I have is that we are not paid enough to collect the amount of spatial data that will allow for rigorous analysis. That is the major problem. So you have clients that give you peanuts but they want you to give them results of the whole universe. And it's just, it's actually just not feasible. So that for me, that's a major issue. So it either means that you, as a consultant, you are not doing the work, you know, or you are, what's the word; extrapolating. And you know, there's so much you can stretch data to give you accurate, any form or semblance of accuracy. So for me, that's my major challenge in terms of accessing data; that we are not paid enough to actually get the right data.*

*Also I think, sorry, also I think another issue is, in terms of even collecting data and the fact that some of the areas we have to go to are in, they are virgin fields or whatever the case is,* *so there is a you know, accessibility and collecting issue, which in areas where there are community crises or you are doing work in the North where Boko haram, and you know, you have issues. And then sometimes, especially if you are doing the work for a big client, say Shell, immediately you go somewhere and the community hears you are doing work for Shell, (Rnotes: they think there is so much money you've been paid) exactly, and so that is another issue. Security is a big issue.*

*Transcript Excerpt 6.4*

*R: What problems do you currently face with the access and use of spatial data for you work?*

*"I": Well, there are problem of obsolete primary dataset. Some of the images may be good. Sometimes it is difficult to go to the field and get data. And the fund is not there, sometimes to go for ground truth. Logistics generally.*

*Transcript Excerpt 6.5*

*R: Are there any particular problems with the use of the accessed spatial data with GIS?*

*"Tun": Incorrect datasets. Incomplete. Inconsistent*

The initial thematic content analysis conducted on the responses provided insight to the problems faced by environmental practitioners in Nigeria with the use of spatial data for environmental analysis. The initial themes observed from the data are presented in Table 6.1 below. Coding from the interview identified a number of the themes which were coded as nodes in Nvivo to reflect the issues that are currently impeding the use of spatial data for environmental analysis.

*Table 6.1: Problems with access and use of spatial data*

| **INITIAL THEMES CODED FROM THE IDENTIFIED PROBLEMS** |
| --- |
| Getting reliable data and consistent data |
| Access to state of the art environmental management tools |
| Regulatory problems |
| Duplication of standards |
| Poor access caused by inexistence spatial infrastructure thus users resort to searching for bits from diverse places |
| Lack of metadata stating when or why the data was collected so as to use the data appropriately |

| |
|---|
| Availability of needed datasets |
| Cost of data (expensive) |
| Internet availability (poor internet) |
| Obsolete primary datasets (Obsolete data, not digitized; mostly in paper form) |
| Funds and funding |
| Non-availability of core fundamental datasets |
| Barriers to accessing available datasets |
| Quality and format of the data; reliability of accessed dataset |
| Time wasted in data preparation and cleaning instead of analysis |
| Incorrect and incomplete datasets; accuracy and completeness of the data |

On further analysis of the identified nodes (themes), eleven factors were defined by grouping themes representing similar issues together while those with more distinct definitions were left to stand as an individual factor. The defined nodes (themes) and their percent counts (sources) are presented in Table 6.2 below.

*Table 6.2: Defined nodes coded: Identified problems*

| **NODES** | **PERCENT** |
|---|---:|
| Access | 22% |
| Cost | 15% |
| Data accuracy | 13% |
| Data availability | 10% |
| Data quality | 10% |
| Funding | 7% |
| Interoperable data formats | 7% |
| Lack of metadata | 5% |
| Poor regulation | 5% |
| Required tools for collection and analysis | 3% |
| Security and safety | 3% |
| **Total** | **100%** |

Problems with data access, cost, data accuracy, availability and data quality, are observed to have been mentioned more frequently by participants this insinuating a higher degree of burden to the use of spatial data in Nigeria.

There were observable similarities between the issues raised in the EIA-SDI case. A critical analysis of the nodes (themes) coded from the data in relation to the results acquired from the EIA-SDI survey (see Figure 4.17 and 4.18 in Chapter 4) provided more insight to the identified problems. The findings from both studies were synergised, comparisons were made to ascertain observable relationships as well as identify areas of similarities and differences. This aided the definition of the final nodes (themes) that represented the fundamental issues obstructing the use of spatial data for environmental protocols in Nigeria as shown in Figure 6.3 below.

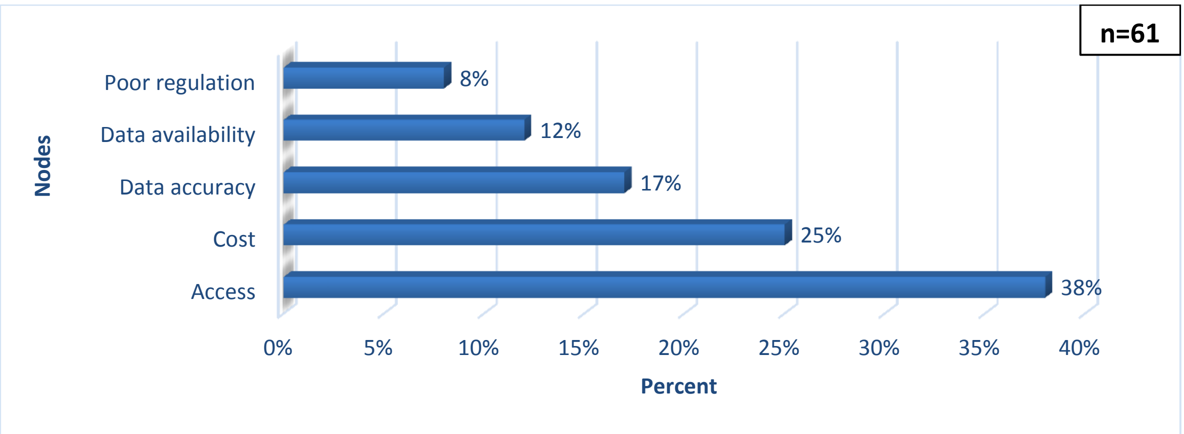



*Figure 6.3: Issues obstructing spatial data use*

Challenges caused by poor internet access as well as the poor access to required tools for data collection and analysis were grouped under ‘access’ due to their corresponding similarities. Security and safety were also grouped under ‘access’ because these also inhibit consultants’ access to the needed spatial data. Cost and funding were also grouped together to create a cost factor. This was done because the lack of or inadequate funding impacts on or contributes to the final cost of acquiring or disseminating the data. Challenges with data accuracy were also combined with those from data quality, the presence of interoperable data formats and the lack of metadata. This is because they all contribute to the completeness, interoperability, usability and quality of the datasets and by implication the output of the analysis in which they are utilised.

### 6.2.3 THE EMERGING NGDI

In order to ascertain their understanding of the prototype objective and to bring the focus of the participants to its intended contribution to the emerging Nigerian geospatial data infrastructure (NGDI), participants were quizzed on their familiarity of the current NGDI, the protocols employed in the management of the NGDI as well as the role of the NGDI in proving spatial data for environmental management protocols in Nigeria. Participants also highlighted some factors limiting the current NGDI as well as some factors that were critical to its success.

#### 6.2.3.1 *FAMILIARITY WITH THE NGDI*

50% of the respondents asserted that they were familiar with the emerging NGDI while 20.83% were very familiar with the NGDI, 12.50% were unfamiliar, and 8.33% were very unfamiliar while another 8.33% were unsure as shown in Figure 6.4.

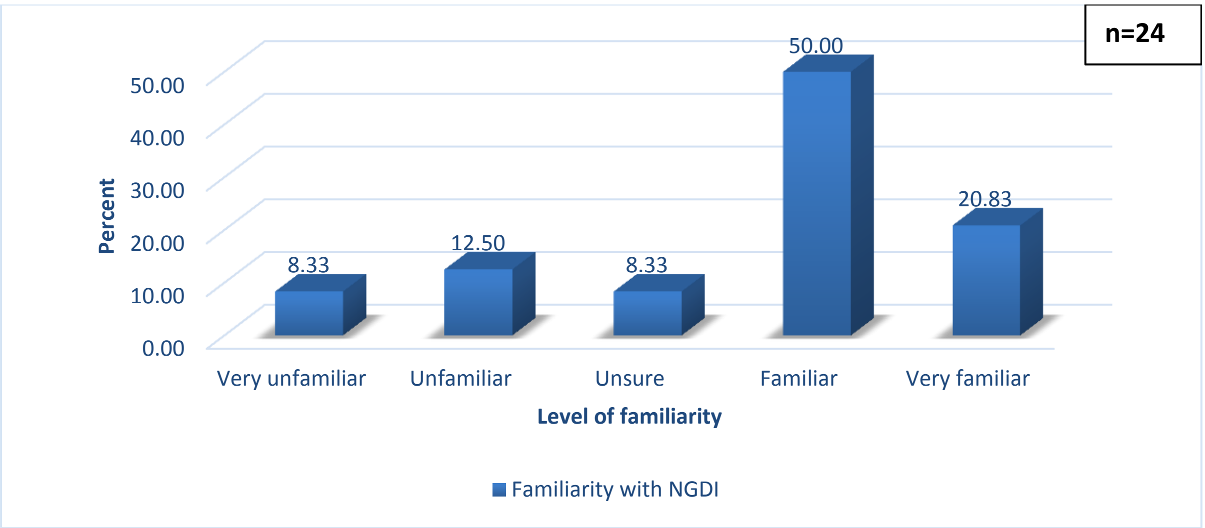
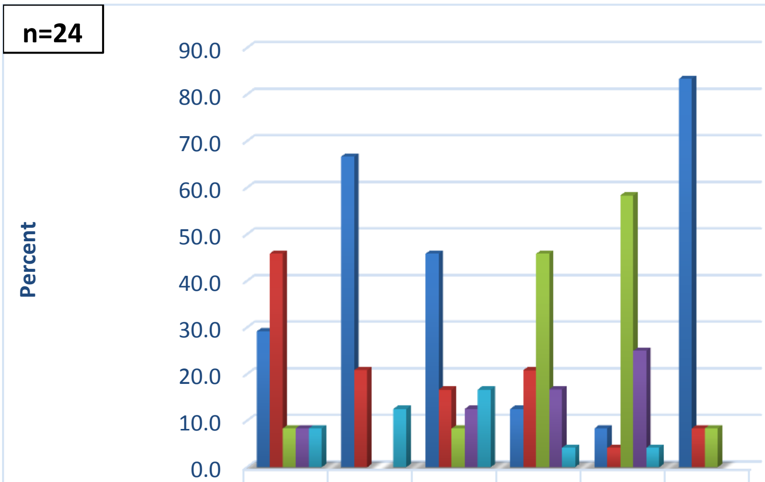



*Figure 6.4: Level of familiarity with the NGDI*

Participants asserted that the NGDI was still in its fundamental stage with landmarks in the policy draft and the execution of a pilot project. However, it is asserted to still be very generic as most of the constituting components are yet to be implemented. Participants also noted that the NGDI would have been a veritable source of spatial data if properly implemented but expressed worry about the current lack of enthusiasm on the path of the government and key stakeholders towards the complete implementation of the NGDI.

### 6.2.3.2 *CURRENT STATE OF THE NGDI*

As a follow-up to these questions, participants were asked to indicate their level of agreement to fundamental issues relating to the NGDI. This is to enable the researcher to decipher current problems and by implication the status of the NGDI. The arguments surveyed express issues that are fundamental to SDI implementation globally but have been defined within the Nigerian context (see Figure 6.5 below).




| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Strongly agree | 29.2 | 66.67 | 45.83 | 12.50 | 8.33 | 83.33 |
| Agree | 45.8 | 20.83 | 16.67 | 20.80 | 4.17 | 8.33 |
| Unsure | 8.3 | | 8.33 | 45.80 | 58.33 | 8.33 |
| Disagree | 8.3 | | 12.50 | 16.70 | 25.00 | |
| Strongly disagree | 8.3 | 12.50 | 16.67 | 4.20 | 4.17 | |

Level of Agreement

*Figure 6.5: Assessment of the status of the emerging NGDI*

| **Legend** | |
|---|---|
| A | Low technical proficiency of end user responsible for reduced NGDI implementation |
| B | Unclear protocol for data sharing limits implementation of NGDI partnership arrangements |
| C | User interface/ infrastructure for NGDI clearing house is not easily accessible |
| D | Data from the NGDI are obsolete as they are not frequently updated |
| E | Data from the NGDI are not accurate or interoperable; it causes challenges during analysis |
| F | Lack of adequate funding limits the advancement of the NGDI in Nigeria |

The questions were developed from a synergy of findings within literature and the challenges experienced during the development of the data access prototype presented in Chapter Five of this thesis. Participants were asked to strongly agree, agree, disagree or strongly disagree with the statements. Participants were allowed to express areas of uncertainty by selecting ‘unsure’ where necessary.

The results have been grouped together according to their level of agreement to clearly show the problems participants assert to pose challenges to the successful implementation of the NGDI. The majority of the participants (83.33%) strongly agreed with the argument that the lack of adequate funding limits the advancement of NGDI in Nigeria (see Figure 6.6). They also expressed strong agreement (66.67%) with the statement that unclear protocol for data sharing limits NGDI partnership in arrangements in addition to 20.83% of the respondents that were in agreement with the statement (see Figure 6.6). Only a few of them (8.33%) strongly disagreed that the data from the NGDI are not accurate or interoperable and thus causes challenges during analysis and a similar percentage (12.50%) strongly agreed with the statement that the data from the NGDI were obsolete as they are not frequently updated.

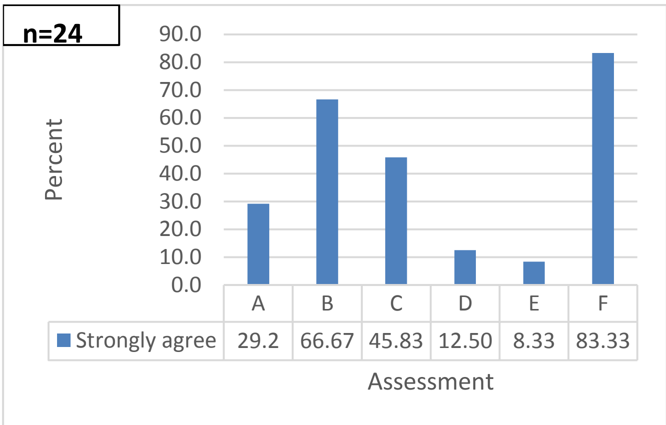



*Figure 6.6: Problems limiting NGDI - **Strongly agree***

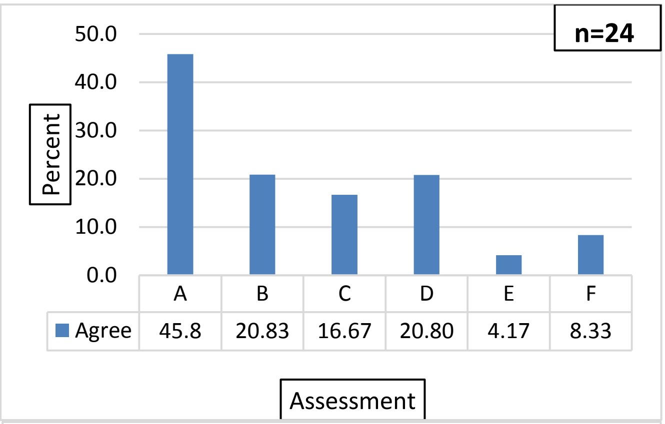



*Figure 6.7: Problems limiting NGDI - **Agree***

Though only 29.2% of the respondents strongly agreed to the statement that low technical proficiency of end user was responsible for the reduced NGDI implementation, a larger percentage of participants 45.8% agreed with the statement (see Figure 6.6). 45.83% of the respondents were in strong agreement to the statement that the user interface/ infrastructure for the NGDI clearing house is not accessible, while another 16.67% of the respondents also agreed with the statement (see Figure 6.7).

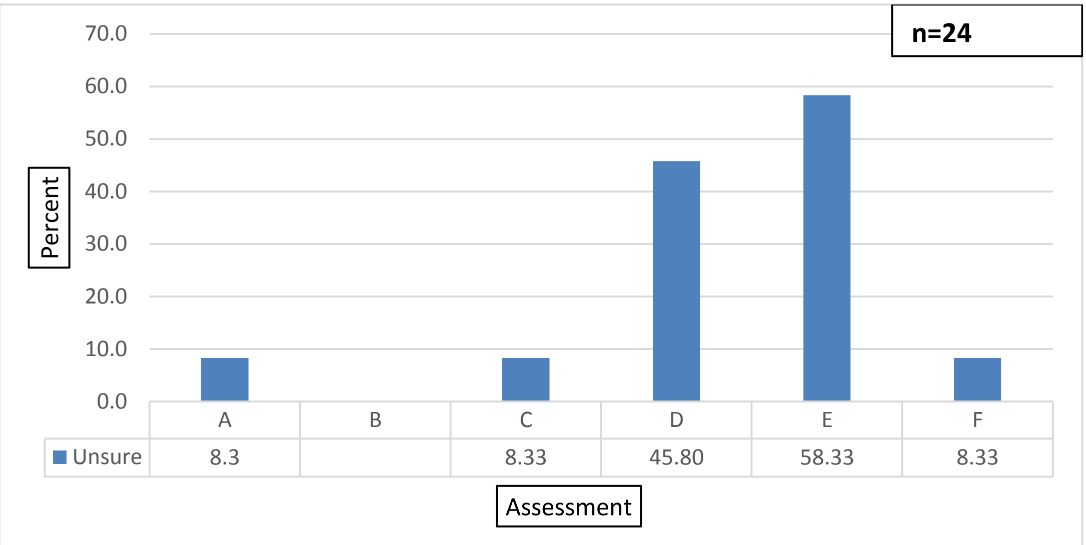



*Figure 6.8: Problems limiting NGDI -* ***Unsure***

Uncertainty was largely expressed concerning problems of data quality within the NGDI. 58.33% of the respondents were unsure that the data from the NGDI are not accurate or interoperable thus causing challenges during analysis while 45.80% were unsure that the data from the NGDI are obsolete as they are not frequently updated (see Figure 6.8 above).

16.70% of the participants disagreed with the statements that data from the NGDI are obsolete as they are not frequently updated while 25.00% also disagreed that "data from the NGDI are not accurate or interoperable; it causes challenges during analysis" (see Figure 6.9).

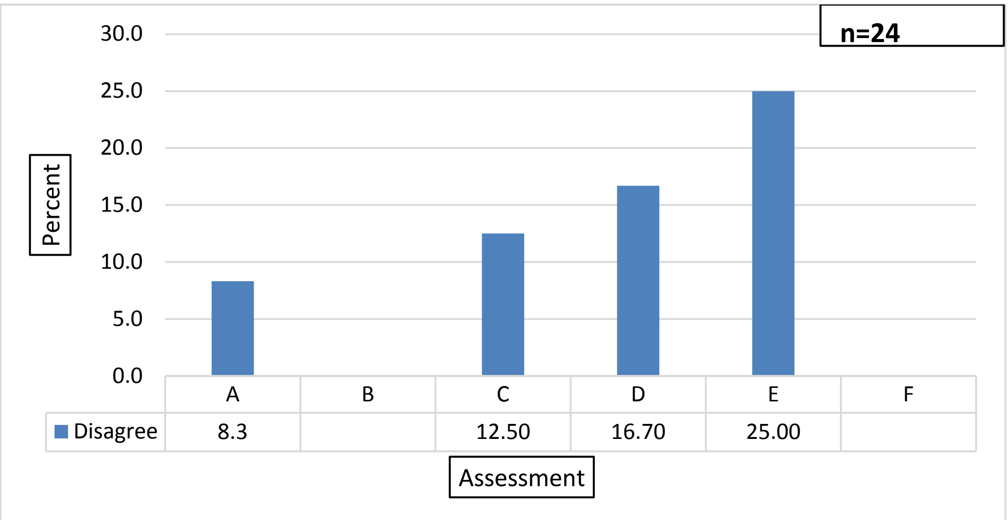



*Figure 6.9: Problems limiting NGDI - **Disagree***

A minimal number of participants (8.3%), however strongly disagreed with the statement that low technical proficiency of end user is responsible for reduced NGDI implementation. A small number of participants (16.67%) also strongly disagreed that the user interface/ infrastructure for NGDI clearing house is not easily accessible. See Figure 6.10 below.

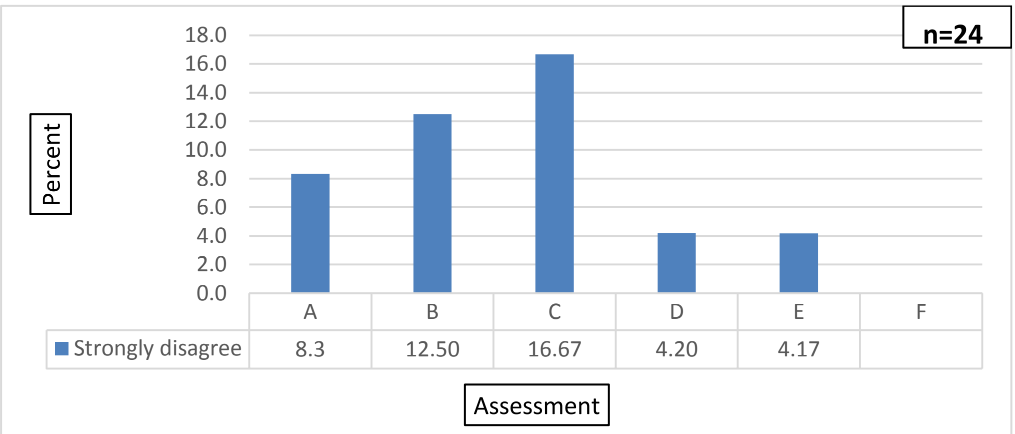
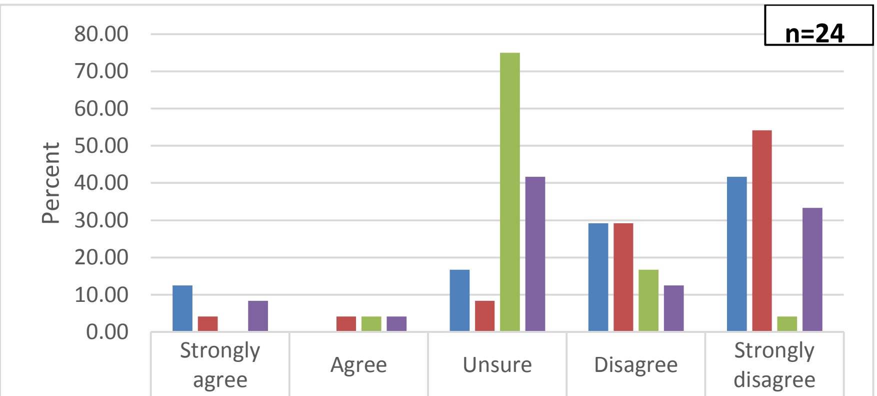



*Figure 6.10: Problems Limiting NGDI - **Strongly disagree***

In order to get a better understanding of the user's perception of the NGDI, further questions on the current status of the NGDI were posed to respondents.




| | Strongly agree | Agree | Unsure | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| A | 12.50 | | 16.67 | 29.17 | 41.67 |
| B | 4.17 | 4.17 | 8.33 | 29.17 | 54.17 |
| C | | 4.17 | 75.00 | 16.67 | 4.17 |
| D | 8.33 | 4.17 | 41.67 | 12.50 | 33.33 |

*Figure 6.11: Assessment of the NGDI status:* ***Reverse Questions***

| **Legend** | |
|---|---|
| A | There is a clear protocol to access data through NGDI |
| B | It is very easy to find suitable data through NGDI |
| C | Cost of accessing data from the NGDI is reasonable |
| D | I can access interoperable spatial data from the NGDI easily |

The questions included statements that argued that the protocols within the NGDI were working and fully implemented. It was important to reverse the pattern of the questions in this research so as to avoid bias and confirm that participants understood the questions posed to them (see Figure 6.11).

The majority of the respondents (75%) were unsure if the cost of accessing data from the NGDI is reasonable. 54.15% of the participants strongly disagreed that it is very easy to find suitable data through NGDI. When asked if they can access interoperable spatial data from the NGDI easily, 41.67% of the participants were unsure while 33.33% strongly disagreed with the statement. Likewise, 41.67% of the participants strongly disagreed with the statement that there is a clear protocol to access data through NGDI, 29.17% disagreed with it, 16.67% were unsure while 12.50% strongly agreed with the statement.

#### 6.2.3.3 *SUFFICIENCY OF NGDI*

Participants were quizzed on the sufficiency of the current NGDI to support geospatial data needs. This is to further emphasise on the usability and accessibility of the current NGDI. In the previous survey (the EIA-SDI survey in Figure 4.23 of Chapter 4), 90.80% of the respondents asserted that the current NGDI protocols were insufficient to support geospatial data needs in Nigeria. The question was posed again to the participants of the NGDI-CF evaluation to ascertain the current status of the NGDI as well as the industry experts' perception of its current sufficiency.

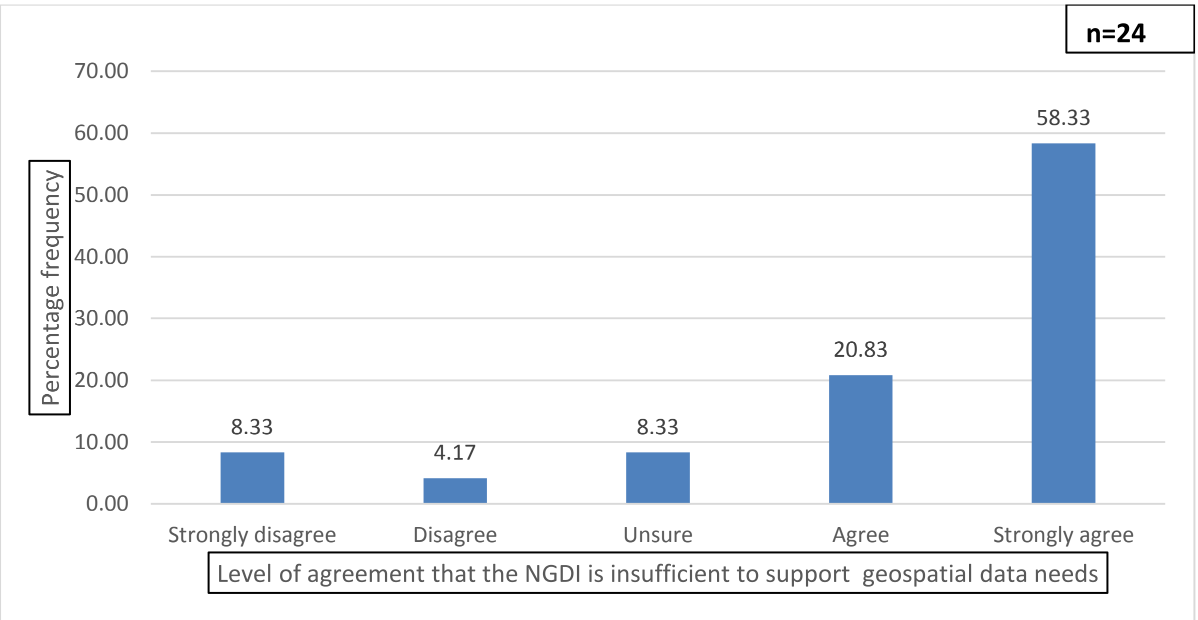



*Figure 6.12: Insufficiency of NGDI*

58.33% strongly agreed with the assertion of the previous survey respondents that the current NGDI protocols are insufficient to support geospatial data needs, 20.83 percent agreed with the assertion, 8.33% were unsure, 4.17% disagreed while another 8.33% strongly disagreed with the assertion.

A number of reasons were presented for their stance. As stated by the participants from the NGDI coordinating body, during the initial stages of the NGDI implementation, regular meetings were held with selected stakeholders to encourage participation. These participants strongly disagreed with the assertion that NGDI was insufficient. They claimed that the respondents of the previous survey lacked sufficient knowledge of what was in place thus alleging that more than 90% the participants in the NGDI-conducted stakeholders meeting lacked the needed technical proficiency. As a result, they may not have understood in entirety what was discussed in the meeting, thus may not have effectively conveyed the NGDI objectives and capabilities to the sectors they represented. However, the participants who strongly agreed with the assertion stated the inaccessibility of the NGDI for data acquisition and the poor communication of the NGDI protocols to stakeholders as key reasons for supporting the assertion. Participants that were unsure stated their limited to non-familiarity with the current NGDI protocol as the reason they were unable to agree or disagree with the assertion.

#### 6.2.3.4 *CHALLENGES OF THE NGDI*

In other to gather substantial information on the state of the NGDI, open-ended questions were included to quiz participants on the current challenges of the NGDI. This would also help allow respondents freely discuss major issues that were not covered in the structured assessment of the NGDI covered in the sub-section above, thus avoiding the bias of generalisation. Participants highlighted a number of issues they believe pose challenges to the successful implementation of the NGDI (see transcript excerpt 6.6, 6.7 and 6.8).

*Transcript Excerpt 6.6*

*R: Can you highlight some of the factors limiting the current NGDI? Can you also state some factors you consider critical to successfully implementing the current NGDI?*

*"Ari": Anything government is usually this way.*

*R: What do you think is the problem and what do you think they can make it better, you mentioned before I paused it that it's because it is government funded and run.*

*Ari: And the fact that communication is poor. They should enlighten people about it. They should put it on TV, newspapers, radio and then they should you know, inform consultants when we have different fora. And then anytime we also have meetings and relationships with the federal ministry of environment for instance, give us fliers. Send fliers to federal ministry of environment and to other government parastatals and them give us those things.*

*Transcript Excerpt 6.7*

*R: And then there were arguments that it is because it was done by government and that if it was done by private sector (it would have worked)?*

*DSA: Some government organisations, like now we have satellite data but they are buying satellite (outside). So you are allowed to make budget for what is available, so that encourage them (that is government agencies are allowed to still make budget to buy data or services that are available in the country or provided by another MDA from outside or overseas. Since there are no laws stopping them and there is no synergy between the various agencies to support each other due to unnecessary competition among themselves and the need to acquire a greater budget allocation from the FG budget, agencies that are supposed to thrive from monies made by purchases or data sharing with each other ends up suffocated or struggle to survive). So you don't, I don't have to go and search there because it may be free or it may be less than the money I budget so I would rather give a consultant to take the money and the consultant too are also working against it because when if something is wrong, it is easier for me to come through the back door and pick the data and say I worked it and I give it to you and you paid me. If you know this data exists for 5000 for example, why would I be putting 25,000? So it doesn't work well for even the consultant. It doesn't work well for the agencies, ministries and the rest that are working their budget (Corruption and Sabotage: MA). So these are part of the clear issues why NGDI should not work. (Yeah: MA). There is also not, because if we said there is no commitment from the government and we are part of the government. We (NASRDA) have been committed. We have the commitment. Again I think, because we don't have money to do what we are supposed to do primarily. It's like somebody who is supposed to dance, you don't have your money for the drums, to buy the drums that they will need for you to dance and you are now asking to meet, we, for the few years we are struggling to do what we are supposed to do. I don't think it was even captured in any of our budgets for the past two, three years because like he said, we are short of funds to what primarily should be our responsibility. Now if you go there with so much* *budget, ours may be neglected at that moment, so what is the wisest thing to do; to concentrate on what you are supposed to do and even this year I don't think it is in our budget (it's there. It is in the budget: MA) Oh it is in the budget.*

*Transcript Excerpt 6.8*

*R: Can you highlight some of the factors limiting the current NGDI? Can you also state some factors you consider critical to successfully implementing the current NGDI?*

*Okay, can you highlight some factors, I know you've already mentioned some, you know, that you think are limiting the current Nigerian geospatial data infrastructure?*

*GE: We don't have joined up thinking in Nigeria. That is the first. There is no joined up thinking, there is no joined up coordination. There is no effort to link top down to bottom up. There is no, and I think that is essential in the management of anything in Nigeria. And I think that is one of the failings, there is no Local government. Local government is basically non-existent (Rnotes: Local and grass root involvement) (R: Because most of these data, abroad, in their institutional arrangement, they come from the Local government level) Exactly, and there is also, I mean (over protectiveness, this one is my own), yeah, apart from that, so there are various, I don't even know that all ministries are, their roles are responsibilities are well delineated. I mean if you look at Federal ministry of environment, you have federal ministry of environment, you have LASEPA, you have NESREA, you have, (DPR), I mean, so who is collecting what? Who is doing what? So already, it is just a, it's a whole mess in terms of the institutional arrangement itself. So that is one thing that will affect any form of data acquisition and extrapolation sort of exercise. Another thing which I think is fundamental is that in Nigeria we have not really learnt from participation wings and how to develop policies that are based on participating principles. It's completely missing. So any form of geospatial data management system or whatever, however it is phrased, that is being used does not have element in a very robust way. It's you know, I mean, it doesn't matter how many people you fly to Abuja to have a meeting. I mean, why are you even flying, is Abuja the centre of information? Why are you flying to Abuja to have a stakeholders meeting? What should be done is to go to different areas, you know, and, and but anyway. That's a completely, so even when you even think of like things like flood warning systems and all of that, you know, how are those things being managed, how are they being aggregated, you know. So for example, you would notice in, abroad, areas where there are flood management systems or flood warning systems, they are translated into languages, (R: yes). But we have documents in Nigeria that are not, you know, they are not translated into any language. They are written in English and the people that are being affected they can't speak English; they can't read or write. (R: And most people, they are not even taught in their local language. That's another problem). Exactly. I mean, those two things are fundamental for me. Okay.*

These responses were assessed and the salient issues were identified. The identified issues ranged from lack of adequate funding to the misappropriation of the available funds, the lack of political will on the part of government, the limited infrastructure available to build on, the poor communication of the NGDI objectives as well as its significant benefits, among others Table 6.3 presents the key issues as itemised by the participants.

*Table 6.3: Asserted challenges of the NGDI: Initial themes*

| ASSERTED CHALLENGES |
| --- |
| Objectives of NGDI not clearly defined; Poor communication of project objectives |
| Lack of appreciation of the benefits of the NGDI; Lack of knowledge about the significance of the NGDI |
| Lack of political will and other political reasons |
| Lack of adequate funding and the misappropriation of available funds |
| Misplaced priorities; priority of government and stakeholders |
| Lack of a legally binding policy |
| State of infrastructure to build on; especially power and IT infrastructure |
| Lack of awareness |
| Lack of autonomy; committees have power to recommend and not able to make implementations |
| Approach to data; unwillingness to share data |
| Focus on interest-based projects rather than fundamental futuristic projects like NGDI with long-term impact |
| Haphazard approach to handling projects |
| Lack of synergy from the bottom (local authority) to the top (state and federal government) |
| Insufficient forums and trainings to communicate objectives |
| Sincerity of purpose; no joined up thinking |
| Misplaced priority in policy implementation |
| Reliability of government-run projects; insufficient private sector inclusion in the implementation |

The highlighted issues were further analysed and coded in Nvivo into nodes (themes) according to the number of times they were referenced in the interview transcript. The first set of nodes generated from the Nvivo coding is presented in Table 6.4.

*Table 6.4: Asserted NGDI challenges: Initial Nvivo nodes*

| **INITIAL NODES** | **PERCENT** |
|---|---|
| Awareness | 10.53% |
| Conflict of interest | 7.02% |
| Corruption and sabotage | 5.26% |
| Data ownership | 1.75% |
| Demonstrate prospects of NGDI to communicate benefits | 3.51% |
| Development not done based on user requirement and level of expertise | 1.75% |
| Duplication of efforts | 3.51% |
| Funding | 8.77% |
| Inexistent LG collaboration for grassroots involvement | 1.75% |
| Knowledge level and Technical proficiency | 5.26% |
| Lack of commitment from government | 3.51% |
| Not prioritizing the NGDI | 8.77% |
| Objectives not clearly defined and communicated | 3.51% |
| Partnership and participation | 3.51% |
| Policy | 5.26% |
| Political will | 8.77% |
| Poor project management culture | 1.75% |
| Poor understanding or communication of NGDI prospects and benefits to stakeholders and policy makers | 7.02% |
| Poorly structured institutional arrangements | 3.51% |
| Roles and responsibilities not clearly defined | 1.75% |
| Unwillingness to share data | 3.51% |
| **Total** | **100%** |

As shown in Table 6.4 above, 22 nodes were generated from the initial coding done in Nvivo. These codes were further examined to ascertain their similarities and differences. Similar nodes were grouped together thus reducing the number of nodes to twelve (12) as shown in Figure 6.13.

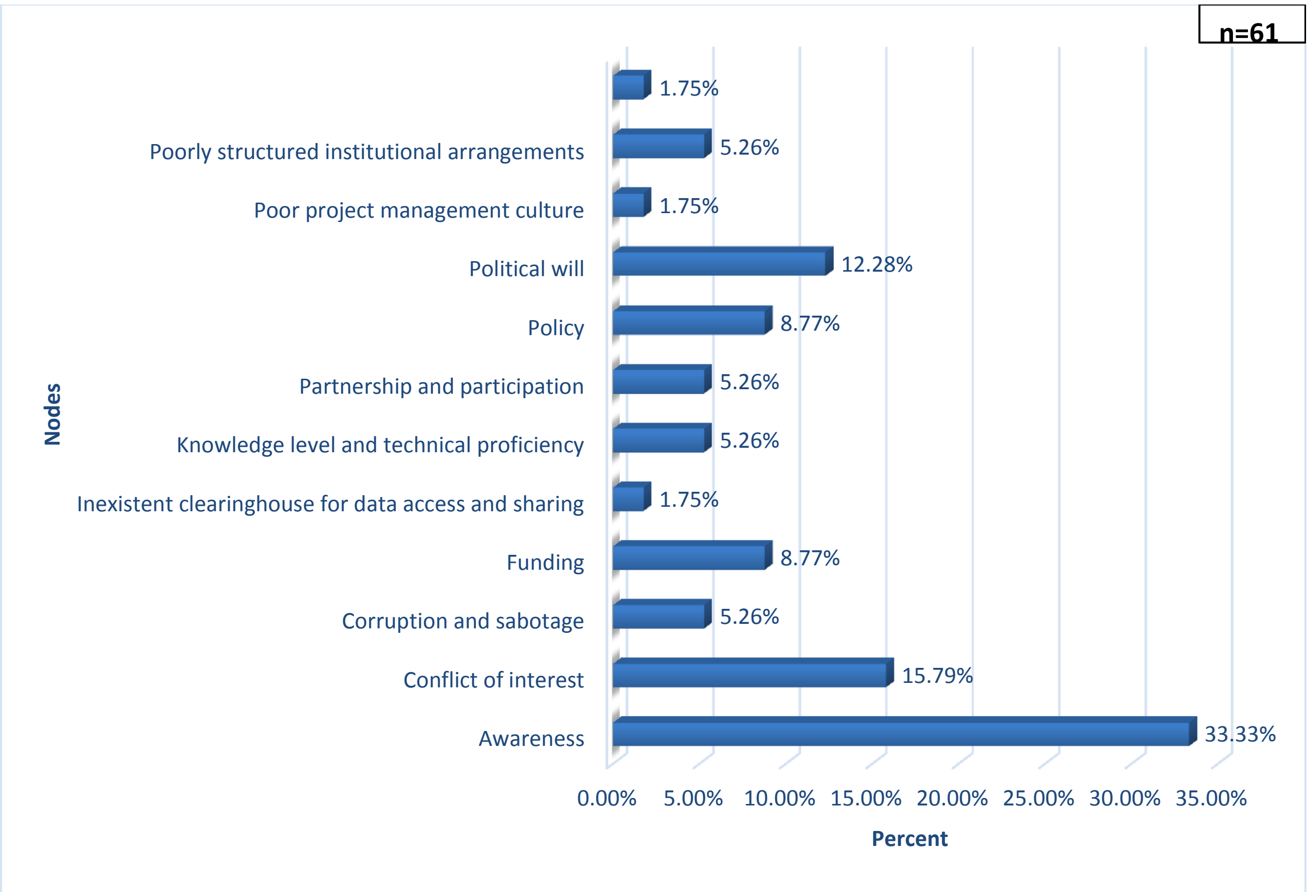



*Figure 6.13: Asserted challenges of the NGDI: final nodes*

Responses that asserted that there was conflict of interest were grouped with those asserting duplication of efforts as well as corruption and sabotage. Issues of data ownership and the unwillingness to share data were grouped together with policy. Political will was also grouped with the lack of commitment from government. Poorly structured institutional arrangement was also merged with the assertion that the roles and responsibilities have not been clearly defined. Other highlighted issues that were assessed to be related were the prioritization of the NGDI, clear definition of the NGDI objectives and demonstration of the prospects of the NGDI. These factors were thus grouped together under awareness.

### 6.2.4 CRITICAL AREAS FOR IMPROVEMENT

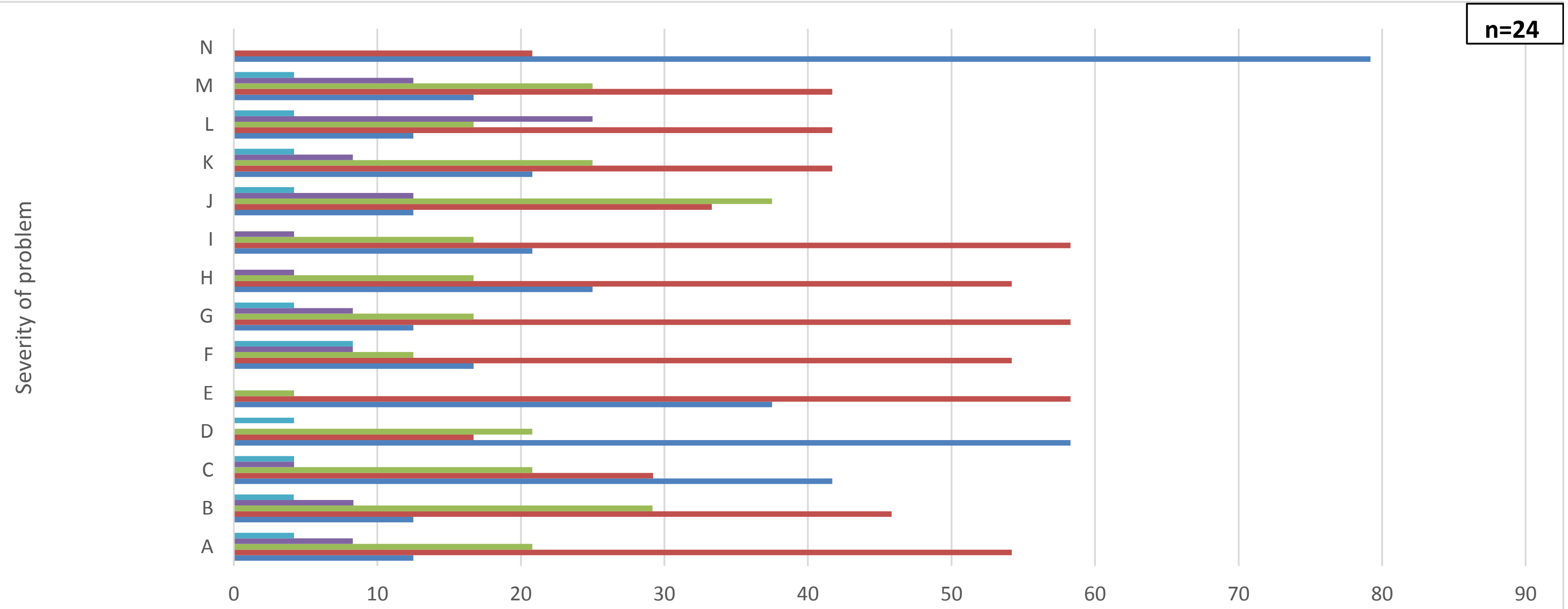
Participants were requested to rank a number of problems (see Table 6.5) that were identified during the course of the literature review and EAI-SDI case study on a scale of 1 to 5 where 1 connotes the issue is of utmost importance and thus poses a major challenge to NGDI implementation in Nigeria.

*Table 6.5: Assessed problems*

| | |
|---|---|
| A | Standards: Inconsistent scales and reference system |
| B | Standards: Integrating data of standards with little or no interoperability |
| C | Policy: Lack of open spatial data policy |
| D | Policy: Inexistent partnership arrangements |
| E | Policy: Restricted data sources |
| F | Access network: Ease of access |
| G | Access network: Usability and interoperability of accessed datasets |
| H | Data: Access to Nigerian datasets |
| I | Data: Quality of accessed data |
| J | Data: Cost of accessing data |
| K | Data: Querying data and handling requests |
| L | People: Technical proficiency |
| M | People: Availability of technical documentation |
| N | People: Awareness of data and SDI existence |

The issues were grouped based on the fundamental components of a spatial data infrastructure; standards, policy, access networks, data, and people. Results from the participants' ranking of the identified problems are presented in Figure 6.14.

From the initial exploration of the data (Figure 6.14), it is observed that majority of the participants (79.20%) noted that the level of awareness to the data and the SDI was a very important problem in Nigeria. 58.30% also specified that the inexistent partnership arrangement is a very important problem, and so is the lack of an open data policy in Nigeria (41.70%). A large number of participants (58.30) also speculated that the usability and interoperability of accessed datasets was an important problem in Nigeria, same with the problem of restricted data sources in Nigeria (58.30% of participants asserted) and the quality of accessed data in Nigeria (58.30% of participants asserted).

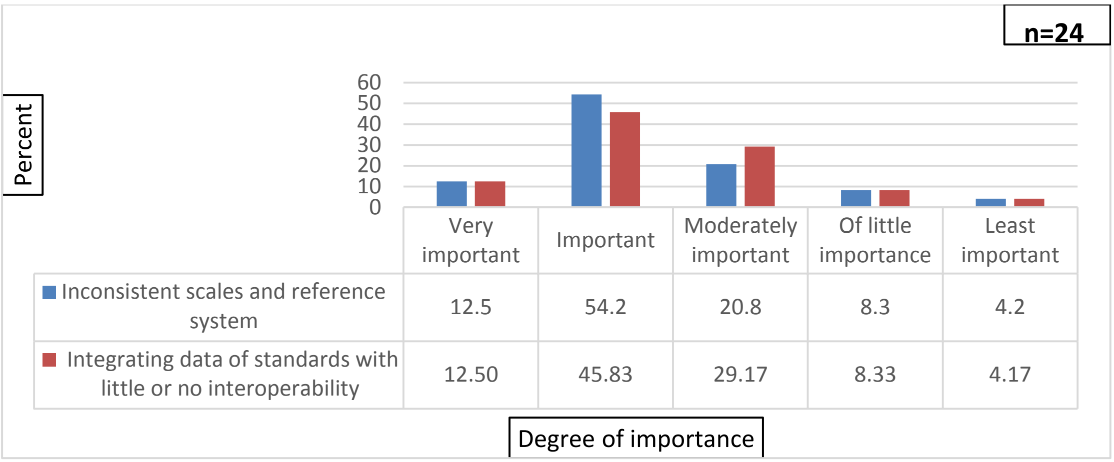



| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Least important | 4.2 | 4.2 | 4.2 | 4.2 | | 8.3 | 4.20 | | | 4.2 | 4.2 | 4.2 | 4.2 | |
| Of little importance | 8.3 | 8.3 | 4.2 | | | 8.3 | 8.30 | 4.2 | 4.2 | 12.5 | 8.3 | 25 | 12.5 | |
| Moderately important | 20.8 | 29.2 | 20.8 | 20.8 | 4.2 | 12.5 | 16.70 | 16.7 | 16.7 | 37.5 | 25 | 16.7 | 25 | |
| Important | 54.2 | 45.8 | 29.2 | 16.7 | 58.3 | 54.2 | 58.30 | 54.2 | 58.3 | 33.3 | 41.7 | 41.7 | 41.7 | 20.8 |
| Very important | 12.5 | 12.5 | 41.7 | 58.3 | 37.5 | 16.7 | 12.50 | 25 | 20.8 | 12.5 | 20.8 | 12.5 | 16.7 | 79.2 |

Percent

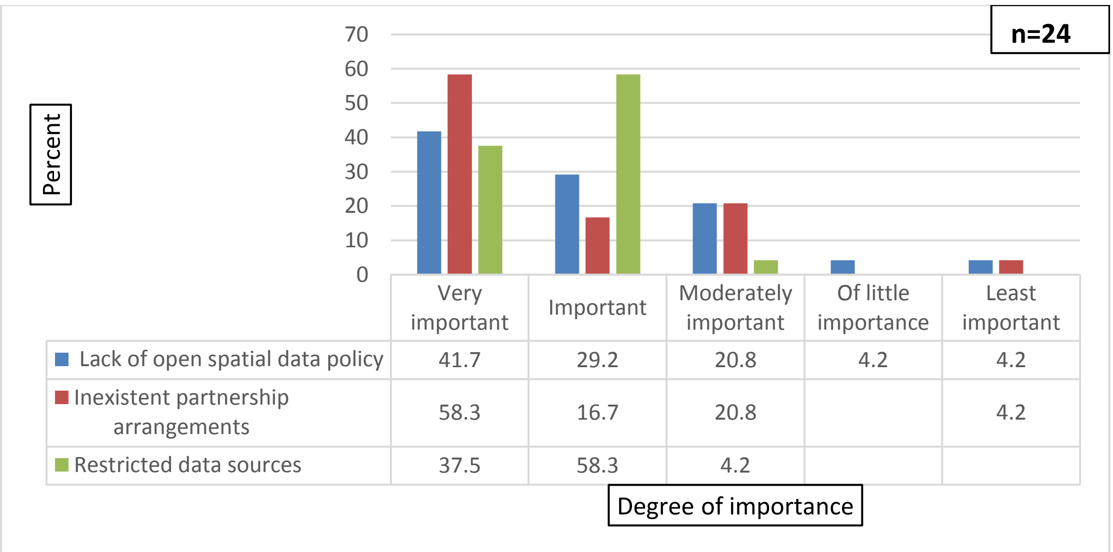
*Figure 6.14: Problems obstructing the NGDI implementation*

A similar percentage of participants, 54.20% also noted that the problem of inconsistent scales and reference systems was an important problem in Nigeria. However, in order to completely understand the data, the responses were separated to reflect the results of the individual groups; standards, policy, access network, data and people as presented in Figures 6.15, 6.16, 6.17, 6.18 and 6.19 to enable a clearer visualisation and informed understanding of participant responses.



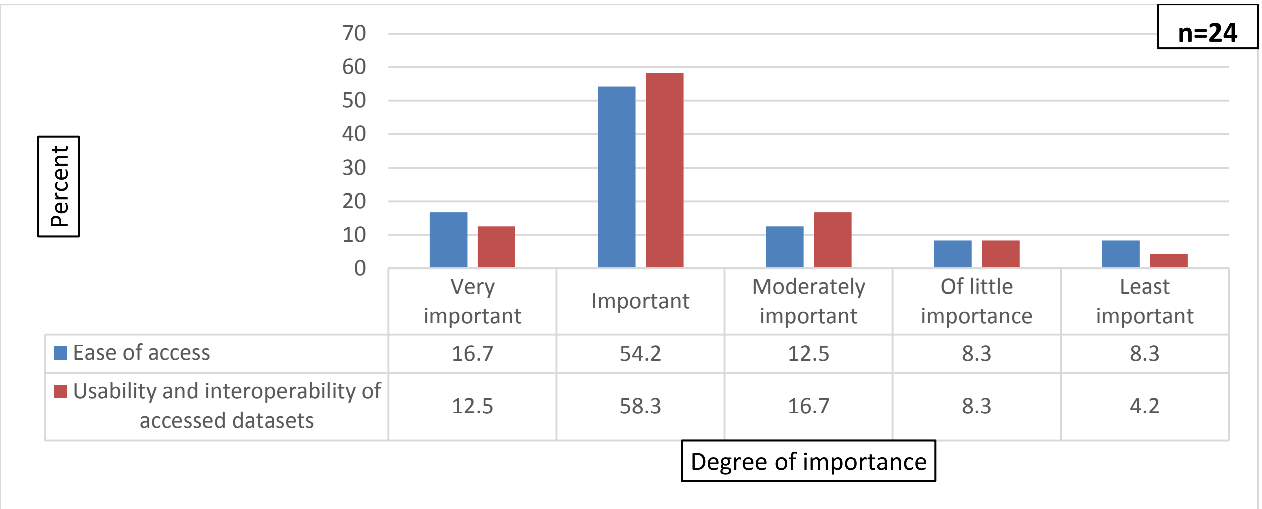

| | Very important | Important | Moderately important | Of little importance | Least important |
|---|---|---|---|---|---|
| Inconsistent scales and reference system | 12.5 | 54.2 | 20.8 | 8.3 | 4.2 |
| Integrating data of standards with little or no interoperability | 12.50 | 45.83 | 29.17 | 8.33 | 4.17 |

*Figure 6.15: Category - Standards*



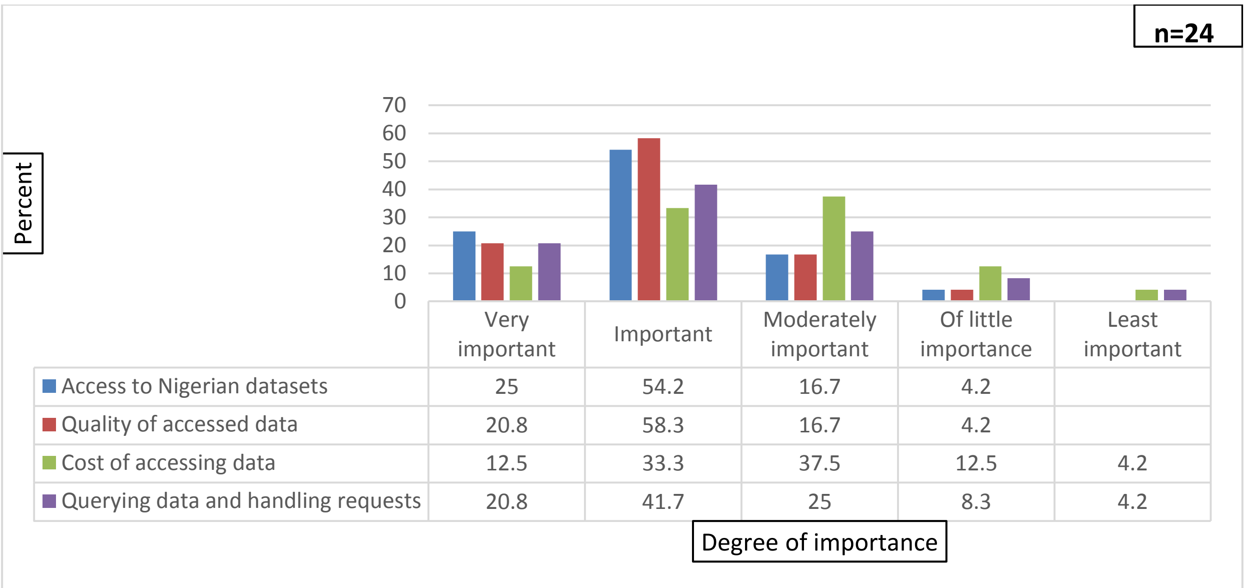

| | Very important | Important | Moderately important | Of little importance | Least important |
|---|---|---|---|---|---|
| Lack of open spatial data policy | 41.7 | 29.2 | 20.8 | 4.2 | 4.2 |
| Inexistent partnership arrangements | 58.3 | 16.7 | 20.8 | | 4.2 |
| Restricted data sources | 37.5 | 58.3 | 4.2 | | |

*Figure 6.16: Category - Policy*



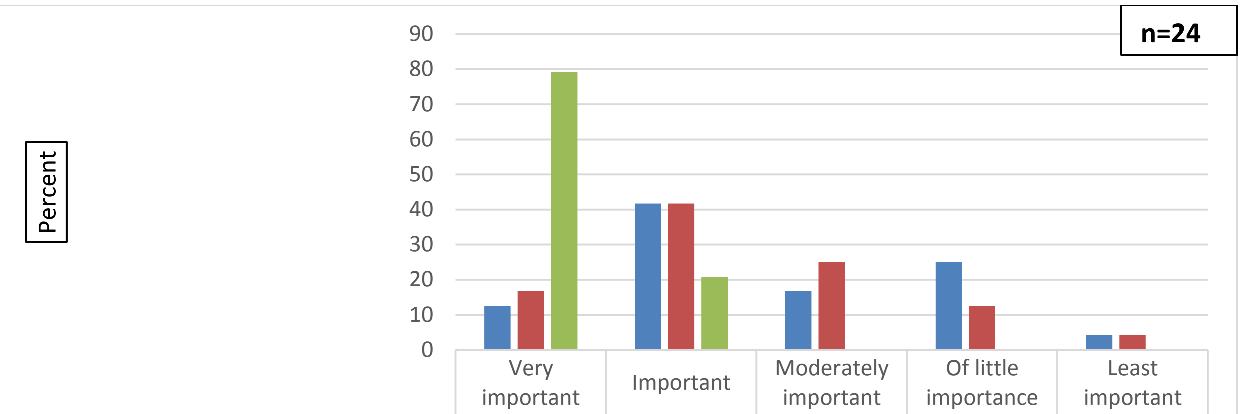

| | Very important | Important | Moderately important | Of little importance | Least important |
|---|---|---|---|---|---|
| Ease of access | 16.7 | 54.2 | 12.5 | 8.3 | 8.3 |
| Usability and interoperability of accessed datasets | 12.5 | 58.3 | 16.7 | 8.3 | 4.2 |

*Figure 6.17: Category - Access Network*




| | Very important | Important | Moderately important | Of little importance | Least important |
|---|---|---|---|---|---|
| Access to Nigerian datasets | 25 | 54.2 | 16.7 | 4.2 | |
| Quality of accessed data | 20.8 | 58.3 | 16.7 | 4.2 | |
| Cost of accessing data | 12.5 | 33.3 | 37.5 | 12.5 | 4.2 |
| Querying data and handling requests | 20.8 | 41.7 | 25 | 8.3 | 4.2 |

*Figure 6.18: Category - Data*




| | Very important | Important | Moderately important | Of little importance | Least important |
|---|---|---|---|---|---|
| Technical proficiency | 12.5 | 41.7 | 16.7 | 25 | 4.2 |
| Availability of technical documentation | 16.7 | 41.7 | 25 | 12.5 | 4.2 |
| Awareness of data and SDI existence | 79.2 | 20.8 | | | |

*Figure 6.19: Category - People*

In furtherance to this, participants were quizzed on their willingness to participate in spatial data sharing partnership and interestingly, 88.33% of the respondents strongly agreed to the statement that they were (I am) very willing to participate in a spatial data sharing partnership within the NGDI, while the remaining participants (16.67%) agreed to the statement (Figure 6.20). None of the participants were unsure, disagreed or strongly disagreed with the statement. They all expressed their willingness and enthusiasm to participant in a spatial data sharing partnership within the NGDI if it is implemented. This is important because participant's readiness to participate in an NGDI partnership in combination with other fundamental factors like awareness, access, clearly define objectives, enforceable policies with roles and responsibilities clearly defined, as well as other factors expressed above is fundamental to the successful implementation of a spatial data sharing partnership for the NGDI.

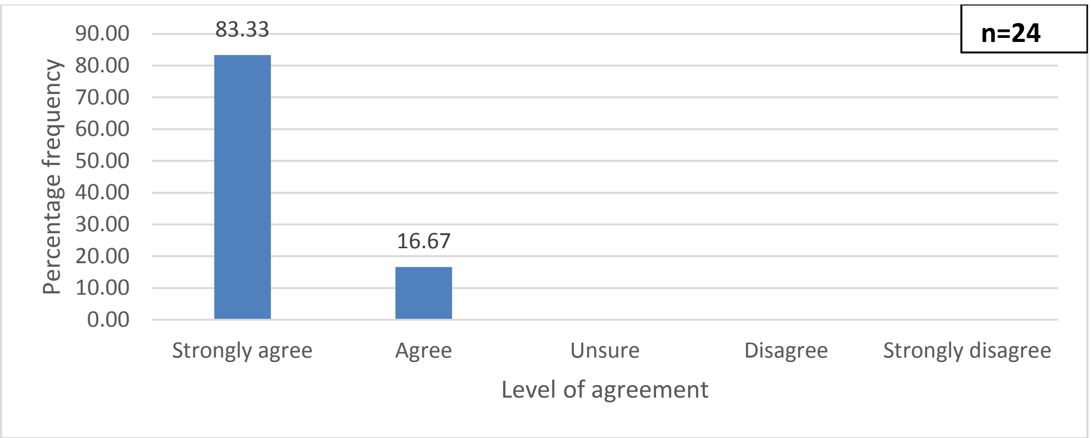



*Figure 6.20: Willingness to participate in a spatial data sharing partnership with the NGDI*

### 6.2.5 DISCUSSION

To further assess the asserted challenges documented in Figures 6.13 and 6.14 of Section 6.2.3, as well as the areas highlighted to be critical to the improvement of the NGDI situation in section 6.24, a PEST analysis was carried out. This is to highlight the political, economic, social as well as technological factors within the NGDI environment that contributes to these challenges.

PEST analysis is a strategic management tool that is commonly used in information systems research to assess the external factors (political, economic, social and technological) affecting a system or an organisation positively or negatively. This is presented in table 6.6.

*Table 6.6: PEST analysis of the NGDI*

| PEST FACTORS | IMPACT | | Comments/Possible Solution |
|---|---|---|---|
| | Positive | Negative | |
| Political | • Some groundwork has been done to draft a NGDI policy with rules of engagement<br>• Data security and ownership is addressed in the policy draft | • Insufficient funding<br>• Political will<br>• Fluctuations in government and its priorities<br>• Misappropriation of funds<br>• Corruption and corrupt practices<br>• NGDI policy stills a draft. Yet to be made law.<br>• NGDI not prioritised by government | Legalisation of relevant NGDI policy, the update of outdated policies to ensure current policies are in line with industry best practices, encourages partnerships and protects the interests of relevant stakeholders. Also, the adequate enforcement (and not just enactment) of the defined policies is fundamental to the effective implementation of the NGDI. |
| Economic | • Economic policies<br>• Partnerships may increase funding | • Investments in IT and other infrastructure<br>• Recession and wastage<br>• Absence of a legal policy obstructs proper budgetary allocation to the NGDI<br>• High cost of creating, collecting and manipulating data | Increased investments in IT infrastructure and developmental projects are important. However, increased investments with adequate follow-up of these projects from concept to reality, as well as the ensured continuity of these projects regardless of changes in government is key to improving the current situation. |
| Technological | • Preponderance of private IT and mobile technology users.<br>• Increasing internet usage and penetration | • Epileptic power supply<br>• Poor data and network services<br>• Technical capabilities<br>• Data security<br>• Privacy and ownership | Data security needs to be prioritised. Efforts need to be made to keep private elements of data confidential.<br>Enact laws within the policy that to protect users and contributors in the event of a conflict or loss of data intentionally or unintentionally |
| Social | • Increased networking and partnership platforms | • Unemployment<br>• Uneducated and poorly educated workforce<br>• Competence | Incorporate SDI implementation and practical GI training to university modules and staff training modules<br>Increase number of effective SDI professionals in implementation body |

From the foregoing, we can deduce that there are huge difficulties with securing top-down support for NGDI implementation in Nigeria. For the NGDI implementation to work, the government needs to prioritise the NGDI by legalising and enforcing an updated NGDI policy that will overcome the failings of the previous implementation attempt.

### 6.2.6 PROTOCOLS FOR IMPROVEMENT

Participants were also quizzed on the protocols they think can be implemented to improve the identified challenges within the NGDI that will enable its successful implementation. A number of factors were identified to be limiting the NGDI as presented in above. The questions were streamlined to stay within the focus of this research and the objective of the prototype development which was to *provide a lightweight and flexible SDI data access protocol that can be accessed using mobile devices as well as computers.* To this end, participants were requested to makes suggestions on protocols they think can be implemented to improve access to the NGDI in Nigeria, improve the quality of data resident within the NGDI, as well as encourage partnership arrangements where end users can contribute to updating the database thus making it more robust and less obsolete. The summary of participant responses is presented in Table 6.7 below.

*Table 6.7: Suggested protocols for improvement*

| Improve the access to NGDI | Improve quality of data resident in NGDI | Encourage partnership arrangements |
|---|---|---|
| Policies: Straightforward government policies, clearly defined policy<br><br>Enforceable policies | Quality assessment and quality control<br><br>Random monitoring | Orientation and reorientation |
| Awareness creation<br><br>Orientation and reorientation | Have hackathons, have developers to use their creativity to come up with solutions | Policy: Do it by legislation<br><br>Make demands from stakeholders and MDAs |

| | | |
|---|---|---|
| | | (ministry, department and agencies) |
| Funding | Awareness; disseminate information on NGDI so people are aware | User forums and surveys to see who has what and who can add what, bring together and harmonize |
| Accessibility: Reduce barriers to data entry<br><br>Allow general public to contribute to improve<br><br>Make data available on multiple sources apart from websites and web portals but mobile networks | Cost: Make (data) affordable<br><br>Make (data) free | Define roles and responsibilities properly |
| Publicity | Accessibility: make as common as possible so man on the street can make input | Clearly define owners |
| Clearinghouse: fully implement a clearinghouse<br><br>Funding for developing clearinghouse | Promote open access to data | Friendly interface |
| Make (data) more frequent, less obsolete | Specify data format and standard<br><br>Develop standard for data provision | Create a NGDI consolidated fund to help stakeholders produce and update data |

## 6.3 INFERENTIAL STATISTICS

This section presents a more in-depth statistical analysis of the key findings from the evaluation interview survey to ascertain areas of statistically explainable significances. The category of the questions asked in the interview were mainly correlational or predictive questions with a range of cause and effect questions to enable effective data gathering and measurement of assessed factors. Descriptive questions were also included to allow respondents discuss their choices and assertions. Correlation analysis and multiple regression analysis were conducted. The results are presented in the proceeding sections below.

### 6.3.1 CORRELATION ANALYSIS

Correlation analysis was conducted to check for statistically significant relationships between the variables used in the interview. The variables used in the interview included a range of measurement and a number of factors were assessed in the interview. The variables predicting those factors were categorised for easy analysis. They are: factors currently predicting the state of the NGDI; factors affirming the effectiveness of the developed prototype; and factors predicting areas of improvement for the full implementation of an effective NGDI. The analysis of these factors is presented in the sub-sections below.

#### 6.3.1.1 *ASSESSMENT OF THE CURRENT STATE OF THE NGDI*

Eleven assessment factors were identified to assess the current state of the NGDI in Nigeria. This research takes into consideration that correlation analysis alone does not provide complete evidence of causation, but the bivariate correlation analysis was conducted to check for trends and significant relationships between the identified factors. Cases with significant positive or negative relationships are highlighted in Table 6.8.

From the results there was significant evidence that the unclear protocol for data sharing which limits implementation of SDI partnership arrangements within the NGDI correlates with the perceived insufficiency of the NGDI to support geospatial data needs in Nigeria($p<0.01$). There was a strong positive association between the two factors thus an increase in one factor is assumed to cause an increase in the other factor, and vice versa. 79.16% of the participants affirmed (58.33% strongly agreed and 20.83% agreed) that the current NGDI was insufficient to support geospatial data needs in Nigeria while 87.5%

affirmed (66.67% strongly agreed and 20.83% agreed) that the unclear protocol for data sharing limits the implementation of NGDI partnership arrangement (see Figure 6.5). This, in addition to the correlation results, informs on the insufficient state of the NGDI, as well as the impact of the unclear protocol for data sharing and the lacking partnership arrangement on the level of insufficiency. It can therefore be posited that the implementation of clear protocols for data sharing within the NGDI to improve partnership arrangements will in turn improve the sufficiency of the NGDI. Likewise, a strong negative association was also observed between participant's response to question that "there is a clear protocol for data access through the NGDI" and their response to the assertion that the NGDI is insufficient to support geospatial data needs in Nigeria. A significant correlation of $p<0.01$ was also recorded. The strong negative relationship insinuates that the more participants disagree with the statement, the more they would agree with the statement that the NGDI was insufficient. 70.84% of the participants disagreed (41.67% strongly disagreed and 29.17% disagreed) with the statement thus informing that there is not a clear protocol for data access through the NGDI (see Figure 6.11). It also puts forward the argument that the clearer the protocol for data accesses through the NGDI, the more sufficient the NGDI to support geospatial data needs. Participants' response to the state of clarity of the protocol to access data through the NGDI also showed a strong negative association with their agreement with the statement that the unclear protocol for data sharing limits the implementation of partnership arrangement within the NGDI. As stated above, 79.16% of participants agreed the protocols for data sharing were unclear, thus a significant correlation of $p<0.01$ informs the research that the protocols for data access and data sharing are very important factors improving the sufficiency of the NGDI to support geospatial data needs. It can also be postulated that clearer the protocol for data access through the NGDI would in turn improve the protocol for data sharing thus improving partnership arrangement.

*Table 6.8: Bivariate correlation of factors assessing the state of the current NGDI*

| Correlations | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** | **K** |
| Familiar with NGDI **(A)** | 1 | | | | | | | | | | |
| NGDI is insufficient to support geospatial data needs **(B)** | -.296 | 1 | | | | | | | | | |
| Low technical proficiency of end user; responsible for reduced SDI implementation **(C)** | .152 | .080 | 1 | | | | | | | | |
| Unclear protocol for data sharing limits implementation of SDI partnership arrangements **(D)** | -.280 | .584** | -.175 | 1 | | | | | | | |
| There is a clear protocol to access data through NGDI **(E)** | .301 | -.835** | .125 | -.536** | 1 | | | | | | |
| It is very easy to find suitable data through NGDI **(F)** | .293 | -.668** | .192 | -.433* | .785** | 1 | | | | | |
| User interface/infrastructure for NGDI clearing house is not easily accessible **(G)** | -.213 | .356 | .093 | .116 | -.514* | -.441* | 1 | | | | |
| Cost of accessing data from the NGDI is reasonable **(H)** | -.115 | -.416* | -.124 | -.362 | .424* | .396 | -.321 | 1 | | | |
| I can access interoperable spatial data from the NGDI easily **(I)** | .166 | -.456* | .060 | -.572** | .596** | .503* | -.336 | .419* | 1 | | |
| Data from the NGDI are obsolete as they are not frequently updated **(J)** | -.004 | .273 | -.034 | .241 | -.276 | -.347 | .239 | -.649** | -.037 | 1 | |
| Data from the NGDI are not accurate or interoperable; it causes challenges during analysis **(K)** | -.085 | .474* | .174 | .575** | -.495* | -.304 | .210 | -.544** | -.494* | .598** | 1 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | | | | | | | | | |
| *. Correlation is significant at the 0.05 level (2-tailed). | | | | | | | | | | | |

Table 6.7 also shows a strong negative relationship between participants' agreement to the statement that it is very easy to find suitable data through the NGDI and their agreement that NGDI is insufficient to support geospatial data needs in Nigeria. A significant correlation of $p<0.01$ was also recorded. 83.34% of the respondents disagreed (54.17% strongly disagreed and 29.17% disagreed) that it was very easy to find suitable data through the NGDI thus signifying that the ease of finding data through the NGDI is an indicator for the NGDI sufficiency (see Figure 6.5). It can be argued that participants would agree that it is easy to find suitable data through the NGDI if the NGDI was more sufficient. Similarly, a moderate negative association was recorded with the argument that "unclear protocol for data sharing limits the implementation of SDI partnership arrangements". A significant correlation of $p<0.05$ was recorded and this is indicative of the impact of the ease of finding suitable data from an NGDI on the clarity of the protocols for data sharing and by implication the implementation of SDI partnership arrangements in Nigeria". Similarly, a significant correlation of $p<0.01$ was recorded with the argument that "there is a clear protocol to access data through the NGDI". Knowing that participants largely disagreed to both statements (see Figure 6.11 above), it can be argued from the strong positive association between the two factors that the clearer the protocol to access data through the NGDI, the easier it would be to find suitable data through the NGDI.

62.5% of the participants were in agreement with the argument that the "user interface/ infrastructure for the NGDI clearing house is not easily accessible" (see Figure 6.5) and from the bivariate correlation analysis, a strong negative association with a significant correlation of $p<0.05$ is recorded for this argument with the argument that "there is a clear protocol to access data through the NGDI". It also recorded a moderate negative relationship and a significant correlation ($p<0.05$) with the argument that "it is very easy to find suitable data through the NGDI". And judging from the results displayed in Figure 6.5, the majority of the respondents disagreed with all three arguments thus informing the position that the clearing house is not accessible. It also gives premise to the argument that the inaccessible clearing house contributes to the unclear protocol for data access which limits implementation of partnership arrangements as well as contributes to the difficulty in finding suitable data through the NGDI. This corroborates with the findings from the interview that indicates that the clearing house is yet to be developed and the full implementation of the clearing house is anticipated to improve data access as presented below.

*Transcript Excerpt 6.9*

*R: What processes or protocols do you think can be implemented to achieve the following?*

- *Improve the access to the NGDI in Nigeria*

*"MA"*

*First and foremost, the nation needs to work on the policy and draft policy to become law because when it becomes law, all the other active player in the field will have no choice than to become part of, because that will make a statement because you will know you are violating the law. So if you have to be part of it, you will become part of it.*

*R: How about the clearing house, do you think the clearinghouse will improve the access?*

*MA: The clearinghouse, if there is funding and the clearinghouse is developed, certainly, many of the participants would be more encouraged because they would have like a platform where they can have their data advertised t a larger community or global audience. So and these are some of the things that are very essential.*

*Transcript Excerpt 6.10*

*R: Can you highlight some of the protocols employed in the management of the NGDI for data dissemination? Stating the current structure, routes and corresponding rules. Thank you very much. Rajabifard, you know is one of the people that write a lot about SDI, he is in Australia, when he was assessing the NGDI, he asserted that the clearing house has not been developed. Can you confirm that?*

*"DMA"*

*That is a statement of fact because the clearing house, the building, I will show you, you will take the picture of the building if you care to. But the money that is supposed to come for the,* *because the clearing house is ICT driven so we never got fund to actually go ahead and develop that critical component.*

Furthermore, a significant correlation ($p<0.05$) was recorded between participants' position on the argument that the "cost of accessing data from the NGDI is reasonable" and two other assessment factors. It showed a significant correlation with a medium negative association with participants' position on the sufficiency of the NGDI while it reflected significant correlation with a medium positive association their position on the argument that "there is a clear protocol to access data through the NGDI". The results presented in Figure 6.11 shows that 75% of the respondents were unsure if the cost of accessing data was reasonable, 16.67% disagreed, 4.17% strongly disagreed and another 4.17% agreed. A medium negative association was recorded with their position on the argument that "there is a clear protocol to access data through NGDI" while a medium negative association was recorded with their position to the statement that the "NGDI is insufficient to support geospatial data needs". This confirms the argument made in this research that suitable data cannot be accessed from the current NGDI this making it inaccessible. Participants are unsure of the reasonableness of the cost of the data because they are yet to access data through the NGDI. The unclear protocols for data access are seen to influence this position.

### 6.3.1.2 *ASSESSMENT OF CRITICAL FACTORS*

Fourteen (14) assessment factors were defined to assess the current problems with the NGDI implementation in Nigeria. The aim was to identify the issues that were more problematic so as to effectively define the facts that were critical to the successful implementation of the NGDI. Descriptive statistics of participants' assertion of the level of importance of these problems to the NGDI implementation were presented in Section 6.2 above. Eleven (11) problem areas were defined and participants categorized these areas according to the areas that were most problematic were also identified and presented in Figure 6.14 and simplified in Figures 6.15 to 6.19.

The bivariate correlation of factors critical to the successful implementation of the NGDI is shown in Table 6.8 below. A significant correlation is seen between the problem of inconsistent scales and reference system (categorised under standards) and two other assessment factors. It recorded a significant correlation ($p<0.01$) with the problem of integrating data of standards with little or no interoperability (also categorised under standards). A strong positive association was recorded for this correlation which informs that improving the standards to ensure consistent scales and reference system would reduce the existence of datasets of standards with little or no interoperability within the NGDI, and by implication, improve the integration of NGDI data for environmental analysis and protocols. The problem of inconsistent scales and reference system also recorded a significant correlation ($p<0.505$) with the insufficiency of the NGDI to support geospatial data needs. A medium positive association was also documented for this correlation. Thus it can be argued that improving the standards to ensure consistent scaled and reference system would improve the usability and interoperability of the accessed datasets. In addition, the problem of integrating data of standards with little or no interoperability also showed a moderate positive association with the problem of the level of technical proficiency of the people (regulators, consultants and operators). A significant correlation (*$p<0.01$*) was observed.

In terms of policy, the lack of open spatial data policy is reported to have a medium positive association with the inexistent partnership arrangements, the ease of accessing data, as well as the people's awareness of the existence of the data and SDI. A significant correlation of *$p<0.05$* was also observed for all three associations. This it can be posited that postulating a legally binding open spatial data policy in Nigeria would influence the development of a successful partnership arrangement, improve the ease of accessing spatial data as well as improve the people's awareness of the SDI and spatial data.

*Table 6.9: Bivariate correlation of factors critical to the successful implementation of the NGDI*

| Correlations | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** | **K** | **L** | **M** | **N** | **O** |
| Inconsistent scales and reference system **(A)** | 1 | | | | | | | | | | | | | | |
| Integrating data of standards with little or no interoperability **(B)** | .637** | 1 | | | | | | | | | | | | | |
| Lack of open spatial data policy **(C)** | .122 | .121 | 1 | | | | | | | | | | | | |
| Inexistent partnership arrangements **(D)** | .010 | -.342 | .477* | 1 | | | | | | | | | | | |
| Policy: Restricted data sources **(E)** | .238 | .053 | -.140 | .143 | 1 | | | | | | | | | | |
| Ease of access **(F)** | .143 | -.044 | .417* | .687** | .339 | 1 | | | | | | | | | |
| Usability and interoperability of accessed datasets **(G)** | .466* | .293 | .123 | .126 | -.267 | .080 | 1 | | | | | | | | |
| Access to Nigeria datasets **(H)** | .000 | -.342 | -.051 | .571** | .099 | .147 | .058 | 1 | | | | | | | |
| Quality of accessed data **(I)** | -.082 | -.205 | .210 | .553** | .239 | .389 | -.080 | .594** | 1 | | | | | | |
| Cost of accessing data **(J)** | -.028 | .049 | .039 | .110 | -.076 | .090 | -.356 | .165 | .307 | 1 | | | | | |
| Query data and handling requests **(K)** | -.171 | -.198 | .263 | .425* | .049 | .365 | -.373 | .425* | .589** | .491* | 1 | | | | |
| Technical proficiency **(L)** | .397 | .460* | -.070 | -.072 | .159 | -.034 | .067 | .148 | .222 | .304 | .318 | 1 | | | |
| Availability of Technical Documentation **(M)** | .248 | .333 | -.037 | -.276 | -.169 | -.365 | .269 | -.105 | -.298 | -.035 | -.182 | .169 | 1 | | |
| Awareness of data/SDI existence **(N)** | .122 | -.139 | .475* | .610** | .124 | .750** | .036 | .269 | .390 | .194 | .433* | .247 | -.325 | 1 | |
| NGDI is insufficient to support geospatial data needs **(O)** | -.053 | -.320 | .588** | .636** | .101 | .466* | -.094 | .175 | .462* | .152 | .369 | -.191 | -.455* | .480* | 1 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | | | | | | | | | | | | | |
| *. Correlation is significant at the 0.05 level (2-tailed). | | | | | | | | | | | | | | | |

### 6.3.2 MULTIPLE REGRESSION ANALYSIS

#### 6.3.2.1 *CURRENT NGDI STATUS*

From the correlation analysis in Table 6.9, participants' agreement or disagreement to the six of the eleven assessment statements were shown to have correlated significantly with their agreement to the statement that the NGDI is insufficient to support geospatial data needs. The attestations were: "unclear protocol for data sharing limits implementation of SDI partnership arrangements"; "there is a clear protocol to access data through NGDI'; 'it is very easy to find suitable data through NGDI"; "cost of accessing data from the NGDI is reasonable"; "I can access interoperable spatial data from the NGDI easily"; and "the data from the NGDI are not accurate or interoperable; it causes challenges during analysis". These attestations were used to assess the current state of the NGDI based on its ability or inability to support geospatial needs in Nigeria. Multiple regression analysis was therefore applied on these assessment factors to assess the level at which these variables predict the outcome (NGDI sufficiency). The NGDI insufficiency (agree that the NGDI is insufficient to support geospatial data needs) was defined as the dependent variable while the other six (6) assessment factors were the independent variables.

*Table 6.10: Coefficients for NGDI status*

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 4.933 | .460 | | 10.718 | .000 |
| | There is a clear protocol to access data through NGDI | -.800 | .113 | -.835 | -7.104 | .000 |
| a. Dependent Variable: Agree NGDI is insufficient to support geospatial data needs | | | | | | |

A significant regression of $p<0.001$ $(F\ (1,\ 22) = 50.47,\ R^2 = 0.70,\ R^2_{Adjusted} = 0\ .68)$. The adjusted R Square value indicated that the model accounted for approximately 70% of the variance in level of independence between the variables. Therefore, the existence or inexistence of a clear protocol to access data through the NGDI is the most useful predictor of the of the NGDI sufficiency, in this case, their agreement that the NGDI is insufficient to support geospatial data needs (see Table 6.10). The model only presented the variables that contribute significantly to the assessment of the sufficiency of the NGDI and excluded others that did contribute significantly as they have not been considered useful in predicting the independence level. For that reason, the ***existence of a clear protocol for data access through the NGDI*** was built-in as a core parameter for the SDI -AF development. This does not imply that only one factor can predict the NGDI status, it simply identifies the factor with the most effect.

#### 6.3.2.2 *FACTORS CRITICAL TO NGDI IMPROVEMENT*

In the correlation analysis conducted on the factors critical to the successful implementation of the NGDI (see Table 6.9), six (6) variables correlated significantly with assessment of the NGDI sufficiency (NGDI is insufficient to support geospatial data needs), showing a strong and medium positive association, as well as a medium negative association as explained above. In order to assess the level at which these variables predict the outcome (NGDI sufficiency), the multiple regression analysis using the stepwise method was conducted using the NGDI insufficiency as the dependent variable and the other assessment factors presented in Table 6.10 as the independent variables.

Three significant models were produced using the stepwise method. Model 1 showed a significant regression of $p<0.005$ $(F\ (1,\ 22)\ =14.93,\ R^2\ =\ 0.40,\ R^2_{Adjusted}\ =0\ .38)$. A significant regression of $p<0.001$ was recorded for both model 2 and 3 (Model 2: *(F (2, 21)*

*=10.88, $R^2$ = 0.51, $R^2_{Adjusted}$ =0 .46);* Model 3***:*** *(F (3, 20) =10.75, $R^2$ = 0.62, $R^2_{Adjusted}$ =0 .56)).* The adjusted R Square value showed that model 1 accounted for approximately 38% of the variance in level of independence in within the variables. Model 2 accounted for 46% of the variance level of independence between the variables while model 3 accounted for 56% of the variance. The amount of variance is seen to have increased by 8% between model 1 and 2 and 10% between model 2 and 3.

*Table 6.11: Coefficients*

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | .513 | .399 | | 1.286 | .212 |
| | Inexistent partnership arrangements | .755 | .195 | .636 | 3.864 | .001 |
| 2 | (Constant) | .027 | .436 | | .063 | .950 |
| | Inexistent partnership arrangements | .546 | .207 | .460 | 2.645 | .015 |
| | Lack of open spatial data policy | .425 | .201 | .368 | 2.115 | .047 |
| 3 | (Constant) | 1.185 | .626 | | 1.892 | .073 |
| | Inexistent partnership arrangements | .409 | .196 | .345 | 2.093 | .049 |
| | Lack of open spatial data policy | .474 | .183 | .410 | 2.590 | .018 |
| | Availability of technical documentation | -.413 | .174 | -.345 | -2.378 | .027 |

a. Dependent Variable: Agree NGDI is insufficient to support geospatial data needs

It was also inferred that the inexistent partnership arrangements, lack of open spatial data policy and the availability of technical documentation had been useful in predicting the assessment of the NGDI sufficiency, in this case, their agreement that the NGDI is insufficient to support geospatial data needs (model 3). From Table 6.11 above, we can see that the inexistent partnership arrangement was the first predictor selected to be entered into the analysis (Model 1), indicating that it is the most useful predictor of the insufficiency of the NGDI, followed by the lack of an open spatial data policy and the availability of technical documentation in Models 2 and 3. This model presented only the variables that contributed significantly to the sufficiency of the NGDI and excluded other variables that had not reached significance; thus they had not been determined useful in predicting the independence level in the stepwise regression equation. As a result, in the development of the SDI augmentation framework, ***existence of partnership arrangements, the existence of an open spatial data policy*** *and* ***the availability of technical documentation*** were prioritised as core contributors for the development of the parameters and contextual factors of the framework.

## 6.4 CHAPTER SUMMARY

This chapter presented results of the descriptive statistics and analysis of the NGDI-CF study conducted in order to ascertain the effectiveness of the NGDI for EAI and critical factors for its success. These factors were not limited to the ones shown by the correlation, as the research took into account the fact that correlation analysis does not completely show cause and effect. Thus, regression analysis was conducted to determine which of the independent variables statistically predicted the value of the dependent variable. The significant predictors from the regression analysis in addition to the assessed factors from the correlation analysis as well as the findings from the EIA-SDI case (Chapter 4) and the PPU (Chapter 5) were combined to develop the core parameters and contextual factors of the SDI augmentation framework (SDI-AF). The next chapter discusses the findings of the NGDI-CF in combination with the findings from the EIA-SDI and the PPU cases to enable us arrive at a more comprehensive conclusion on the findings which will drive the design of the SDI-AF.

# 7 CHAPTER SEVEN: SYNERGY OF FINDINGS

## 7.1 INTRODUCTION

This chapter discusses the research outcomes. It seeks to synergise the findings from the EIA-SDI case, the PPU evaluation and the NGDI-CF evaluation. The outcomes of the three empirical data components were aligned to develop the SDI Augmentation Framework (SDI-AF) proposed in this research.

### 7.1.1 SAMPLE POPULATION

The EIA-SDI case surveyed certified EIA preparers under the two main EIA regulators (the FMEnv and the DPR) within the Nigerian oil and gas sector. The sample population for the NGDI-CF and PPU evaluations on the other hand, surveyed environmental consultants (which include EIA preparers), operators (oil and gas operators) and regulators. The regulators in this case were similar to those from the EIA-SDI case as they were sampled from the DPR and the FMEnv. However, an additional set of regulators was included in the NGDI-CF and the PPU evaluations. This additional set comprised regulators from NASRDA, the coordinating body for the NGDI. The regional SDI regulator, ECOWAS (Economic community of West African states) was also included for a more robust data gathering.

For the EIA-SDI case, 35% of the survey population were from organisations that carry out and prepare formal EIA statements, 17% of the survey population contribute to environmental analysis while the remaining 48% engage in both operations. This indicates a suitable amount of experience with EIA preparation for making valid assertions on the state of the EIA and its challenges as it relates to spatial data access and use. Conversely, 45.83%

of the participants for the NGDI-CF and PPU evaluations were seen to be spatial data producers, end users and policy makers which indicate a robust knowledge of the spatial data issues as well as the policies surrounding the data. 29.17% of the participants were both spatial data end users and spatial data providers, 8.83% were only involved in spatial data policy making while 16.67% were spatial data end users alone. Additionally, 71% of the participants were experts in the use of computers and GIS while 29% were at an intermediate level. None of the participants were starters. The range of the participants' organisational category in combination with their level of expertise was considered sufficient for the NGDI-CF and PPU evaluations.

In the first EIA-SDI case 61.5% of the surveyed population claimed to be familiar with the NGDI and 25% of the population were not familiar with it while 70.83% of the participants in the NGDI-CF evaluation were familiar with the NGDI (by different degrees of familiarity; 20.83% very familiar and 50% familiar as shown in Figure 7.4). 8.33% were very unfamiliar, 12.50% were unfamiliar and another 8.33% were unsure. The degrees of familiarity within the two sampled populations was considered sufficient for both evaluations as it accounted for over 50% of the population and also corroborates with the argument made in this research that there is lack of awareness of the existence as well as the capabilities of the NGDI.

Participants also had similar assertions on the sufficiency of the NGDI to support geospatial data needs in Nigeria. 90.80% of the respondents in the EIA-SDI survey disagreed with the statement that the current NGDI protocols are sufficient to support geospatial data needs as shown in Figure 7.1. The participants of the NGDI-CF evaluation were then quizzed on the position of the participants from the EIA-SDI survey so as to get their perspective of the sufficiency of the current NGDI. 79.16% agreed with the assertion of 90.80% of the respondents of the EIA-SDI survey that the current NGDI protocols were insufficient to support geospatial data needs in Nigeria (58.33% strongly agreed and 20.83% agreed - see Figure 6.16). This indicates that the level of the sufficiency of the NGDI was yet to improve between 2014 (when the EIA-SDI survey was conducted) and 2016 (when the PPU and NGDI-CF evaluations were conducted).

There are also observable similarities between the data collection methods for EIA-SDI case and the prototype evaluation. They both utilised empirical data sourced through questionnaires and interviews. Questionnaires were utilised for the EIA-SDI case and it provided sufficient data on the current issues with spatial data usage as well as the status of the emerging NGDI. This was very useful for the development of the prototype demonstrating the prospects of a fully implemented NGDI that enabled data access and sharing in Nigeria. It however did not provide many details on the current protocols within the NGDI and the factors that were critical to improving the NGDI. To this end the prototype evaluation utilised semi-structure interviews to enable the gathering of more detailed data to make valid conclusions. The assessment factors relevant for the evaluation of both the prototype and the NGDI were structured in Likert scale questionnaire formats to improve their measurability while allowing them to discuss their choices or answers to each question as in an interview process. This addressed the limitation of the initial data collection (EIA-SDI survey) and provided ample information for the analysis and the development of the SDI-AF.

## 7.2 ANALYSIS AND DISCUSSION OF FINDINGS

### 7.2.1 CHALLENGES TO SPATIAL DATA USE

A number of issues were identified to hinder the use of spatial data for environmental analysis in Nigeria. Content analysis of the findings from the EIA-SDI survey conducted in 2014 identified issues with the use of spatial data for environmental analysis as the problem of finding the data, accessing the data, integrating the data, the quality of the data and the cost of the data (see Figures4.17 and 4.18 in Chapter 4). The variation between the frequencies of these issues in participants' responses in the EIA-SDI survey was minimal, thus inferring that the problems were perceived to have a relatively similar degree of importance. This, in addition to other results from the survey as well as the reviewed literature, informed the need for the creation of viable frameworks that would improve data sourcing (finding the data), data access, integration (interoperability), data quality, as well as improve the cost effectiveness of producing, disseminating and acquiring the datasets. The SDI Data Access Protocol was developed demonstrate the prospects of addressing these gaps by implementing a suitable SDI (see Chapter 5). Following the prototype evaluation, the NGDI-CF evaluation was conducted to assess the problems obstructing the NGDI implementation, so as to ascertain the current state of affairs as well as identify any improvements or further deterioration. The issues highlighted were analysed and the final nodes were presented in Figure 6.13 of Chapter 6.

In both studies, the problem faced when trying to access spatial data for environmental protocols are observed to have the highest frequencies inferring a higher degree of importance. The non-availability of core fundamental datasets impairs the conducting of robust environmental analysis thus limiting the ability to make informed predictions and environmental decisions from such analysis. Knowing where to find the data is a first step to accessing it. The lack of a clear structure or process for accessing fundamental datasets needed for environmental analysis is seen to contribute to the current limitation as participants attributed the problem faced with accessing spatial data for environmental protocols on the inexistent spatial data infrastructure in Nigeria. Others blamed the challenges with data access on the poor and sometimes, unavailable internet infrastructure in Nigeria to allow for the creation of web portals for data access and consequently inhibiting data access from the web.

Another predominant issue is the occurrence of obsolete and redundant datasets. They alleged that most of the datasets were not recent enough as they are not frequently updated thus rendering them unreliable. Accuracy and completeness of the accessed datasets was also highlighted to pose challenges as resourceful time is spent cleaning the data. Categorically, accessing complete, accurate and consistent datasets that are provided in the right format is presently a challenge.

Access to relevant tools for spatial data collection and analysis, in addition to the presence of data of inconsistent standards and formats, was also reported to pose a challenge to the integration of the accessed dataset. It was also noted that the access to the right tools alone may not improve without a corresponding increase in the proficiency of those using the technology and spatial datasets (see Transcript excerpt 6.2).

The security situation in Nigeria caused by youth restiveness and terrorism was also cited as an inhibiting factor. The presence of incomplete datasets has been attributed to consultants' inability to access areas of restiveness where communities are in crisis or are under terror attacks. Consultants in many cases are forced to appeal to the restive communities using monetary means, which in turn increases the cost of data collection. This again results in cases where consultants have to over stretch the incomplete data in order to get any semblance of accuracy from the data thus reducing the quality and accuracy of the environmental analysis or EIA report produced with the data. Regulatory issues were also cited. Participants argued that the poor institutional arrangements of the regulatory bodies contribute to the present challenge.

### 7.2.2 STATE OF THE EMERGING NGDI

In addition to asserting the sufficiency of the NGDI as discussed in Section 6.2.3.3, participants were also quizzed on their perception of the current state of the emerging NGDI as presented in Section 6.2.3. This is important as it provides an informed understanding of where the NGDI is presently and the areas that need to be harnessed or created to move it from its current state to a state of full effectiveness. As part of the data collection process for the NGDI-CF evaluation, a focus group was conducted in NASRDA, the custodians and coordinators of the NGDI. The purpose of the focus group was to find out the state of the NGDI from the perspective of its facilitators. Three key members of the NGDI committee were also interviewed (one-on-one interview) after the focus group to provide a clear view of the issues raised. Other stakeholders, consultants, operators and regulators with various degrees of familiarity with the NGDI were also interviewed so as to get a balanced view of the status of the NGDI (see Figure 6.14 of the NGDI-CF evaluation and Figure 4.23 of the EIA-SDI case).

The interview assessment had two parts. The first part used predefined assessment criteria (see Figures 6.5 to 6.11). The second part used open-ended questions where respondents discussed other issues affecting the NGDI that were not covered by the defined assessment criteria (see Table 6.6). Some of the predefined assessment criteria examined the protocol for data access and sharing through the NGDI as an indicator for the existence and workability of the NGDI clearinghouse. 54.17% strongly disagree and 29.17% disagree that there is a clear protocol to access data through NGDI. 41.67% strongly disagree and 29.17% disagree that it is very easy to find suitable data through NGDI (see Figure 6.11). Thus, depicting the inexistence of the NGDI clearinghouse for data access and sharing, as well as the need for the creation of an access protocol.

Poor communication of NGDI objectives and the poorly structured institutional arrangements for data for the definition of corresponding roles and responsibilities was reported to result in conflicts of interest, thus causing duplication of efforts and the waste of resources (time and money). Poorly communicated objectives, in addition to poor demonstration of the NGDI prospects to stakeholders and policy makers, was reported to have slowed down the process. Issues of inadequate to no funding were also mentioned. Some argued that the funding available was inadequate while others argued that the misappropriation of available funds and not the lack of funds was the problem.

A number of participants attributed that the NGDI in itself was inexistent while others claimed it was in limbo due to the exhaustion of the available funds and the failure of the government to prioritise the NGDI by including it in its budget. Another issue raised was the lack of a legally binding policy to compel stakeholders to participate fully in the NGDI development or to fund it. Though the NGDI is not operational at the moment, the coordinators argued that concerted efforts have been made to organise meetings with stakeholders to encourage participation and partnership but was slowed down by the lack of funding.

*Transcript Excerpt 7.1*

*R: As a follow-up to question 9, can you please indicate your level of agreement with the following statements:*
*Lack of adequate funding limits the advancement of the NGDI in Nigeria*

*That's difficult to answer because I don't know how much they were, been funded so far and what they used the money to do, so it's more of even, I don't know. It's even more of a transparency issue. (Yeah). It is more of a transparency and accountability issue. (So unsure?) Unsure yeah.*

The lack of synergy between the agencies that should be involved in the partnership arrangement within the NGDI was also highlighted, with the cause of this issue attributed to the lack of a binding policy to enforce partnership and avert the unhealthy competition that impedes the success of government projects.

### 7.2.3 SDI DATA ACCESS PROTOTYPE

The demonstration of a prototype for spatial data access was designed to show the technicalities of data access and sharing within an SDI which is relevant and within the scope of this research. As corroborated by the experts who participated in the PPU evaluation, the current development is sufficient for the purpose of demonstrating the intricacies and promoting the benefits of the SDI to developing nations like Nigeria. Suggestions were made for further development and improvement but to be carried out by the constituting agency or department that is saddled with the responsibility of developing the SDI in Nigeria and bringing the research output to reality.

The usability check was done to ascertain if the developed prototype actually suits the needs of users. This is to concretely ascertain whether or not the developed prototype is relevant to environmental consultants and contributes to addressing the current gaps within the NGDI. The effectiveness of the design was tested to ascertain the technical validity of the system. As shown in Figure 5.19 in Chapter 5, 54.17% of the respondents rated it as very effective while the remaining 45.83% rated it as effective. Suggestions were however provided to improve the design of the prototype for better performance and user experience. Suggestions included the addition of more prompts and increased icons to represent spatial elements. However, other participants were of the opinion that new functions should not be included as it is sufficient for the demonstration as a prototype and suggested that more functions should be added when the research output is developed into a full project and the prototype users have increased to multiple users. Search tabs and links for more information were also suggested to improve the design and make it more user friendly to people with lower GIS knowledge.

As explained, the prototype was developed as a demonstration of SDI data access and sharing with the aim of contributing to addressing the current gaps of inaccessibility of NGDI data, inexistent clearing house, and inexistent partnership arrangements identified in earlier sections. To this end, participants after going through the demonstration were asked to attest on the effectiveness of the prototype to demonstrate data access from an SDI. 79.17% of the respondents rated the prototype as a very effective demonstration for accessing spatial data from SDI while the remaining 20.83% of the respondents rated it as effective (see Figure

5.22). Similarly, 70.83% of the respondents strongly agreed, while the remaining 29.17% agreed that the prototype addresses concerns of accessing NGDI data as shown in Figure 5.29. They however noted that the prototype in itself is not the utopic solution but the deployment of the prototype data access and sharing protocol in combination with strict protocols for quality control, data updating with the correct versioning system and the completeness of the data imputed into the system. It was also added that though the prototype portrays elements of user friendliness due to the fact that it is conventional to both mobile and desktop technologies, training and sensitisation of the users was also stated as important to allow for wider usage and adoption.

## 7.3 CHAPTER SUMMARY

This chapter discussed the findings from the EIA-SDI, NGDI-CF and PPU evaluations for the development of the SDI-AF.

# 8 CHAPTER EIGHT: SDI AUGMENTATION FRAMEWORK

## 8.1 INTRODUCTION

The final objective of this research sought to develop a new SDI framework within which the novel data access protocol can flourish. This chapter documents the development of the SDI Augmentation Framework (SDI-AF).

## 8.2 DEVELOPMENT OF CONTEXTUAL FACTORS

The framework seeks to augment SDI implementation in Nigeria and other countries where the SDI is performing below expectations. It utilised the NGDI case to identify problem areas with emphasis on the areas that are critical to its successful implementation. In Chapter 4 a number of factors were identified from the EIA-SDI case. The possibility of overcoming the identified challenges was explored in Chapter 5 with the PPU case that assessed the developed SDI data access prototype. Further assessment carried out to assess the factors critical to the NGDI implementation in the NGDI-CF case in Chapter 6 and the results of the inferential analysis identified key factors that were considered critical to the improvement of the NGDI following the conduct of both the correlation and regression analysis.

The EIA-SDI case provided an understanding of the specific EIA activities on-going in Nigeria and the current use of spatial data as inputs to EIA reports. It identified the effects of the problems obstructing spatial data use on EIA reporting and the sufficiency of the NGDI to support geospatial data needs in Nigeria. It also highlighted the effect of the NGDI status on the quality of data used for EIA and subsequently the effectiveness of EIA reports. The PPU however evaluated the prototype to ascertain its ability to contribute to overcoming the challenges identified by the EIA-SDI case. It assessed the effectiveness of the prototype design to show its technical validity as well as the users' satisfaction with the prototype. In relation to the framework development, it assessed the effectiveness of prototype to demonstrate data access from an SDI as well as the prospect of the prototype as a solution to SDI data access and sharing. It further pried to assess the participants' level of agreement to the assertion that the prototype addresses the challenges of accessing NGDI data. This was further elaborated by the assessment of the prototype to improve the performance of relevant tasks like finding suitable spatial data, downloading spatial data, improving partnership arrangement as well as data updating. The NGDI-CF case on the other hand pried further to reassess the current issues obstructing the use of spatial data for environmental analysis, as well as the assertion from the EIA-SDI survey on the insufficiency of the NGDI to support the geospatial data needs in Nigeria. It re-examined the current state of the emerging NGDI, assessing the NGDI protocols, as well as identifying the factors obstructing the NGDI uptake. It went further to identify the factors mitigating NGDI advancement and successful implementation, as well as identifying some factors that were considered critical to the success of the NGDI.

For the definition of the contextual factors of the SDI augmentation framework, the factors critical for the improvement of the NGDI identified from the three empirical studies conducted in this research (EIA-SDI, NGDI-CF and PPU) were integrated in accordance with the SDI model proposed by Rajabifard and Williamson (2001). Thus, they were modelled under the five SDI components: standards, access networks, policy, people, and data (see Figure 2.2 in Chapter 2). The defined contextual factors, the SDI category of these factors and their sources are presented in Table 8.1.

*Table 8.1: Definition of contextual factors*

| SDI CATEGORY | IDENTIFIED PROBLEMS | SOURCE | DEFINED CONTEXTUALFACTORS |
|---|---|---|---|
| **Standards** | • Non-conformity with stated guidelines and standards on the part of the Oil and Gas operators<br>• Incompatible format and high cost of data acquisition and processing<br>• Harmonized standards<br>• Poor EIA reports that don't match nationally or internationally specified standards<br>• There is an urgent need to put in place adequate and up-to-date infrastructure for data capture and standardization to ensure whatever reference is generally accepted not only to Nigerian user but also internationally.<br>• Raising standards and enforcing high standards for quality of EIA analyses, prediction and reporting mechanisms.<br>• Developing the NGDI protocols to meet international standards.<br>• Non-conformity with stated guidelines and standards | NGDI-CF (Q9, Q11) EIA-SDI (Q31) | • Scales and reference systems<br>• Data standards<br>• Data formats<br>• Interoperability<br>• Obsolete datasets<br>• Accuracy and consistency<br>• Metadata formats |
| **Access Networks** | • Undefined process of accessing data<br>• Knowledge of the existence of NGDI is limited.<br>• Communication of its existence, role and activities should be more readily made available to relevant persons involved in EIA studies.<br>• Most of the needed data is not yet updated in any of the relevant organization website<br>• The NGDI is not accessible<br>• Lack of support from government in the area of making sure they collect regular data and store it somewhere for consultants to uses when preparing EIA. Also, the impatience of some consultants to source for quality data and so they use mere assumptions.<br>• Access to relevant information<br>• Information On NGDI Not Widely Disseminated<br>• no adequate information Access to information in Nigeria is generally difficult<br>• Inadequate information dissemination and cumbersome bureaucracy<br>• Ensuring that produced data are kept in a database and made available freely to people that need it for EIA preparation | EIA-SDI (Q23) NGDI-CF (Q9, Q11) | • Clearinghouse and collaborative data hubs<br>• Ease of access<br>• Data access protocol<br>• Data upload protocol<br>• Data update (versioning system) protocol<br>• Internet and mobile network<br>• Security: permissions and access control<br>• Ease of response<br>• Webservers |

| | | | |
|---|---|---|---|
| **Data** | • Specific ones may not readily available and sometimes when available, the resolution may be poor.<br>• Data versioning and update<br>• Redundant and obsolete data<br>• Incompatible format and<br>• Restricted data sources<br>• Because it is not made available to users caused by level of civilisation and secrecy of every information with intent to profit from its release.<br>• Limited access to data<br>• Getting the right data for analysis<br>• Lack of sufficient and accurate spatial data | EIA-SDI (Q23, Q32) NGDI-CF (Q9, Q11) | • Data quality and accuracy<br>• Data redundancy<br>• Metadata<br>• Data development<br>• Database: storage and archival system<br>• Consistent data scales<br>• Restrictions and restricted data sources<br>• Confidentiality<br>• Quality assessment and control |
| **People** | • Use of non-competent professionals<br>• Knowledge level and technical proficiency<br>• More training is required to increase the number of people who have access and know how to use spatial data<br>• Partnership and participation<br>• Access to data and information on best practices, policies and standards<br>• Orientation and re-orientation | NGDI-CF (Q10, Q11) NGDI-CF (Q9) EIA-SDI (Q31) | • Awareness: consistent workshops and sensitization<br>• Technical proficiency and competence<br>• Access to technical documentation<br>• Training and re-training<br>• Participation and partnership<br>• Participant classification: policy maker, data provider or producer and end user |
| **Policy** | • Funding and challenges in accessing data from other government agencies due to bureaucracies and bottlenecks<br>• Poor regulation hence the production of substandard EIA that is not based on facts<br>• Partnership and participation<br>• Data ownership; unwillingness to share data<br>• Poor communication of NGDI prospects and benefits to stakeholders; objectives not clearly defined and communicated.<br>• Inexistent LGA collaboration for grassroots involvement<br>• Poorly structured institutional arrangements<br>• Poor regulation; wrong peg in the wrong hole leading to cumbersome legislations and unwholesome enforcements<br>• Lack of government commitment; political will<br>• Collusion with regulators to avert the laid down guidelines and standards for operation in the oil and industry<br>• Policy / legislature enforcement, | NGDI-CF (Q9,Q10) NGDI-CF (Q9, Q10) EIA-SDI (Q31, Q32) | • Open spatial data policy<br>• Funding and appropriation<br>• Partnership arrangement<br>• Data ownership and privacy<br>• Terms of business and rules of engagement<br>• Cost and pricing<br>• Roles and responsibilities: request and response<br>• LGA, state and federal SDI collaboration; protocol and data centres<br>• Institutional arrangements<br>• Legal; legislation and policy enforcement<br>• Motivation and rewards for participation and sharing |

| | | | |
|---|---|---|---|
| | compliance<br>• High cost of data acquisition and processing; conflicting demands from regulatory authorities resulting in cost escalations and inefficiencies<br>• Duplication of responsibilities; lack of clearly defined roles resulting in conflicts of interest<br>• Lack of synergy between stakeholders and agencies roles and responsibilities not clearly defined.<br>Corruption and sabotage. | | |

The defined contextual factors were classified according to the five SDI components as purported by Rajabifard and Williamson (2001) to align the development with the established theoretical paradigm (see Figure 8.1).

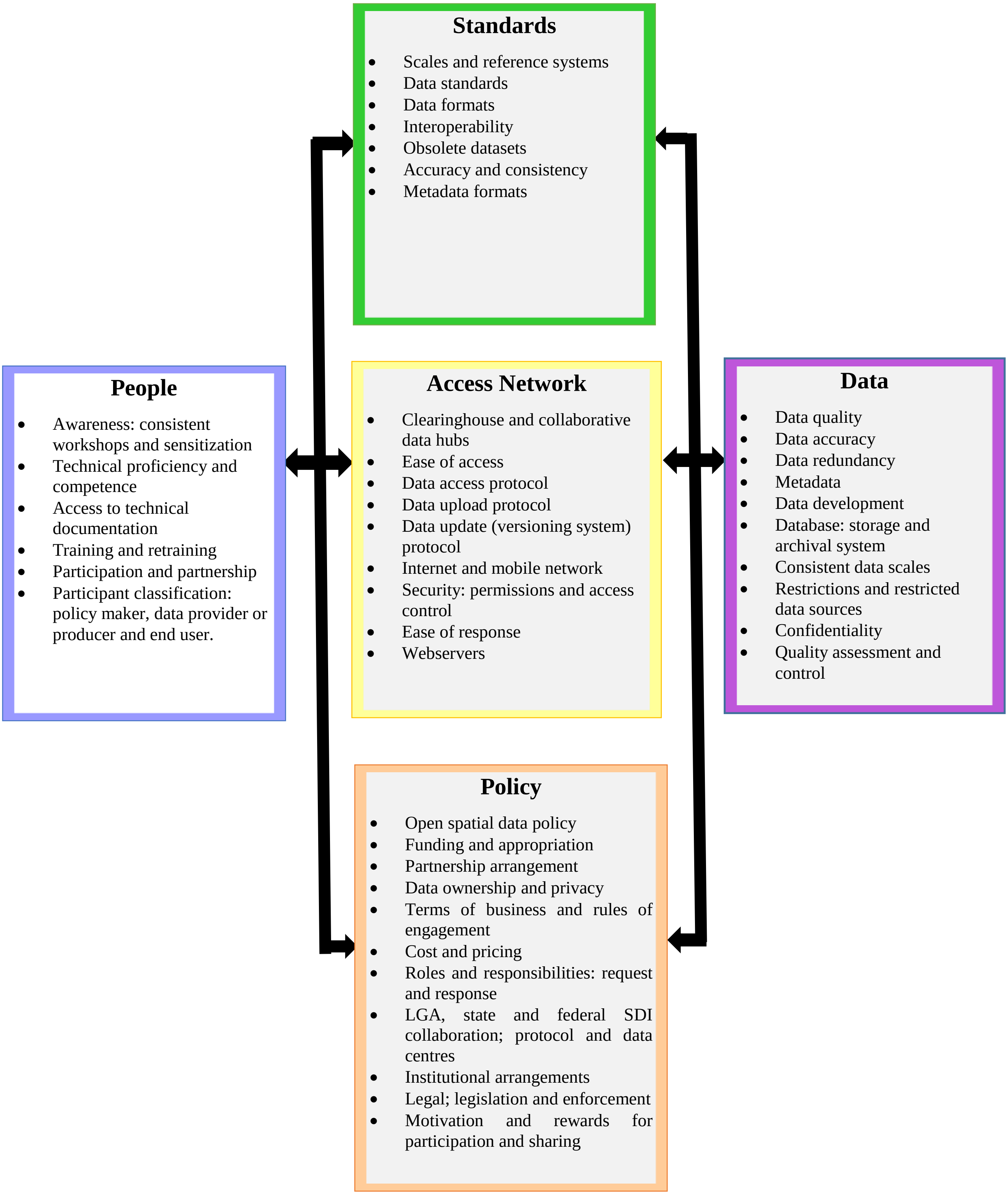



*Figure 8.1: Conceptual Factors Classified According to SDI Components*

To develop the SDI–AF therefore, possible solutions to these problems were proposed. For instance, the access to spatial data from the NGDI was documented as a fundamental problem to EIA preparation, which the prototype development sought to address. Though the prototype effectively demonstrated how to access spatial data from an SDI by enabling the access to and sharing of standardized spatial data via the web (through the Geoserver and the web interface), other fundamental factors like policy enforcement and partnership arrangements needs to be prioritised to develop an effective SDI. These factors were defined to address the problems emanating from poor legislation, technical proficiency, incompatible data formats, inadequate and misappropriated funds, as well as others listed in Table 8.1 above. It was important to define the factors within which the SDI data access protocol can flourish and by implication contribute to an effective SDI.

From the analysis of the contextual factors, the SDI–AF was developed to ensure the following;

- Improve spatial data access and sharing.
- Improve the quality and accuracy of spatial data obtainable from the NGDI.
- Amplify the legislation and enforcement of a policy that reflects the needs of the SDI.
- Consistently improve technical proficiency and consistency.
- Heighten awareness, as well as amplify participation and partnership.
- And therefore, aid the full implementation of the NGDI

## 8.3 INITIAL FRAMEWORK

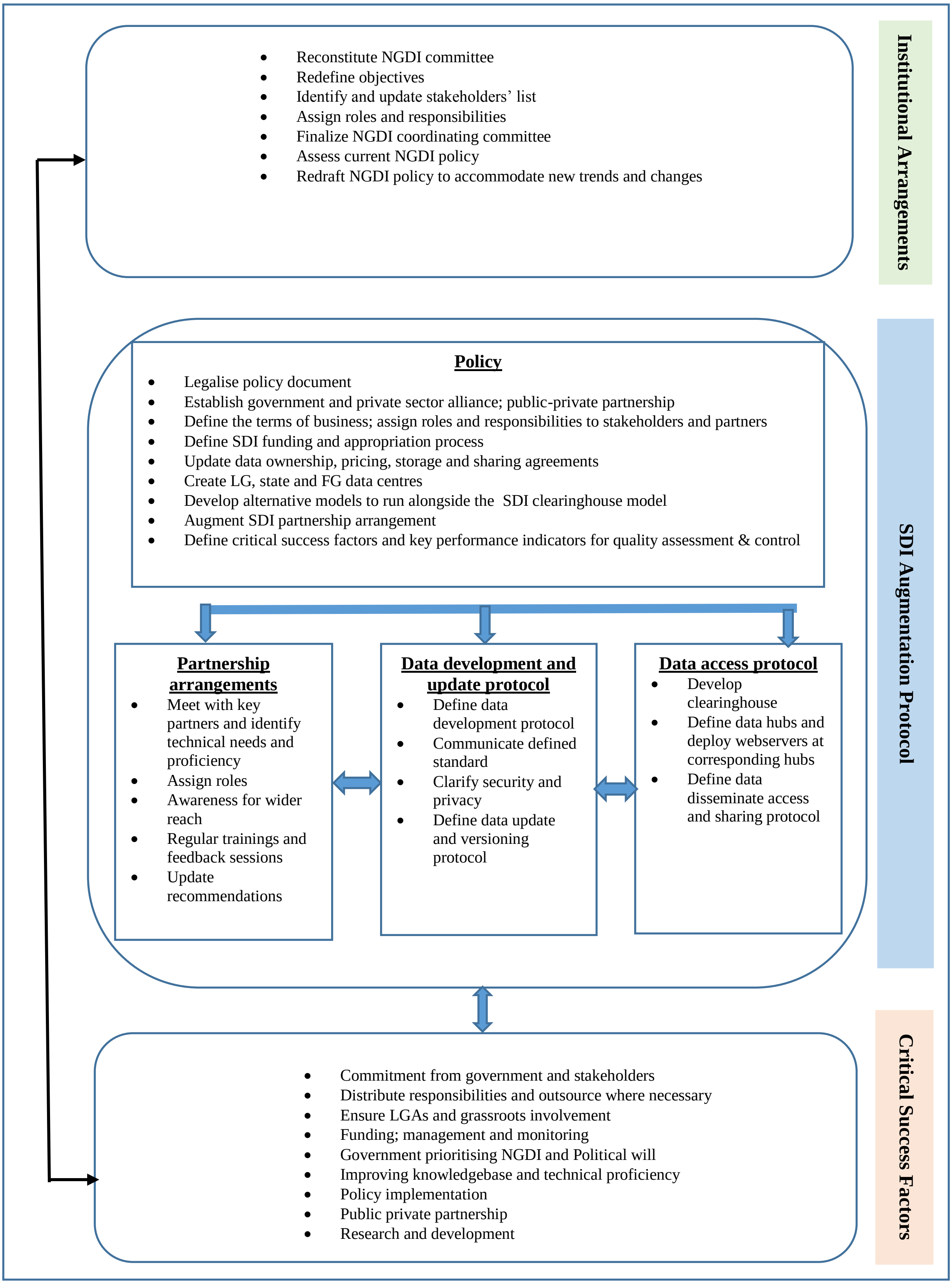



*Figure 8.2: Initial SDI Augmentation Framework*

The framework was structured into three components; institutional arrangements, SDI augmentation protocol and critical success factors as presented in Figure 8.2.

The institutional arrangements were developed to enable an effective NGDI committee where the roles and responsibilities are well defined to prevent duplication of efforts. It highlighted the need to reconstitute the NGDI committee to ensure the right people are put in the right place. The re-definition and clear communication of the research objectives was also considered important to accommodate the changes proposed by the framework. This seeks to improve the partnership and participation, data development and update, as well as enduring seamless data access. To aid partnership and participation, improving SDI awareness and the knowledge level (technical proficiency) of all stakeholders was observed to be fundamental. Training and continuous orientation was proposed as one of the protocols to employ to aid partnership and participation. For data development however, the policy definition, as well as enforcement of the data production standards was considered fundamental and thus was proposed. The SDI data access prototype, developed in a large scale to cater for more users, was recommended to aid data access. Consideration of the critical success factors, however, was recommended to enable the framework to thrive. These factors have been defined from the assessed problems and in their absence the framework may not achieve effectiveness.

The initial framework was further assessed to ensure it aligns with the research question and aim. On further assessment, a revised framework was developed for validation by industry experts.

## 8.4 REVISED FRAMWORK

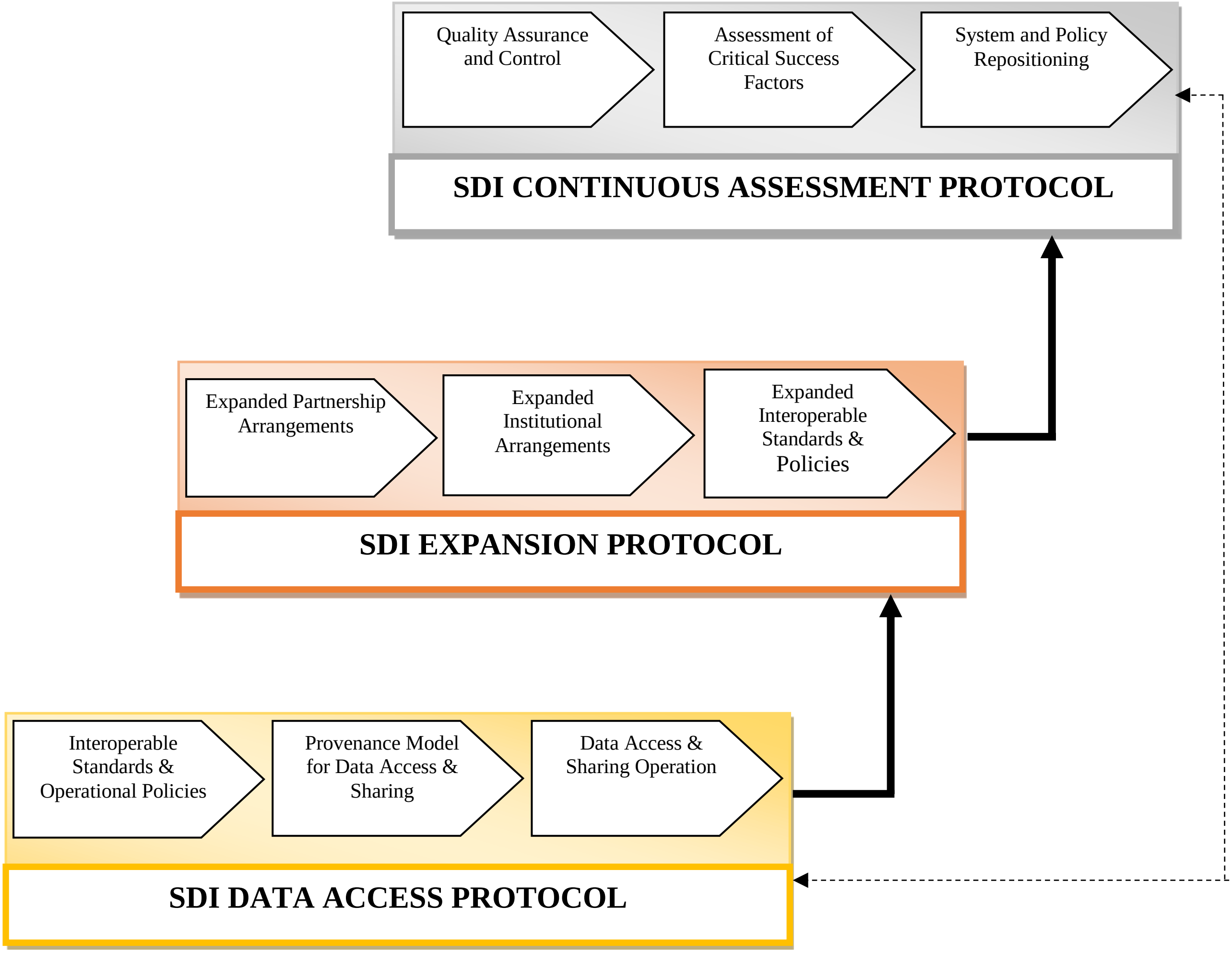



*Figure 8.3: SDI Augmentation Framework (SDI-AF)*

Figure 8.3 shows the revised SDI-AF framework to be presented for industry validation. We argue that one of the main problems in the advancement of SDI has been the emphasis on a centralised, top-down approach and that a scalable, bottom-up, distributed approach, which could progress alongside a top-down approach, would offer more opportunity to exploit available spatial data to the benefit of local economies. In developing countries like Nigeria, the implementation of a clearing house has shown to be problematic. Clearing houses are expensive to implement, require cooperation from many parties, and good underlying technical infrastructure across the regions covered. These aspects have been more problematic in Nigeria because of security in some areas, economic issues, lack of robust, reliable, pervasive underlying infrastructure and multi-level jurisdiction. Other developing countries suffer with similar problems. This framework addresses this need by developing a bottom-up data access protocol based on web services as an alternative to the centralised approach, to create a new type of SDI which can be built up gradually and be user-driven. That is, the framework matures from the SDI data access protocol into the expanded SDI in the SDI expansion protocol which then matures into the full blown SDI that is reviewed and updated bi-annually using the SDI continuous assessment protocol.

### 8.4.1 COMPONENTS OF THE SDI AUGMENTATION FRAMEWORK

This section describes the three major components of the SDI-AF: the SDI Data Access Protocol; the SDI Expansion Protocol; and the SDI Continuous Assessment Protocol.

#### 8.4.1.1 *SDI DATA ACCESS PROTOCOL*

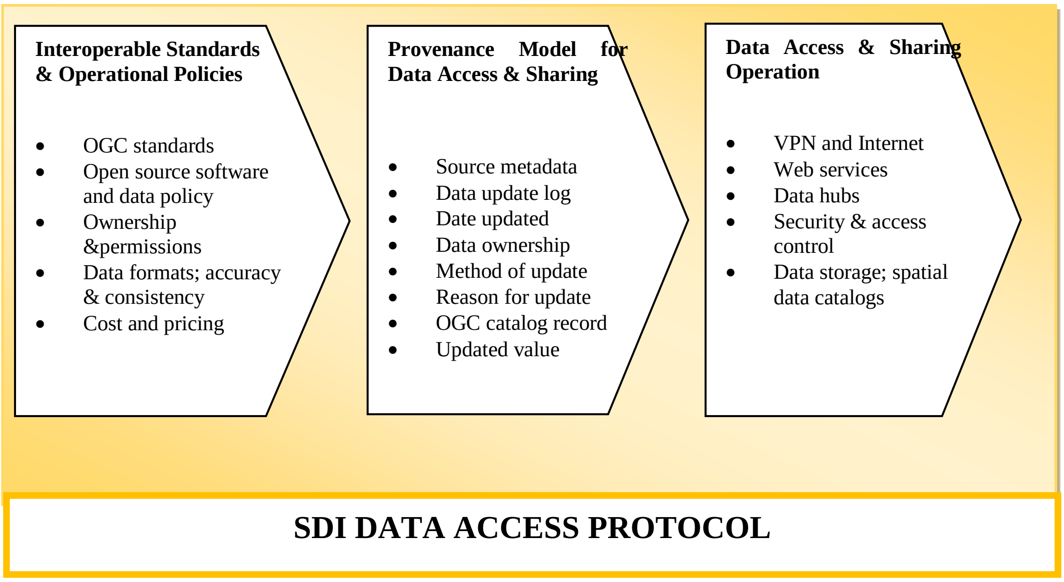



*Figure 8.4: SDI Data Access Protocol*

The framework is built on the basis of the data access protocol which is shown in Figure 8.4. It comprises three key areas:

Interoperable Standards and Operational Policies

Provenance Model for Data Access and Sharing

Data Access and Sharing Operation

*Interoperable Standards and Operational Policies*

The interoperable standards and operational policies are important to the seamless access and sharing of accurate, compatible, consistent and quality data. It also includes agreements for data ownership and permissions for access control. It utilises open source software and thus the open source policy. To support quality of data in a bottom–up approach, a provenance model has been included for data access and sharing in the data access protocol.

*Provenance Model for Data Access and Sharing*

The provenance method ensures the maintenance of an acceptable quality level in the distributed, scalable approach as it ensures information is provided about the provenance of the data set. This includes items such as its ownership, its history in terms of how it was derived and its update log hence it is different and more valuable than just having standard metadata records which is the current practice. Users can then decide how far to trust the data provided according to their application needs.

To support quality of data in a bottom–up approach, the provenance model has been included for data access and sharing in the data access protocol. The provenance model was included to help overcome the challenges of interoperability and resource integration often associated with the use of heterogeneous data (and data sources) and computing resources within distributed service oriented architectures like those utilised in this research. It was ultimately included so that users would have some idea on the quality of the data they were using and to enable good governance in that in any case of discrepancy or issues found at application level, traceability would be possible to find the source and correct it. If, when deciding whether to use a data set, the users are able to see a quality statement and also trace the source of the data and its creation steps, including the actors at each stage, they can be in a position to decide how much trust to put into the data set.

There are purported interoperability and compatibility challenges between provenance and workflow models. Di, Shao and Kang (2013) defined provenance capture for a webservice workflow environment using the ISO19115 and ISO19115-2 lineage model for provenance mapping and using LE_ProcessStep to map the process work flow and LE_Source to map the data elements of the provenance information. Figure 8.5 shows the Lineage Information Classes from the ISO19115 and ISO19115-2 standards.

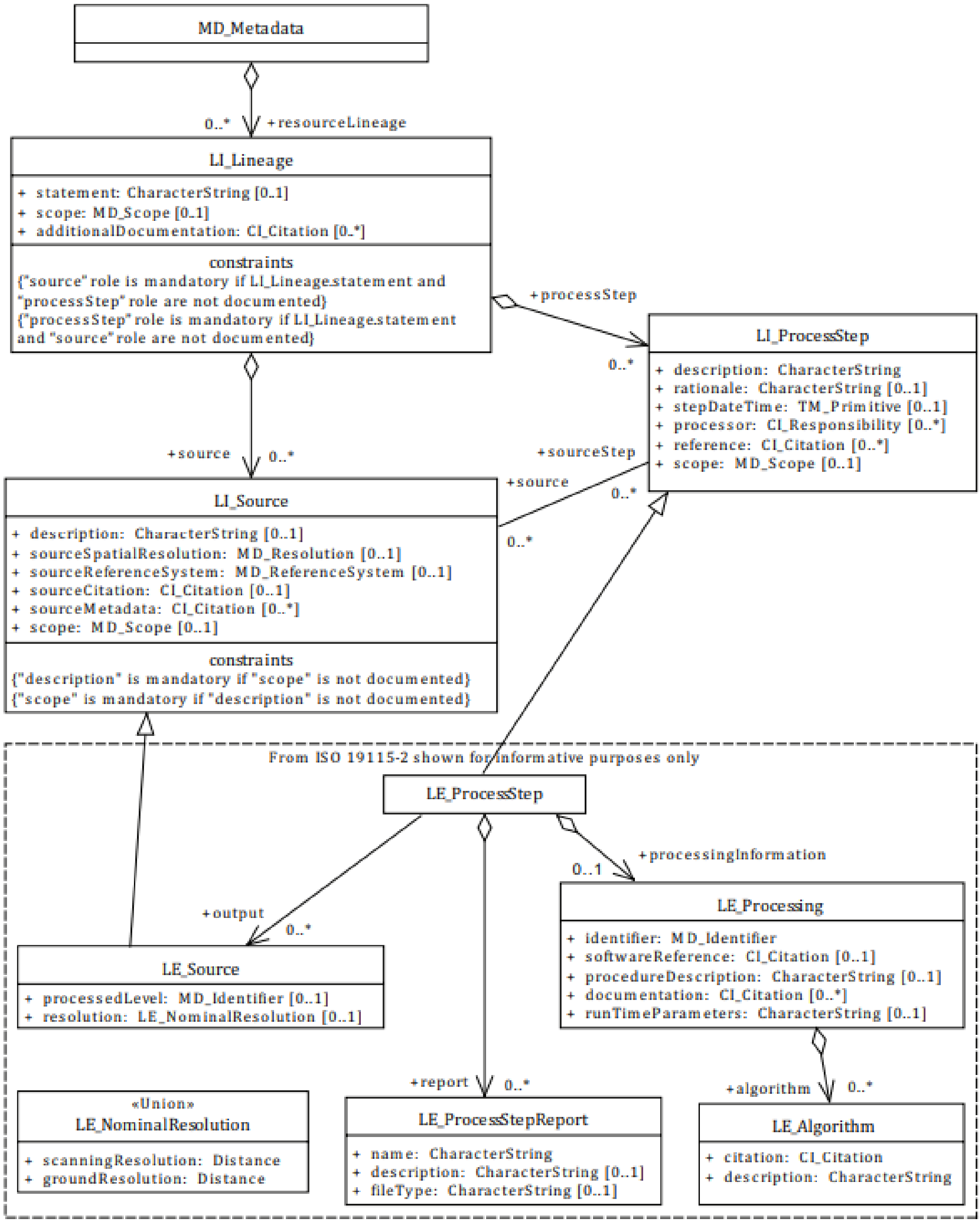



*Figure 8.5: Lineage information classes - ISO19115 and ISO19115-2*

Di, Shao and Kang (2013) addressed the inability to capture sufficient provenance information as previous models were limited to input and output parameters which provided limited provenance information. Though they emphasised the use of the LE_ProcessStep and the LE_Source, their proposed model relies solely on the ISO19115 Lineage model which cannot explicitly express service quality information within the LE_Processing and the LE_Algorithm classes. Feng (2013) however, proposed another provenance model from an integration of the Open Provenance Model (OPM) and ISO19115 (and ISO19115-2) Lineage model. Figure 8.6 presents the primitives and causal relations of the OPM.

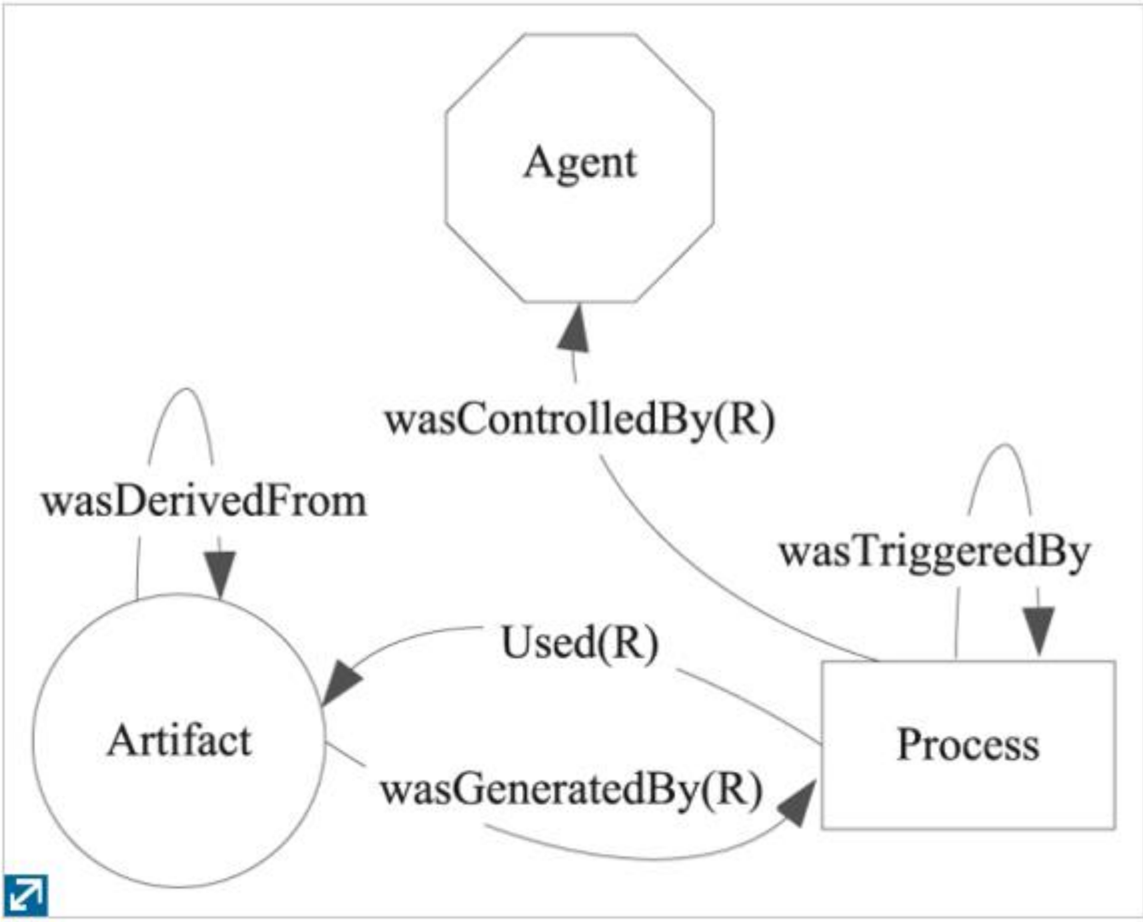



*Figure 8.6: OPM primitives and causal relations (Feng 2013)*

The three primitives of the OPM (Artifact, Process and Agent) and the corresponding five causal relations (used, derived by, triggered from, controlled by and generated by) were mapped to the elements of the LE_ProcessStep and LE_Source to establish a correspondence between OPM and the ISO GMD (Feng 2013). This however is limited in the level of granularity it provides for provenance capture in comparison to the WC3 PROV model which is purported to provide a more flexible and interoperable provenance model for provenance capture (Missier, Belhajjame and Cheney 2013). A more recent study by Closa et al. (2017) investigated the possibility of describing provenance at the three levels of granularity (dataset, feature and attribute level) and considered how this might be achieved in ISO19115 and W3C Prov (Closa et al. 2017). The W3C PROV model comprises of similar primitives like the OPM model referred to as classes and its causal relations referred to as property relationships. The causal relations of the W3C PROV provide more details than the OPM model especially as it relates to the activities surrounding the data or service. See Figure 8.7 below.

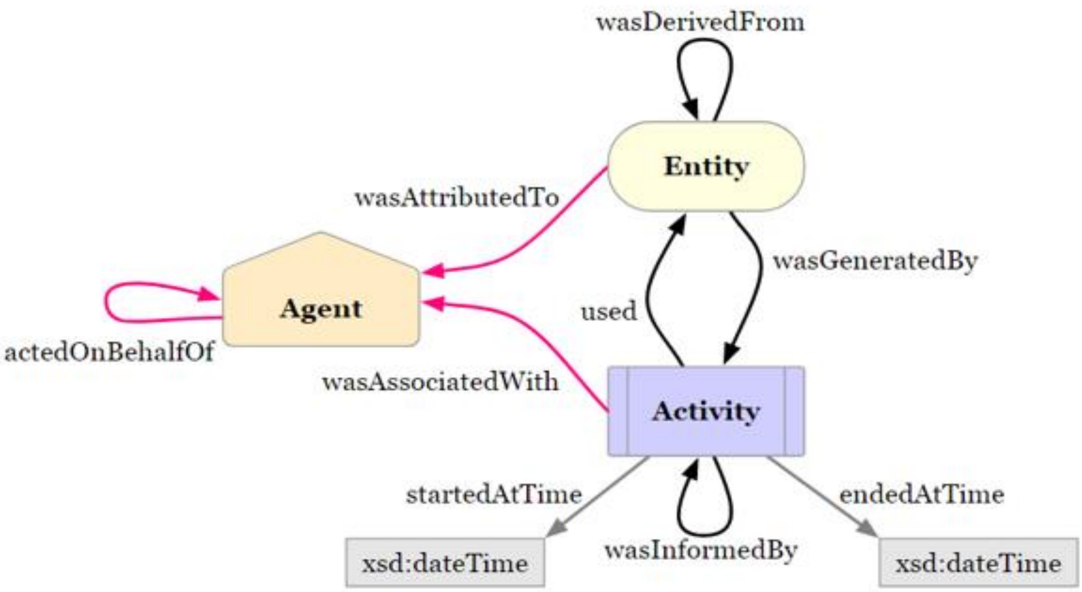



*Figure 8.7: Classes and the property relationships of the W3C PROV model (Lebo et al. 2013)*

Closa et al. (2017) however encountered challenges with adequately integrating feature and attribute granularity with the ISO19115 model without the need for modification of the Geographic Markup Language (GML) and the consumption of massive storage spaces due to verbosity. On the other hand, the authors found that feature and attribute granularity could be added without major changes to the PROV model. By adding two entity property types (*hadProperty* and *hadGeometry*), the PROV model was used to connect the feature level with the attribute level.

The OPM and W3C Prov models contain richer information with regard to relationships than the ISO19115 and were intended as improvements on it. They also avoid issues of referential and functional integrity that have been noted with the ISO19115 model (Jeffery and Asserson 2016). However as mentioned above there have been challenges in integrating richer models with ISO19115; a widely accepted standard.

In this research, the provenance model conforms to the ISO19115 standard for metadata, realised through the ISO19115 Lineage model with some adaptions. From the OPM model and W3C Prov model, it has adopted the idea of representing the Processor (Agent in OPM and W3C Prov) as a separate entity for improved referential and functional integrity (see Figure 8.10). Since a Processor is the person or party which may carry out more than one process step it is better to represent this actor as a separate entity rather than an attribute of Process Step record. In the following paragraphs the ISO19115 model and its relationship to the provenance model proposed (The SDI Data Access Protocol Provenance Model) is described.

Lineage describes the sources and production processes used in producing a resource. The recording of lineage or provenance overcomes issues with data ownership and quality. To incorporate provenance information in the OGC catalog entry it is necessary to refer to source metadata and its lineage information. The conceptual catalog entry proposed for the SDI Data Access Protocol is shown in Figure 8.8.

| Catalog Entry Id (M) | Source Metadata | Quality Statement | Lineage Record |
| --- | --- | --- | --- |

*Figure 8.8: Conceptual catalog structure for the SDI Data Access Protocol*

The catalog entry contains a number of components. Figure 8.9 shows the main descriptive components of the Source Metadata component according to the ISO19115 standard. Within the Source Metadata, the Description gives information about the source, the Citation provides standard bibliographical information, the Extent specifies the spatial and temporal coverage and the Source Step record specifies process steps used to create the source. In the provenance model proposed the Source Step information will not be included in the Source Metadata as the same information is included in the Lineage record. This decision is explained in more detail a few paragraphs on from here (following Figure 8.13).

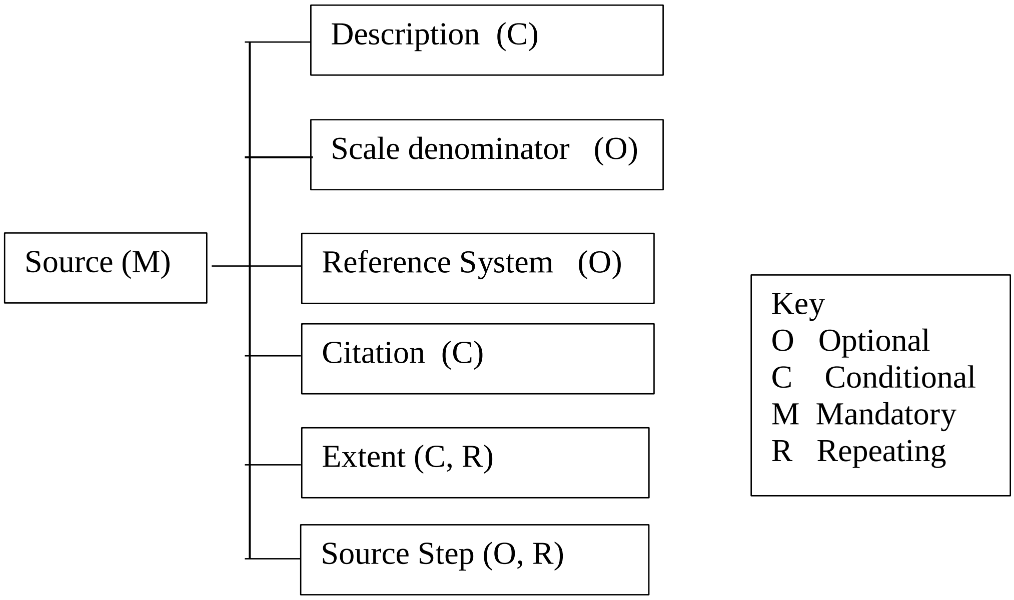



*Figure 8.9: Main components of Source metadata according to ISO19115*

Also included in the Catalog record is a Quality Statement and a Lineage Record. In the ISO19115 standard the Lineage model is part of the Data Quality package. Figure 8.10 shows the Data Quality package components. The Scope represents the extent of characteristics for which data quality information is reported. The Report is a statement of the quality of the resource specified by the Scope. The Lineage comprises information on the events and source data used to construct the dataset within the specified Scope. In ISO19115, Report and Lineage are conditional meaning that at least one of these must be mandatory.

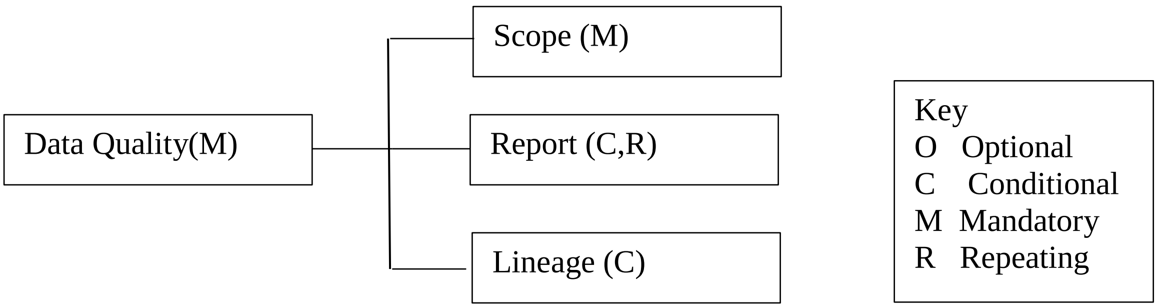



*Figure 8.10: Data Quality record of ISO19115*

In the catalog record (Figure 8.8) a Quality Statement is used instead of Report and a Lineage record is included which follows the structure of the ISO19115 Lineage record. The Quality Statement is not repeating unlike Report (in the ISO19115 Data Quality record) because it will only relate to the source described in the same catalog entry.

Figure 8.11 shows the Lineage record that may be associated with a Source. The Statement provides a general description of the Source lineage.  Each Process Step describes a stage in its creation. The Source instances within Lineage refer to other sources that may have been used in the Process Steps to create the Source to which the Lineage record refers. ISO19115 states that best practice is that there must be at least one occurrence of Statement or Source or Process Step. This is why all three are categorised as conditional.

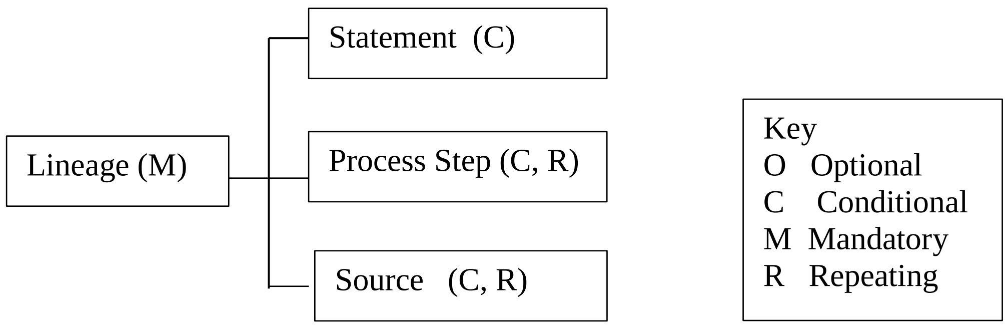



*Figure 8.11: Lineage record of ISO19115*

Figure 8.12 shows the breakdown of the Process Step record which is part of the Lineage record. The Processor refers to the responsible actor which carried out the process. The Source record refers to sources that were used in the process.

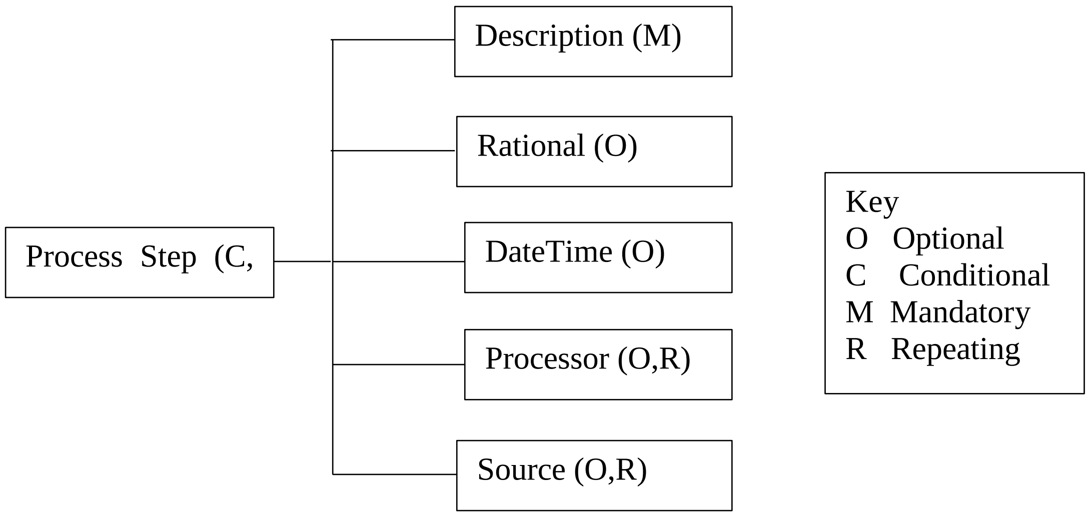



*Figure 8.12: Process Step record of ISO19115*

Conceptually and using ISO19115 terminology, the proposed provenance model (SDI Data Access Protocol Provenance Model) captured in the catalog can be seen as shown in Figure 8.13.

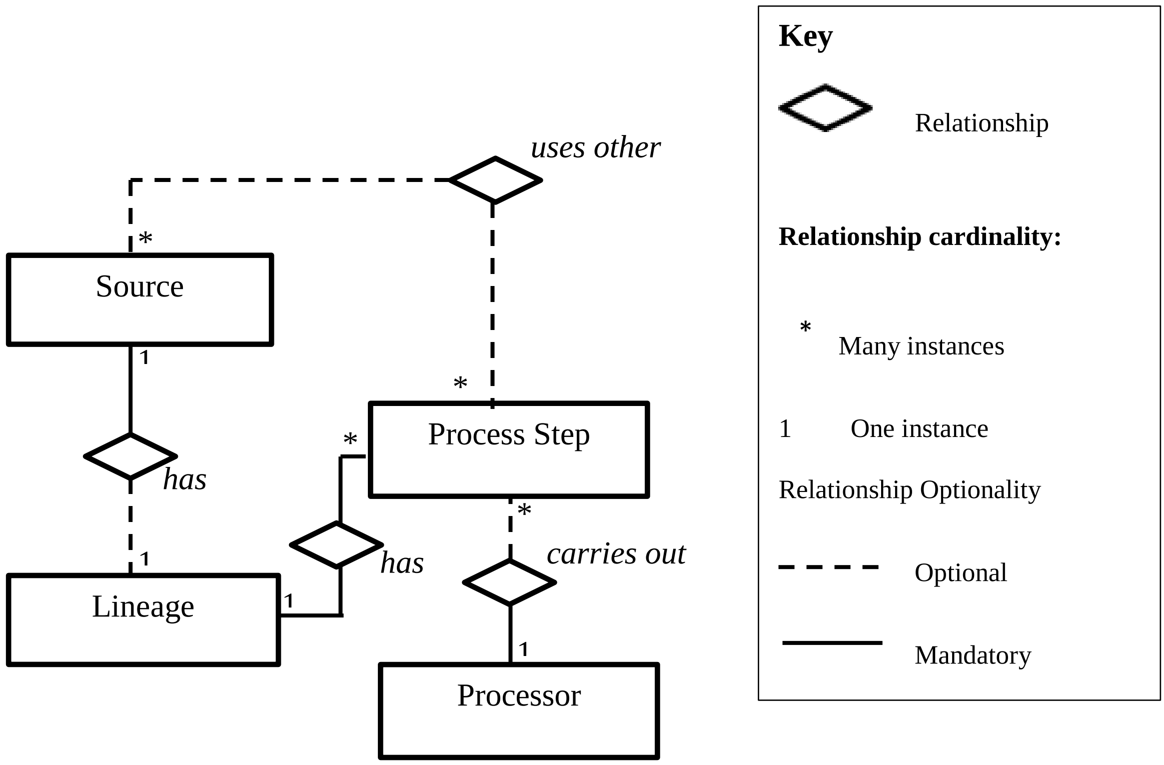



*Figure 8.13: High level conceptual view of provenance model of SDI Data Access Protocol*

Figure 8.13 shows that each source may have a Lineage record which will have at least one process step. Each process step belongs to a Lineage record and may use a number of sources. These sources are sources other than the source which owns the Lineage record to which the process step belongs. As seen in Figure 8.9, the Process Step record will hold information about the process itself (Description – what the process step was), the reason (Rationale – why the process step occurred), the date and time (when the process step occurred), the agent (Processor – who or what organisation performed or is responsible for the process step) and a reference to other sources used in the process step (Source – which other sources were used).

The ISO19115 Lineage model as presented in the standard has some issues. We see that there is a Lineage record that conditionally links Source to Process Steps. We see also that there Source record also has an optional link to a Source Step record which also represents process steps. Having both records representing the same information could lead to inconsistency without proper integrity checking. For this reason the Source Steps record is not included as part of the Source metadata record in the provenance model proposed. It is not necessary as the same information can be obtained through the Lineage record, thus removing possibility of inconsistency. In fact the ISO19115 standard has been criticised for lacking referential integrity and functional integrity if implemented in its basic form (Jeffery and Asserson 2016). This occurs because objects may have independent items as attributes that need but do not have an independent external representation. In the provenance model proposed (see Figures 8.8 and 8.13), referential and functional integrity would be maintained via appropriate organisation at implementation stage. For example, the Lineage record may have a number of Process Steps but each Process Step belongs to just one Lineage record and each Lineage record belongs to just one Source which belongs to just one Catalog entry. Suitable keys would be set up to maintain these functional links and through this referential and functional integrity can be maintained. Processor as an independent entity would need a unique identifier and would be implemented in a way that preserves referential integrity.

The provenance model shown in Figure 8.13 was developed as a result of considering the OPM, WC3-Prov and ISO19115 standards. The provenance model enables the recording of a provenance link to a previous catalog entry (or entries) from which the queried entry is derived. It assumes a catalog entry for each ancestor data set. The Processor (agent that carries out the update) is not shown in Figure 8.13 but would be a separate entity linked to the Update record such that, for each update, it can be clarified who was the responsible person or party. The Update record corresponds to a Process step record as given in ISO19115. The Update record also includes an Update Effect component where detail can be recorded on data items updated and their new values. This component corresponds to the idea in the Closa et al. (2017) research which investigated including feature and attribute granularity in provenance. This level of granularity does not appear in the OPM, W3C Prov and ISO19115 models and is made optional in the SDI Data Access Protocol Provenance Model since it may not always be practical to provide such detail and also could result in unwanted verbosity if made mandatory. The provenance model enables the recording of a provenance link to a previous catalog entry (or entries) from which the queried entry is derived. It assumes a catalog entry for each ancestor data set.

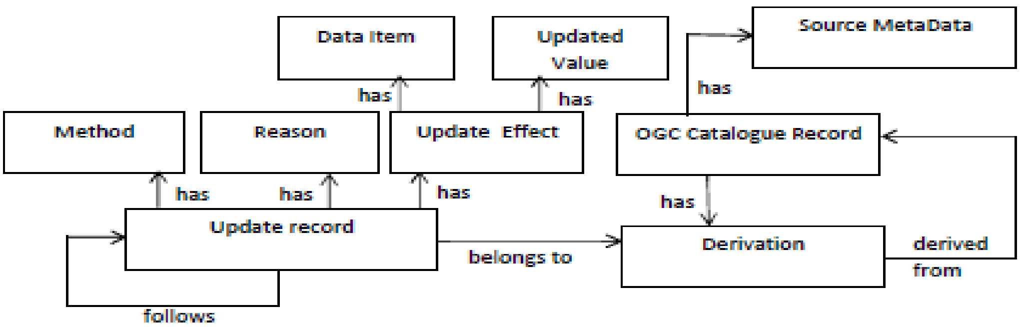



*Figure 8.14: SDI Data Access Protocol Provenance Model*

In this section, three provenance models OPM, W3Prov and ISO19115 have been discussed, as well as some other research that has investigated extending the models. A new provenance model has been proposed which follows ISO19115 but has some small adaptions to better support integrity and adds finer granularity. The conceptual basis of the four models is very similar in terms of what is represented. Table 8.2 provides a high-level mapping of concepts across the models and Table 8.3 maps the main components of the SDI Data Access Protocol Provenance Model with the ISO19115 standard.

*Table 8.2: High-level Concept Mapping of some Provenance Models*

| **Concept** | **ISO19115** | **OPM** | **W3C Prov** | **SDI Access Protocol (this research)** |
|---|---|---|---|---|
| Actor that manipulates the data | Processor | Agent | Agent | Processor |
| Data | Source | Artifact | Entity | Source |
| Manipulation of the data | Process Step | Process | Activity | Update record |

*Table 8.3: SDI Access Protocol Provenance Model*

| **SDI Access Protocol Provenance Model** | **ISO19115** |
|---|---|
| OGC Catalog Record | n/a (equivalent implied) |
| Source meta data | Source record |
| Derivation | Source record |
| Update record | Process Step record |
| Reason | Rationale |
| Method | Description (from Process Step record) |

*Data Access and Sharing Operation*

For the development of the data access and sharing operation, various software and components were coupled together to create a flexible web-based system to store, process and transfer spatial data to enable easy access and sharing, thus increasing the usability of the prototype to prospective users. The resulting system realises the data access protocol.

The data access protocol supports spatial data providers and consumers. Providers can choose to restrict access or make data publicly available through the possibility of assigning access controls to data sets. Consumers need to run client software such as Java Open Layers which allows display of linked geographical data sets. Providers need to run data base and web server software capable of handling spatial data. In the prototype, Geoserver was used with OGC standards WMS and WFS for the data sets.

The internet is assumed as the underlying connection but VPNs can be established for applications requiring increased security. A unique feature of the data access protocol is the addition of the provenance facility which can be used to enable consumers to see where the data comes from and its update history. Extra security can be implemented through access control.

#### 8.4.1.2 *SDI Expansion Protocol*

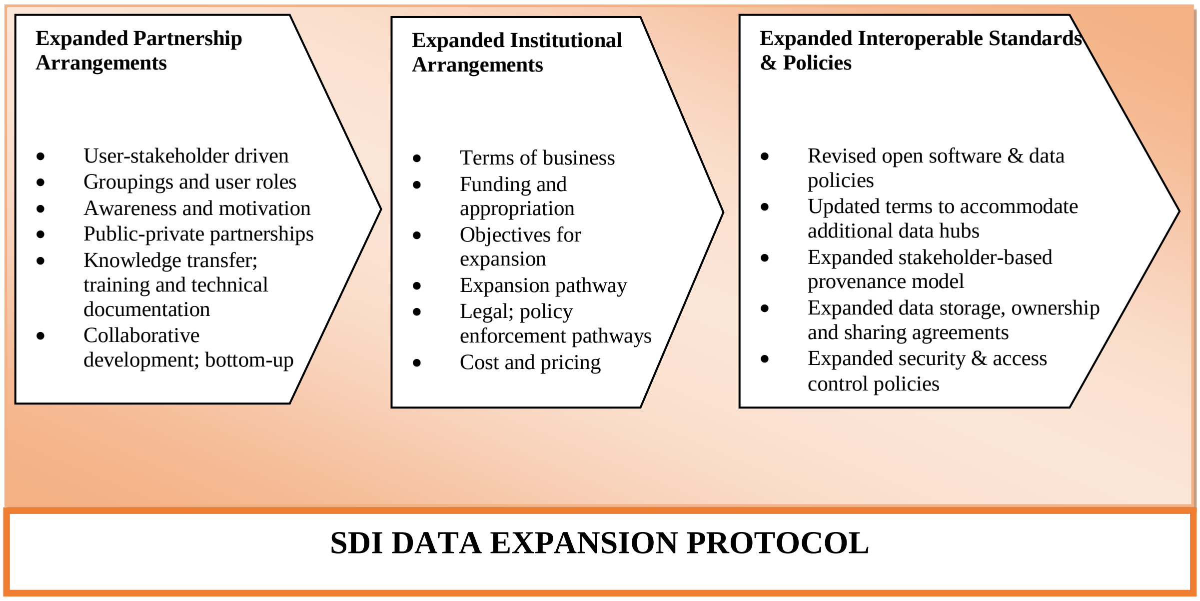



*Figure 8.15: SDI Expansion Protocol*

The SDI expansion protocol shown in Figure 8.15 is the second level of the framework. At this level it is assumed that the SDI data access protocol has been established with the data access operation, institutional arrangements and provenance model. At this level, the SDI expands to create a centralised "clearinghouse" through the establishment of partnerships and the collaborative networks. The collaborative partners create individual data access protocols which are then aligned to form a regional or national harvester.

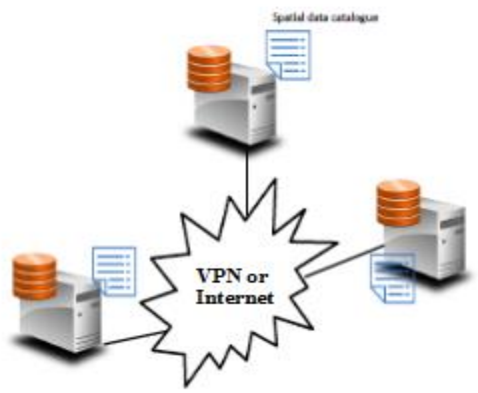



*Figure 8.16: Network Architecture of the Data Access Protocol Expansion*

A region sets up a server and runs the Data Access Protocol. An available harvesting service accesses all the servers in the network within a particular region to harvest the catalogs and thereby create a regional catalog that holds all the metadata for a region in one place. The architecture is shown in Figure 8.16. Additional services that the region might apply are data cleansing, enhanced quality checks and additional information provision. Additional services that could be applied at a national level are translation services between standards. This is addressed by the expanded institutional arrangements, as well as the expanded interoperable standards and policies.

#### 8.4.1.3 *SDI CONTINUOUS ASSESSMENT PROTOCOL*

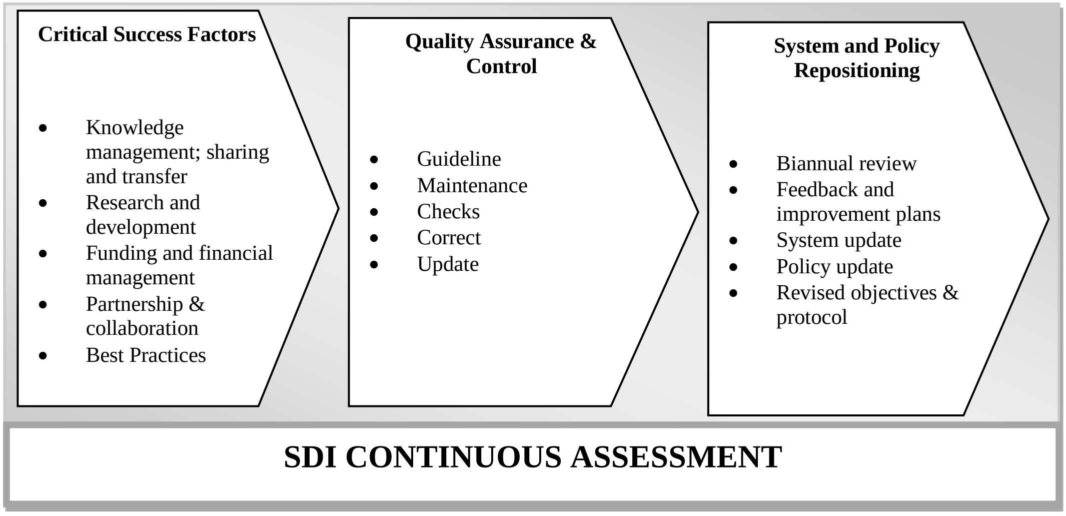



*Figure 8.17: SDI Continuous Assessment*

The SDI Continuous Assessment Protocol is the third and final level of the framework and is shown in Figure 8.17. It tackles the problem of infrastructural failure due to non-fulfilment of objectives, obsolete technology, outdated protocols, and the inability of the infrastructure to address prevailing challenges over time. It comprises of three key areas; Critical success factors, Quality assurance and control, and System policy and repositioning. The critical success factors were recommended to enable the framework to thrive. These factors have been defined from the assessed problems, and in their absence, the framework may not achieve effectiveness. Knowledge management is important to ensure steady sharing and transfer of best practices across all partners, and also to ensure the synergy of the people, process (SDI expansion protocol) and the technology (SDI Data Access Protocol). Research and development is also prioritised to ensure the system is up to date and sufficient to tackle current challenges. Funding and financial management is also highlighted as a critical success factor because the lack of funds, as the appropriation of available funds, has been highlighted as hindering the deployment of infrastructures globally. Quality assurance and control was included to ensure timely monitoring of processes to ensure quick fixes where necessary. And the system and policy repositioning is to ensure the comprehensive review and update of the entire system for optimum effectiveness.

### 8.4.2 The SDI-AF AS A DISTRIBUTED BOTTOM-UP SCALABLE ARCHITECTURE

The idea of having three levels to the SDI-AF is to enable a scalable, bottom-up approach to the development of the SDI. The infrastructure can be built up gradually, starting with small systems at the SDI Data Access Protocol level. The SDI Data Expansion Protocol will be developed gradually and finally when the system becomes large and widely used there will be need for stronger governance in the form of the SDI Continuous Assessment Protocol. One of the problems of the NGDI development has been the reliance on a central clearing house which can be a bottle neck to both development and operation. The development an architecture which is distributed allows smaller groups to set up open GIS systems for sharing data through the novel lightweight SDI data access protocol. More bases can add themselves gradually in a peer-to-peer fashion. While a centralised approach may be able to engender more trust through maintenance and control of the shared data, the distributed provenance model, which is part of the SDI data access protocol, can develop trust in a non-centralised way.

The use of the bottom-up approach to augment take-up of SDI does not preclude the top-down approach which national and regional bodies may wish to pursue. These latter can start at the level of the SDI Continuous Assessment Protocol to develop standards and regulations and then develop national or regional hubs which can be linked into eventually by the emerging user-developed GIS resources. Furthermore, the national or regional hubs can instigate harvesters to collect, check and clean as necessary data shared by the user-driven systems. The provenance model will provide information on the quality of the data sets harvested.

## 8.5 CHAPTER SUMMARY

This chapter presented the SDI-AF which is the main contribution of this research. The novelty is the scalable multi-level architecture. The SDI Data Access Protocol allows for easy data access and sharing enabling the SDI to be user-driven. The provenance model can aid in the development of trust and maintenance of data integrity. The SDI Data Expansion protocol allows the SDI to be built up gradually through small scale networks or hubs which can gradually combine to service either a centralised or distributed clearing house. The SDI Continuous Assessment is included to deliver overarching quality and policy review. Crucially the SDI can be built from bottom-up enabling early local operation and avoiding the current lack of progress due to issues identified in the EIA-SDI and NGDI-CF surveys.

# 9 CHAPTER NINE: FRAMEWORK VALIDATION

## 9.1 INTRODUCTION

This chapter details the validation of the SDI–AF developed form the synergy of the findings gathered in this research.

## 9.2 VALIDATION METHOD

The purposive non-probability sample design was adopted against the probability sample design to tailor the selection of the most useful respondents to address the final research objective which is "to evaluate the developed SDI framework". The inclusion criteria for the participants were their knowledge and hands-on experience with the emerging NGDI. Following the conduct of the EIA-SDI survey, the PPU evaluation and the NGDI-CF survey, the researcher was able to establish connections with key the members of the defunct NGDI committee (cited in section 2.4.2 of chapter 2) that were still active in academia, as well as in the geospatial information (GI) sector in Nigeria. The defunct NGDI committee was composed of two (2) representatives from NASRDA (the federal nodal agency), two (2) representatives from Universities selected in rotation within Nigeria, two (2) representatives from Poly/Monotechnics selected in rotation within Nigeria, six (6) state nodal agencies from the six geopolitical zones in Nigeria, four (4) private, inter-governmental and non-governmental agencies operating in the GI sector of Nigeria and eleven (11) federal ministries and agencies in Nigeria (Kufoniyi and Agbaje 2005). The agencies and institutions represented in the committee have staff sizes of between 1000 – 5000 active staff members. A more critical look at the composition of the committee reflects three distinct categories which are: the coordinating agencies (Federal and state nodal agencies), academia (Universities and Poly/Monotechnics) and partner agencies (private, inter-governmental and non-governmental agencies, federal ministries and agencies). The researcher was only able to establish contact with five (5) of the past committee members hence the small sample size. Most of the committee members have transitioned into other sectors or were unreachable.

The five (5) participants comprised of two (2) experts from the coordinating agencies group, two (2) experts from the academia group and one (1) expert from the partner agency group with some cases of overlaps as there are experts who are in academia that fall under two or more categories. The small sample size and its findings may not necessarily be generalizable in other settings but it is posited that the small sample size is a representative of the larger organisation they represent, and also provides the scope for gathering the lessons/experiences from the experts that were a part of implementing the failed NGDI. That is, the agencies and institutions represented by the participants have staff sizes of between 1000 – 5000 active staff members as stated above. The participants were representatives of these organisations like it was with the NGDI committee, and thus responded on behalf of these larger organisations. We argue that that there are no conflicts of interests because the interviewees are to comment on the SDI-AF put forward by the researcher and not the NGDI-CF they were a part of. To this end, the researcher further argues that they are in the best position to provide an informed judgement on the feasibility of implementing the SDI-AF in practice, in a way that it overcomes the failings of the NGDI; and eventually facilitate the implementation of an effective SDI in Nigeria and other countries.

The experts assessed the validity and feasibility of implementing the framework in practice providing comments on areas for improvement. The purpose was to confirm the presented framework as the preliminary framework and on validation, the final SDI–AF would be developed and thus concluding the research. Participants were be briefed via telephone. On consenting to participating in the study, the framework validation instrument was sent to them via email. The email contained the participant information and consent information, with details of the framework attached in a document tagged ‘Framework Validation Instrument’ (see Appendix VI). The document comprised of an introduction of the SDI-AF, the components of the SDI-AF and the validation questions. Semi-structured, open-ended questions were employed to enable experts comment on the fundamental components of the framework. This allowed experts to comment freely with little restrictions and to tailor their comments to the focus of this research. The industry experts responded to the validation questions and returned their responses via email. Further clarifications on their responses were done via follow-up emails and telephone conversations.

### 9.2.1 VALIDATION CRITERIA

Industry experts assessed the framework based on the following criteria;

- The feasibility and validity of the framework
- The validity of the proposed bottom-up approach for implementing SDIs, against the current top-down approach
- The sufficiency of the framework components and implementation path
- The clarity of the framework and implementation path to ascertain the feasibility of replication it in practice

The problem addressed in this research was the insufficiency of the NGDI to provide comprehensive spatial data access which meets the spatial data needs for environmental management (see Section 1.2.1). The SDI–AF was proposed to address the issues affecting the adoption of the NGDI and to enable better SDI implementation. To this end, the validation questions also included the framework's capability to contribute significantly to the following;

- Improving spatial data access over the web
- Hastening SDI implementation
- Overcoming the challenge of developing clearinghouses
- Harvesting economic and environmental benefits from spatial data and SDIs
- Amplifying the legislation and enforcement of a user-driven policy and objectives for SDI implementation
- Heightening awareness, as well as amplifying participation and partnership

## 9.3 ANALYSIS VALIDATION OUTCOMES

Table 9.1 presents the analysis of the validation outcomes. The data was analysed using content analysis. For the analysis of the findings, the results from the framework validation are assessed to show experts' corroboration of the frameworks capability to fulfil the assessed criteria and its overall aim of augmenting SDI adoption. The results were further assessed to highlight drawbacks and improvements suggested by the experts to improve the effectiveness of the framework and its feasibility to succeed in practice. The results of the analysis are presented below.

*Table 9.1: Analysis of validation outcomes*

| VALIDATION CRITERIA | CORROBORATION | DRAWBACKS AND SUGGESTED IMPROVEMENTS |
|---|---|---|
| 1. Feasibility and validity of the framework | • Implementation looks feasible<br>• Most suitable for Nigeria considering various challenges that has stopped the full implementation of the NGDI implementation<br>• Expected to improve access to data for majority of the users of the infrastructure.<br>• It has the key ingredients required to achieve its aim of building an effective SDI for Nigeria.<br>• Has the capacity to ingest data produced from different organisations into developing level 2 and 3; expansion and continuous assessment protocol | • Sensitisation and awareness of SDI procedures, applications and benefits to stakeholders is fundamental to its feasibility in practice<br>• Legislating mandated institutions and targeting them for sensitisation<br>• Will depend largely on internet access and penetration<br>• Assumes some level of existing technical capability thus capacity building is important to ensure clear understanding; Most users in developing countries lack clear understanding of what SDI is<br>• Recognising and adhering to the fundamental datasets for the nation is important<br>• Anticipated issues with 'accessing large data such as remote sensing and GIS datasets |

| | | | |
|---|---|---|---|
| 2. | Assessment of the proposed bottom-up approach advocated by this framework instead of the typical top-bottom approach | • The bottom-up approach is best for Nigeria<br>• It is more feasible for implementation<br>• It is better than the traditional top-down approach<br>• Takes more factors into consideration than the top-down approach<br>• Plausible to adopt<br>• The components of the proposed bottom-up approach guarantees data verification, completeness and consistency.<br>• The proposed approach should speed up the development process; Prospect of amplifying SDI development<br>• The user-driven and open source component of the bottom-up approach is an advantage and will ensure successful implementation<br>• Complete SDI development can evolve from the bottom through state government initiatives<br>• Sub nodes can start implementation with the understanding they will be added to the national network<br>• Well established hubs and nodes can be gradually integrated into a fully functional SDI with expanded mandates | • Regulation at national level would guide the process and ensure adherence to industry best practices<br>• Regulation is also important to ensure linkages of individual hubs and nodes |
| 3. | Thoughts on the ability of the provenance enabled, scalable, bottom-up distributed approach for SDI data access over a web would hasten SDI implementation as suggested by the framework | • Agree; the provenance enabled, scalable, bottom-up distributed approach for SDI data access over a web would hasten SDI implementation<br>• The provenance model is a good idea and it would encourage users to utilize validated data.<br>• It would improve data quality<br>• It would improve data accessibility<br>• It is fundamental to data discovery and sharing<br>• Provenance model should resolve data verification problems; Data can be verified<br>• It would reduce the cost of implementing SDIs | • Emphasise benefits and motivation for data providers to ensure willingness to participate.<br>• Important to expand metadata aspect so it is incorporated fully with the provenance model as the metadata aspect is somewhat silent.<br>• Requires preparation of fundamental datasets in many cases from analog to digital in Nigeria<br>• Requires adherence the right protocol as propagated in the framework<br>• The need for training and capacity building was also reiterated. |

| | | |
|---|---|---|
| 4. Possibility of developing a central NGDI clearinghouse from the development of individual hubs, its subsequent expansion and harmonisation over time | • Agreed that the development of individual hubs and its subsequent expansion can be harmonised organically over time to develop a central NGDI clearinghouse that would be readily accessible<br>• Framework overcomes the challenge of developing clearinghouses<br>• The Expansion and the Continuous Assessment Protocols (Levels 2 & 3) actually unbundled what the clearinghouse is expected to do | • Without an adequately regulated security and access control feature, the harmonisation of the different hubs would not lead to a clearinghouse but a huge data that needs the right personnel to manage with necessary tools for granting access to users<br>• A peer-to-peer approach between the hubs can be equally effective. |
| 5. The sufficiency and inclusiveness of the framework components | • Framework captures all aspects required for implementing the NGDI very well<br>• Framework components are sufficient and inclusive of the factors needed to augment SDI adoption | • Highlighted that the workability in actually performing the intended SDI functions is more important. That is the ability implementing body or nation to handle and synergise all framework components as its corresponding tasks during the implementation of the framework is fundamental |
| 6. Assessment of the clarity and replicability of the framework in practice | • The framework is clear to understand<br>• It is clear and easy to replicate in practice<br>• Workable for implementation in Nigeria<br>• Expressed confidence in the framework's ability to hasten and ensure SDI adoption<br>• Implementing this framework is a good step towards achieving a national SDI (NGDI)<br>• This is a nice and very useful research. I believe that your approach can achieve the desired result | • Implementation in Nigeria and other developing countries would involve adaption of the components and addition of other components as it fits the environment it is being adopted to |
| 7. Ability of framework to amplify the legislation and enforcement of a user-driven policy, as well as objectives for SDI implementation | • Definitely, implementing the proposed protocol will amplify the need for legislation.<br>• Framework would amplify legislation and enforcement of user-driven policy | • Unsure because it will depend on the policy framework, data standards like ISO, OGC and existing national standards, as well as political enforcement. These factors will play significant roles in the implementation |

| | | |
|---|---|---|
| 8. Ability of framework to heighten awareness, as well as amplify participation and partnership | • Agreed framework would increase awareness and participation<br>• It promotes faster penetration and participation among stakeholders<br>• Framework will fast-track awareness not only among GI practitioners but also among other user communities | • Proper publicity is needed<br>• Further reiterated the need for training and re-training (capacity building) to teach key stakeholders how to deploy it |
| 9. Ability of framework to provide economic and environmental benefits from spatial data and SDIs | • Agreed framework would provide economic and environmental benefits | • As long as there is awareness and demonstration of the benefits and capacity building to improve political will and funding |
| 10. Overall Assessment of the Framework | • Very good<br>• A well-defined framework for environmental reporting and regulation would support implementation in environmental management.<br>• The framework is clear to understand<br>• It ensures data accuracy and quality<br>• It takes the access to quality and verifiable data into consideration<br>• It ensures faster penetration amongst stakeholders at lower levels<br>• It is in line with SDI implementation<br>• Cost: It will reduce the cost of implementing SDI<br>• Feasible; bankable<br>• Worth giving a try<br>• Relies on smaller units thus simplifying implementation<br>• It captures the essence of what is being presented; valid | • Access to fast and affordable internet is important<br>• Suggested the rename of the 'SDI Expanded Protocol' to 'SDI Governance Protocol' to provide more emphasis to its governance role within the framework<br>• Assessment to include compare and contrast with the generic GSDI Architecture top down approach<br>• Additional feedback loops needed to connect the "System and Policy Repositioning" sub-block to the "Interoperable Standards and Operational Policies" sub-levels<br>• Emphasis and adjustment of VPN position in diagram showing network architecture of the Data Access Protocol<br>• Additional components would be discovered in practice and adjustments would be made<br>• Incorporate existing statistical data for the use with spatial analysis models for improved decision making<br>• Periodic user assessments to assess the practical validity and usability of the framework; will reveal whether or not to continue with proposed framework. Covered by the SDI Continuous assessment protocol at level 3 |

## 9.4 DISCUSSION OF VALIDATION OUTCOMES

### 9.4.1 FEASIBILITY AND VALIDITY OF THE FRAMEWORK

Industry experts corroborated the validity and feasibility of the framework, stating that it covers the fundamental components needed to overcome the current challenges obstructing the NGDI implementation to build an effective SDI for Nigeria. Overall, they expressed confidence in the framework's ability to achieve the aim of amplifying and enabling the full implementation of SDI.

*Transcript Excerpt 9.1*

*"The model is most suitable for Nigeria considering various challenges that has stopped the full implementation of the NGDI"– DrM*

*Transcript Excerpt 9.2*

*"Consequently, access to fast, affordable internet is pertinent. On the whole, the implementation of the framework looks feasible"- DrF*

The access and penetration of existing internet infrastructure was however highlighted as a significant factor that will determine its feasibility in practice. This is because Data Access Protocol which underpins the framework requires internet connection to enable communication between the data hubs as well as allow the access and sharing of data. As a result, it is expected that the majority of users of the infrastructure will have access to internet to access the data. Problems of poor power and internet supply have been documented to limit the successful implementation of infrastructures in developing countries like Nigeria (Mas'ud et al. 2015, Solomon, Opawole and Olusegun 2012, Apulu, Latham and Moreton 2011). This was also reiterated in the NGDI-CF evaluation (see Table 6.1 of Chapter 6) as one of the problems impeding spatial data access and use in Nigeria. Therefore, to limit the effect of this challenge, the Data Access Protocol which underpins the framework, was built using easily adoptable technology that requires minimal physical infrastructure. This was also tested and demonstrated during the PPU evaluation conducted in Nigeria to establish accessibility using the regular telecom network available in Nigeria (see Figure 5.15 of Chapter 5).

*Transcript Excerpt 9.3*

*"Clear understanding of what SDI is by users and providers which are in most developing countries the critical mass (quantity) of such personnel is non-existence" – DrA*

The need for improved awareness, training, re-training and capacity building was also highlighted. This is to ensure stakeholders and other participants have a clear understanding of an SDI and the benefits it offers (Agbaje et al. 2014, Tumba and Ahmad 2014). Regular sensitisation to demonstrate SDI benefits as well as the planned implementation procedures, detailing the short, medium and long term applications as propagated by the framework's expansion and continuous development protocol is anticipated to increase participation by both government and private sectors. This is important because the lack of participation and political will of government to support SDI adoption with legislative enforcements and funding has been documented as a major challenge in research (Okuku, Bregt and Grus 2014, Makanga and Smit 2010), and emphasised in the NGDI-CF evaluation (see Figure 6.13 of Chapter 6 and Table 8.1 of Chapter 8).

### 9.4.2 VALIDITY OF THE PROPOSED BOTTOM-UP APPROACH

The validity and effectiveness of the proposed bottom-up approach in comparison with the traditional top-down approach was also assessed. Industry experts noted their preference for the proposed bottom-up approach, stating that the approach was best for Nigeria, considering the current challenges.

*Transcript Excerpt 9.4*

*"Bottom-up approach usually takes more factors into consideration than top-down approach by relying on building blocks and that guarantees data verification, data completeness and data consistency. The approach is better than top-down" – DrF*

*Transcript Excerpt 9.5*

*"It seems plausible to adopt" – MrO*

They stressed that the ability of the approach to guarantee data quality through the provenance model as a unique selling point of the approach. Through the provenance model, available data is verified to ensure the access and use of complete, consistent and quality data for spatial operations. This is very important because the access to complete, consistent, compatible quality spatial data is a major gap that this research sought to address in see Section 2.3.1 and 2.6 of Chapter 2.

*Transcript Excerpt 9.6*

*"I like the aspect of making it user-driven and open source; this should speed up the development process"- DrFo*

The use of open source components and the employment of user-driven protocols by the bottom-up approach was also highlighted as an advantage. Increased stakeholder engagement will ensure successful implementation as the SDI can evolve effectively from the individual organisations, state government initiatives or established GIS Centres to a fully implemented and functional SDI (as demonstrated in Figure 8.3). Industry experts expressed the plausibility of adopting the advocated bottom-up approach but highlighted the importance of including a national level coordination to ensure the adherence to introduce and ensure best practices. This incorporates fully with the framework as the national coordinating body would oversee the synergy of the framework components, enforce the terms of the 'Interoperable Standards and Operational Policies' and monitor the integration of the participating hubs to prevent inconsistencies and incompatibility. This is very important to SDI research as the assurance of compatibility and interoperability is still a major challenge in practice (Visconti et al. 2013, Devillers et al. 2010).

*Transcript Excerpt 9.7*

*"The SDI at the national level mainly guides and leads using test beds and introducing best practice to States" – DrA*

### 9.4.3 VALIDITY OF THE PROVENANCE MODEL

As stated in Section 9.3 the validators stated that the inclusion of the provenance enabled, scalable, bottom-up distributed approach for SDI data access over a web would improve data quality.

*Transcript Excerpt 9.8*

*"Yes I think so. The provenance model is a good idea and it would encourage users to utilize the validated data."-DrFo*

It was corroborated that the inclusion of the 'Provenance Model for Data Access & Sharing' within the framework would resolve the critical problem of faced with accessing verifiable spatial data. It was also highlighted that the integration of smaller hubs instead of the traditional process of creating a large access networks or clearinghouses from the start will significantly reduce implementation costs (Rautenbach, Coetzee and Iwaniak 2013, Crompvoets et al. 2004).

*Transcript Excerpt 9.9*

*"One key issue to consider is verifiability of data, which is based on the validity of the methods applied in acquiring the data. The inclusion of the Provenance Model in the*

*framework should resolve this critical problem of data generated by organisations. The SDI Augmentation Framework as presented in the figure seems to take such critical issues into consideration." –Dr M*

It is fundamental to data discovery within the framework and it is anticipated to promote faster penetration amongst stakeholders at lower level for data access, sharing, and use. The experts unanimously agreed that the provenance-enabled, scalable, bottom-up distributed approach for SDI data access over a web to hasten SDI implementation. However, it was noted that the willingness of stakeholders, especially data providers to participate in the SDI is fundamental to its success and pace of success. They highlighted that the importance of integrating the provenance method with the metadata and metadata schema. Thus, the provenance model advocated in this research incorporates metadata schema of the fundamental datasets to ensure interoperable discovery, sharing and use of data.

### 9.4.4 OVERCOMING THE CHALLENGE OF DEVELOPING A CLEARINGHOUSE

Experts agreed that the development of individual hubs and its subsequent expansion can be harmonised organically over time to develop a central NGDI clearinghouse that would be readily accessible. It was stated that levels 2 and 3 of the SDI-AF unbundles the objectives of the clearinghouse and so would overcome the challenge currently of developing clearinghouses.

*Transcript Excerpt 9.10*

*"Not really a clearinghouse, but huge data that needs the right personnel to manage with necessary tool prior to granting access to users. With the clearinghouse there is security implication to be addressed as wrong information have legal and financial costs. In fact a national SDI (NGDI) should be treated as a critical secured agency of government noting that cybercrime is on the rise" – DrA*

It was however cautioned that the absence of an adequately regulated security and access control feature as well as the effective harmonisation of the different hubs would lead to the development of a huge database instead of a clearinghouse. Security and access control are fundamental requirements for clearinghouses (Cinquini et al. 2014, Maguire and Longley 2005). It was advocated that the framework implementation includes extensive security and access control features with the right personnel to regulate the access process for it to metamorphose into an ideal clearinghouse. Thus, with the right security and access control individual hubs like the Health Information System and the Land Information System in Nigeria (Agbaje et al. 2014) can start implementation with the understanding that they will be connected to national network of nodes. The need for extensive security is addressed by the protocol ‘Security and Access Control’ included in the ‘Data Access and Sharing Operation’ sub level presented in the SDI Data Access Protocol (see Figure 8.4) and the ‘Expanded Security and Access Control policies’ sub level presented in the SDI Expansion Protocol (see Figure 8.15). Though the ‘System and Policy Repositioning’ sub level of the ‘SDI Continuous Assessment’ includes a protocol for ‘Policy Update’ (see Figure 8.17), it will be updated to emphasise the need for consistent update of the security and access control in the final framework presented in Figure 9.1.

In addition, a peer-to-peer approach between the hubs was advocated. The peer-to-peer approach has been used successfully in cloud computing to enable decentralised communication between the hubs in the absence of a formal central system (Mayer et al. 2013). It enables all participating hubs to communicate with the main server, in this case the integrated database or clearinghouse, and also communicate among themselves with little or no reliance on a central system. The framework executes some protocols of the peer-to-peer approach by allowing collaboration between individual hubs but emphasises on the relevance of a central coordinating body to ensure the strict adherence to interoperable standards and best practices in developing countries like Nigeria.

*Transcript Excerpt 9.11*

*"Yes, I agree that it can. However, I also believe that a peer-to-peer approach between the hubs can be equally effective." -DrFo*

### 9.4.5 SUFFICIENCY OF THE FRAMEWORK COMPONENTS

Industry experts expressed confidence in the framework and its components. They asserted that the components included all aspects required for SDI adoption in Nigeria.

*Transcript Excerpt 9.12*

*"Generally speaking, the model captures all aspect and is workable for implementation in Nigeria. Figures 2, 6, & 8 capture the framework needed for the proposed model of SDI (NGDI) it very well" –Dr M*

*Transcript Excerpt 9.13*

*"Yes I do. I think the components, stages and links are just fine."-DrFo*

*Transcript Excerpt 9.14*

*"Sufficient, I can tell; but inclusive for augmenting SDI's adoption, I would say yes." – MrO*

Minor adjustments to the framework diagram were also suggested to improve the feasibility of implementing the framework in practice. A feedback loop was suggested to connect the 'System and Policy Repositioning' sub-level to the 'Interoperable Standards and Operational Policies' sub-level instead of the initial feedback look that connected the Data Access Control Protocol block to the Continuous Assessment Protocol block (see Figure 8.3). Also, a new name was suggested for the 'SDI Expansion Protocol' of the framework the 'SDI Governance Protocol'.

*Transcript Excerpt 9.15*

*"YES. However, I'm not comfortable with the use of the word 'Expanded' Protocol. I will suggest using 'SDI Governance Protocol'"-DrA*

Adjustments were also suggested within the 'Network Architecture of the Data Access protocol' in Figure 8.16, to accentuate VPN connection of the participating hubs. However, the current network architecture was retained.

### 9.4.6 CLARITY AND REPLICABILITY OF THE FRAMEWORK

Participants corroborated that the framework was clear and understandable to follow and replicate in practice.

*Transcript Excerpt 9.16*

*"The framework is clear and understandable" – Dr A*

*Transcript Excerpt 9.17*

*"This is a nice and very useful research. I believe that your approach can achieve the desired result" - Dr F*

The bottom-up approach builds up on the integration of smaller hubs. This simplifies the implementation process and thus was posited to significantly reduce the cost of implementation posited and increase users' participation in the implementation as well as increase the access and use of spatial data.

*Transcript Excerpt 9.18*

*"The fact that, it relies on the smaller units (State GIS Centres) will drastically reduce the cost of implementation as well as promotes faster penetration amongst stakeholders at lower level for both data sharing, accessibility and uses of the infrastructure when finally or fully implemented" - DrM*

The possibility of recalibrating the framework to suit different environments and contexts was highlighted. Though the framework was developed to augment SDI adoption globally, it was built around the problems and conditions obtainable in Nigeria. As a result, it is noted that a number of factors can be altered, removed or included to enable the effective adoption to the conditions of developing countries as well as the developed countries (Cinquini et al. 2014, Proctor, Powell and McMillen 2013). For instance, enormous capacity building would not be necessary in counties where there is already some awareness of SDI, its procedures and benefits. However, rigorous sensitisation, training and re-training would be required in cases where there is little or no knowledge of SDIs.

### 9.4.7 AMPLIFYING LEGISLATION AND POLICY ENFORCEMENT

Experts agreed that the SDI-AF would amplify the legislation and enforcement of a user-driven policy and objectives for SDI implementation.

*Transcript Excerpt 9.19*

*"Definitely, the approach will fast-track the awareness not only the GI practitioners but even amongst the user community. Many states of the Federation are at certain stage of the SDI development through GIS Centres" - Dr M.*

*Transcript Excerpt 9.20*

*"Definitely to implement the proposed protocol will amplify the need for legislation"– DrA*

However, one of the experts expressed uncertainties in the ability of the framework to amplify legislation and enforcement, urging that the existing policy framework, data standards, as well as the political enforcement available in each scenario, determines the feasibility of the SDI-AF to amplify legislation and enforcement.

*Transcript Excerpt 9.21*

*"Not really sure about that. Remember different policy framework, standard (e.g. ISO, OGC, existing national geodata standards, etc.) and political enforcement will play significant roles in NSDI implementation in various country at different governmental levels"* – MrO

These factors, policy, standard and people, as well as the access network and data are fundamental factors for SDI development (Grus et al. 2011, Rajabifard, Williamson and Feeney 2003). For the development of the SDI-AF, these fundamental factors were considered extensively and they formed the basis of the SDI-AF (see Section 8.2). Thus the SDI-AF addresses that uncertainty.

### 9.4.8 HEIGHTENING AWARENESS AND PARTICIPATION

Participants believe that the approach would fast-track awareness.

*Transcript Excerpt 9.22*

*"Definitely, the approach will fast-track the awareness not only the GI practitioners but even amongst the user community" – DrM*

The need for proper publicity, training and re-training was also highlighted as key factors that are needed to ensure this. In the SDI-AF presented in Figure 8.3, awareness and motivation as well as knowledge transfer with emphasis on training and the provision of technical documentation is only included the 'Expanded Partnership Arrangements' sub-level in the 'SDI Expansion Protocol'. There has been continued emphasis on the need for awareness and capacity building as critical factors that would ensure the success of the SDI-AF. Therefore to emphasise the importance of awareness and capacity building and to ensure participants are equipped with the right knowledge to implement the framework, awareness and capacity building have been included in all levels of the framework (see updated and final framework in Figure 9.1). This will bridge the existing knowledge gap in Nigeria (Agbaje et al. 2014) and improve the probability of the framework to succeed in practice.

### 9.4.9 PROVIDING ECONOMIC AND ENVIRONMENTAL BENEFITS

Participants established that the implementation of the SDI-AF would lead to the harvesting of economic and environmental benefits from spatial data and SDIs. Conditions were however highlighted to ensure the feasibility in practice. They include the need for effective monitoring from a regulatory body and sufficient awareness.

*Transcript Excerpt 9.23*

*"Yes, if implemented and monitored by some regulating body" –DrFo*

This is in line with the intentions of the SDI-AF, as it does not eliminate the need for a regulatory body, but puts forward better methods and procedures for SDI implementation and regulation. It was however noted that the revised framework presented in Figure 8.1, which was used for the validation did not show enough emphasis on the inclusion of the regulatory body and thus this aspect was added in the updated and final framework (see Figure 9.1).

The need for sufficient capacity building and awareness to demonstrate spatial data and SDI benefits to stakeholders, using live projects in user forums and sensitization campaigns is anticipated to maintain, as well as increase the participation and use of spatial data to support environmental analysis. Also, the increased collaboration would lead to the development of cost-effective processes of utilising spatial data for economic benefits.

### 9.4.10 REMARKS

In general, participants gave a positive validation of the SDI-AF. They affirmed that it was well designed and included the components needed to overcome the challenges that limit the implementation of the NGDI, in spite of its institution since 2003 (Idrees et al. 2012, Kufoniyi and Agbaje 2005, Nwilo and Osanwuta 2004). The clarity and feasibility of replicating the project in practice was also verified by industry experts. Drawbacks and suggested improvements were also highlighted. This informed the development and deployment of the updated and final framework presented in the following Section 9.4 below.

## 9.5 UPDATED AND FINAL FRAMEWORK

Following the assessment of the framework some minor recommendations were provided by the validators. These recommendations were further assessed and the recommendations that were within the scope of this research were included in the updated final framework presented in Figure 9.1 below.

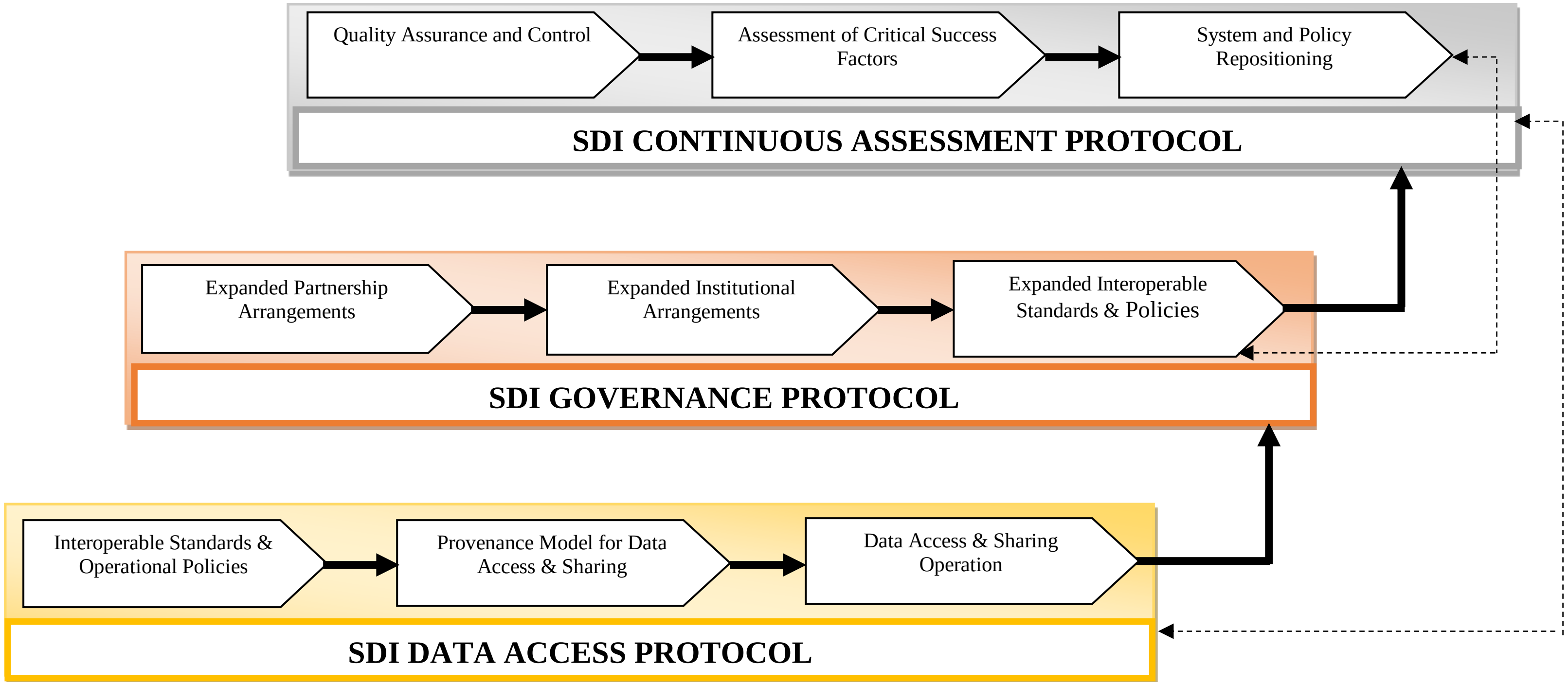



*Figure 9.1: Updated and final SDI Augmentation Framework*

Industry experts expressed no concerns with the representation of the framework as a maturity model and thus the framework representation was retained. As shown in Figure 9.1 above, the suggested name for the 'SDI Expansion Protocol' was adopted, hence it is now referred to as the 'SDI Governance Protocol'. It is the layer that binds the expansion process and it determines the successful adoption of the framework to develop a full blown SDI. Thus the 'SDI Governance Protocol' was assessed to effectively underscore the role of the second or middle layer of the framework than the previous 'SDI Expansion Protocol'. Also, additional feedback loops have been added to connect the 'System and Policy Repositioning' sub-layer and the 'Expanded Interoperable Standards & Policies' to ensure the strict adherence to industry best practices, and also to ensure a quicker incorporation of changes within the host environment. Additional connectors were added within the framework to emphasise the implementation path to improve the clarity of the framework for replication in practice.

As stated in Section 9.4.8, the need for sufficient awareness and consistent capacity building was reiterated by the industry experts during the validation to bridge the knowledge gap in developing countries and also adequately communicate the benefits of spatial data and SDI to stakeholders. To this end, the components of the updated and final framework have been updated to include awareness and capacity building at all levels of the framework. This improves on the components of the previous framework presented in Figure 8.1 which only included awareness and capacity building in the second level of the framework.

The need for effective regulation was also reiterated in the validation to enforce interoperable standards, best practices, as well as manage security and access control. Though the SDI-AF presented in Figure 8.3 hinted on the presence of regulation to establish and enforce 'Interoperable Standards and Policies', in the 'SDI Governance Protocol' (formerly 'SDI Expansion Protocol'), and the 'SDI Continuous Assessment Protocol', the presence of a central regulatory body was not sufficiently emphasised. To this end, the framework components have been updated to emphasise the role of the regulatory body. The framework components are presented in Figures 9.2, 9.3 and 9.4. The additional and updated framework components are highlighted for emphasis.

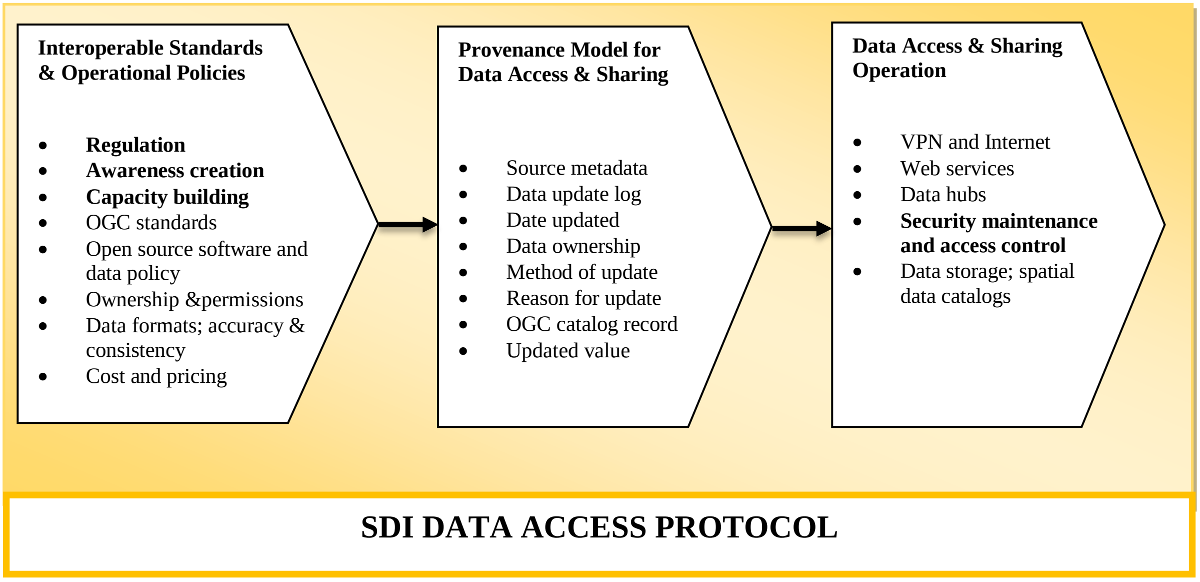



*Figure 9.2: Updated and final 'SDI Data Access Protocol'*

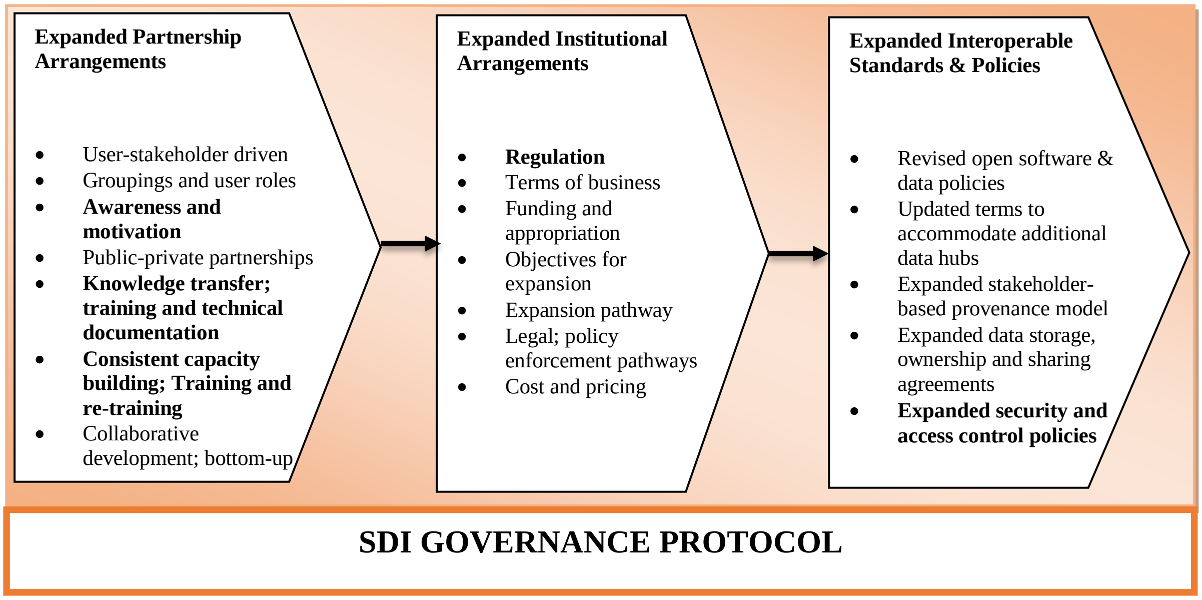



*Figure 9.3: Updated and Final 'SDI Governance Protocol'*

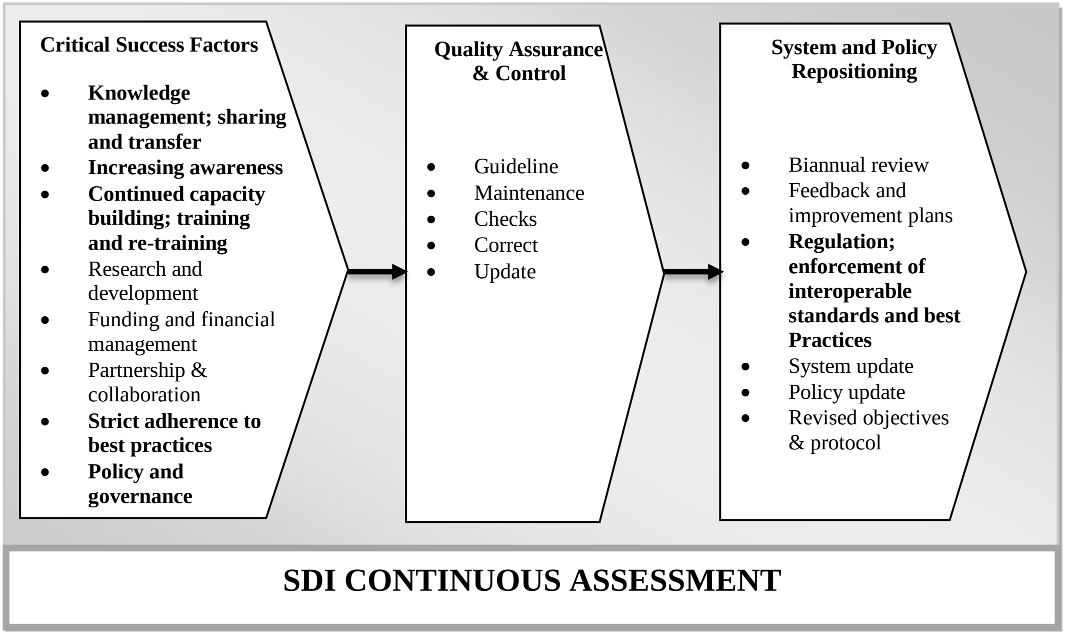



*Figure 9.4: Updated and final 'SDI Continuous Assessment Protocol'*

### 9.5.1 IMPLEMENTING THE SDI-AF

A number of factors have been highlighted and discussed in this research to have obstructed the successful implementation of the NGDI in Nigeria. To ensure the SDI-AF overcomes the failings of past implementation attempts, it was important to proffer specific guidelines that will ensure the successful implementation of the proposed SDI-AF. To define these guidelines, a SWOT analysis of the SDI-AF was conducted to identify the strengths, weaknesses, opportunities and threats of the proposed framework. This is anticipated to help overcome the political, economic, social and technological loopholes obstructing current NGDI implementation efforts.

**SWOT ANALYSIS OF PROPOSED FRAMEWORK**

A SWOT analysis of the proposed framework was conducted to highlight the fundamental strengths, weaknesses, opportunities and threats of the SDI-AF. This is important to emphasise the benefits of the bottom-up approaches purported in this research as well as map out was to overcome some of the weaknesses of this method as well as the threats to its successful implementation in practice. The swot analysis of the SDI-AF is presented in Table 9.2.

*Table 9.2: SWOT Analysis of SDI-AF*

| Swot factor | Assessment | Guidelines for SDI-AF Implementation |
|---|---|---|
| Strengths | • Benefits of the bottom-up approach<br>• Easily accessible free and open source software with available documentation.<br>• The provenance model for data quality updates.<br>• The SDI Augmentation framework. | • Deploy implementation protocols to follow the incremental process purported by the SDI Augmentation Framework maturity model. This will expedite SDI implementation. |
| Weakness | • Over-reliance on open source data and software.<br>• Technological capacity of stakeholders and their willingness to unlearn old methods of implementing spatial data services.<br>• Possible hurdle in policy enactment and enforcement to support new technology and method.<br>• Possible challenges with establish effective stakeholder partnerships.<br>• Potential financial constraints.<br>• Economic viability. | • Invest in awareness and capacity development programs.<br>• Implementation to include the training and retraining of stakeholders and users in user-centred knowledge management protocols.<br>• Secure government and stakeholder commitment.<br>• Implementation process to encourage massive investments in IT to contribute to the maintenance of open source software.<br>• Adoption of the provenance model to maintain data quality of open source data.<br>• Retain valuable aspects of the top-down approach to drive policy development and implementation.<br>• To emphasise increased funding and management of funds.<br>• Include cost benefit analysis to ensure return on investment. |
| Opportunities | • Partnerships arrangements.<br>• Definition of an inclusive and enforceable NGDI policy.<br>• Deployment of small scale SDI using free and open source software together with the purported distributed bottom-up approach.<br>• Advancement of provenance documentation.<br>• Financial opportunities and revenue generation from SDI and SDI services.<br>• Prospects utilising SDI products and services to facilitate administrative, planning and developmental activities within government and private sector. | • Implementation should prioritise stakeholder partnership arrangements.<br>• Harness existing structure, policies and stakeholder networks.<br>• Exploit the financial benefits of SDI products and SDI services for both government and private sector.<br>• Distribute responsibilities and outsource where necessary.<br>• Ensure continuous research and development. |
| Threats | • Security issues; privacy and data protection.<br>• Data ownership and management issues | • Policy should include a comprehensive data ownership and management plan.<br>• Implementation to include sufficient |

| | | |
|---|---|---|
| | • Epileptic power and internet services.<br>• Weak government policies and enforcements<br>• Difficulties of securing top-down support when trying to merge into a large SDI<br>• Poor partnership arrangement. | user-data protection and access control.<br>• Concerted efforts need to be made by government to foster public and private partnerships that will be geared towards improving power and internet services in Nigeria.<br>• Ensure LGAs and grassroots involvement. |

In the SWOT analysis presented in Table 9.2 above, possible solutions to overcoming the identified threats and weaknesses were presented. The SWOT analysis also included measures that will help harness the strengths as well as the opportunities the SDI-AF offers. These measures are presented as 'Guidelines for SDI-AF implementation' in Table 9.2 above. If followed, it is anticipated that the implementation of the SDI-AF will be successful and it will overcome the failings of previous implementation attempt.

## 9.6 HYPOTHESES TESTING

Following the review of literatures and the establishment of the research gap in Chapter 2 of this research (see Section 2.6), five hypotheses was formulated in to guide the research and demonstrate its validity. This section assesses the hypotheses to test for the plausibility and accuracy of the arguments put forward in the hypotheses using confirmatory evidences from the field data collected. The hypotheses postulated that:

- ***$H_1$***: *The NGDI is insufficient to support the geospatial data needs for Nigeria*
- ***$H_2$****An adequately updated NGDI will have significant influence on the way EIA is being carried out in the Nigerian oil and gas sector.*
- ***$H_3$:*** *The Data Access Protocol is an effective demonstration of accessing SDI data*
- ***$H_4$:*** *The Data Access Protocol addresses the challenges of accessing NGDI data*

- ***$H_5$*: *The SDI-AF, which includes the SDI data access protocol, the SDI governance protocol and SDI Critical Assessment Protocol, is sufficient to augment SDI adoption.***

As hypothesized in ***$H_1$***, the evidences from the data collected from the EIA-SDI survey (see question 24 in Appendix I) and the NGDI-CF evaluation (see Question 8 of Appendix II) supported the proposition that the NGDI is insufficient to support the geospatial data needs for Nigeria. This was affirmed by 90.8% of the respondents in the EIA-SDI case and 79.16% of the respondents in the NGDI-CF case (58.33 strongly agreed and 20.83 agree) presented in Figures 4.23 and 6.12 respectively. Evidence from the correlation analysis presented in Table 6.7 suggests that the insufficiency of the NGDI is influenced by the absence of a clear protocol for data access and sharing. ***$H_1$***, showed a strong negative association ($p<0.01$) with the argument that there is a clear protocol to access data through the NGDI. It however showed a strong positive ($p<0.01$) association with the argument that unclear protocol for data sharing limited implementation of SDI partnerships. These evidences support the hypothesis and suggest that the provision of a protocol for data access and sharing within the NGDI would improve its sufficiency to support geospatial data needs in Nigeria.

***$H_2$***is supported by the EIA-SDI survey results (see section 4.3.1.2). A large majority (78.5%) of EIA preparers disagreed with the notion that an adequately updated NGDI will have no significant influence on the way EIA is being carried out, therefore supporting the hypothesis that an adequately updated NGDI will have significant influence on the way EIA is being carried out in the Nigerian oil and gas sector. The support of this hypothesis validates the research question of how *a scalable and sustainable SDI can be developed which overcomes failings of the NGDI project* and the research aim *to develop a new SDI conformant GIS framework that will improve interoperable spatial data access.*

***$H_3$***and ***$H_4$***aresupported with evidences from the PPU evaluation. All participants affirmed the arguments propagated by both ***$H_3$*** and ***$H_4$***. 79.17% affirmed that the prototype was a 'very effective' demonstration of accessing spatial data from an SDI while the remaining 20.83% affirmed it was 'effective' (see Figure 5.20and Question 2 in Appendix III), thus supporting the assertion put forward by ***$H_3$***. 70.83% of the participants 'strongly agreed' with the assertion provided by ***$H_4$***that the development of the prototype addresses the concerns of accessing NGDI data while the remaining 29.17% 'agreed' (see Figure 5.29 and Question 10 in appendix III). ***$H_3$*** and ***$H_4$*** showed a medium positive correlation ($p<0.05$) with the clarity of the prototype evaluation tasks suggesting that participants had sufficient understanding of the prototype to affirm these arguments (see Table 5.4). Also, the assertion of ***$H_3$*** showed a strong positive correlation ($p<0.01$) with the user satisfaction with the prototype, this suggesting that their view of *the data access protocol as an effective demonstration of accessing SDI data* influences their rate of satisfaction with the prototype in which 58.33% of the participants were "very satisfied" while the remaining 37.50% were "satisfied" (see Figure 5.27).

***$H_5$*** was assessed using the qualitative evidence provided by the framework validation reported in Chapter 9 of this thesis. In most research, it is considered that hypothesis should be examined and proven using quantitative statistical methods. However, some researchers have argued that evidences from qualitative assessments can indicate support for a hypothesis, redefine theories or aid the development of new theories, notwithstanding the lack of typical scientific proof (Kansou and Bredeweg 2014, Bendassolli 2013). In this case, the researcher assessed ***$H_5$*** qualitatively by assessing the answers to questions 4 and 6of the framework validation (see Appendix VI). From the results of the framework validation assessed in Chapter 9, participants affirmed that the SDI-AF is sufficient, and inclusive of the components (SDI Data Access Protocol, the SDI Governance Protocol and SDI Critical Assessment Protocol) necessary for augmenting SDI adoption (see Section 9.4.5 and Transcript Excerpts 9.12, 9.13 and 9.14). This was also supported by participants' affirmation that the SDI Data Access Protocol, which is the underpinning component of the SDI-AF would hasten SDI implementation as suggested by the framework (see section 9.4.3 and Transcript Excerpt 9.8). Therefore, the researcher considers $\boldsymbol{H_5}$ supported by this investigation.

## 9.7 CHAPTER SUMMARY

This chapter presented an analysis of the SDI-AF validation provided by industry experts. The results of the validation were assessed and the findings synthesised to develop the updated and final SDI-AF presented in Figure 9.1 above. The chapter also presented the results of the hypotheses testing.

# 10 CHAPTER TEN: CONCLUSION

## 10.1 INTRODUCTION

This chapter concludes the research by highlighting the findings and knowledge gained from the research. It clearly explains how each research objective was addressed. It also highlights the limitations to this study and elucidates the recommendations posited.

This research aimed to develop a new SDI conformant GIS framework that would improve interoperable spatial data access. The study sought to address the insufficiency of the current NGDI to support geospatial data needs for environmental analysis using the EIA case in Nigeria. It investigated the possibility of developing a scalable and sustainable SDI which overcomes failings of the current NGDI project in Nigeria. To this end, a number of research questions and objectives were defined. Section 10.2 presents the assessment of research questions, aims and objectives to ascertain that they have all be adequately addressed.

## 10.2 ASSESSMENT OF RESEARCH QUESTIONS, AIM AND OBJECTIVES

The research set out to answer the question below;

*How can a scalable and sustainable SDI be developed which overcomes failings of the NGDI project?*

Four sub-questions were however created to adequately answer the main research question. They include;

i. *What are the current problems hindering the use of spatial data for environmental analysis?*

ii. *How do the challenges experienced with spatial data use affect environmental management in Nigeria?*

iii. *What is the state of the emerging Nigerian SDI and how does it benefit environmental management?*

iv. *What are the barriers to maximizing SDI adoption to support environmental management in Nigeria?*

The research aim and objectives (see Section 1.2.3) were thus defined to answer the research questions. An overview of the individual research questions and the objectives used to address it are presented below.

### 10.2.1 SPATIAL DATA USE FOR ENVIRONMENTAL ANALYSIS

To answer sub-question i. of *current problems hindering the use of spatial data for environmental analysis*, objective 1 was addressed (see Section 1.2.3). Existing theories and practices on the application of spatial data, GIS and SDI for environmental management were reviewed in the literature. The current problems hindering spatial data use for environmental management (see Section 2.3.1) were identified and the prospect of data standardization using SDI was introduced.

### 10.2.2 ENVIRONMENTAL MANAGEMENT IN NIGERIA

To identify the effect of the challenges experienced with spatial data on environmental management in Nigeria (sub-question ii), objective 2 was pursued and the use of spatial data for EIA in Nigeria and the sufficiency of the NGDI was investigated through literature and the EIA-SDI survey. EIA is the foremost environmental management tool in Nigeria which relies on the access to accurate spatial data to assess, predict and monitor environmental impacts hence it was selected as the tool of choice. To this end, EIA-SDI case was deployed.

### 10.2.3 STATE OF THE EMERGING NGDI

Part of objective 2 was to ascertain the sufficiency of the NGDI to support geospatial needs. This was achieved using the EIA-SDI survey which gave a good picture on the state of the emerging Nigerian SDI and how it benefits environmental management. Literature review was also used to answer research sub-question ii which concerned the state of the emerging Nigerian SDI and how it benefits environmental management

### 10.2.4 BARRIERS TO SDI ADOPTION IN NIGERIA

Objective 3 was followed to ascertain the critical success factors as well as barriers which affect the successful implementation of an SDI. The objective was satisfied by the results of the EIA-SDI and NGDI-CF surveys, thus answering research sub-question iv.

### 10.2.5 SCALABLE AND SUSTAINABLE SDI

The main question answered in this research was to investigate the possibility of developing a scalable and sustainable SDI which overcomes failings of the current NGDI project in Nigeria. Answering this question fulfils the research aim which is to develop a new SDI conformant GIS framework that will improve interoperable spatial data access.

Towards fulfilling the research aim, objective 4 was to develop a novel data access protocol that encourages and improves spatial data access and sharing and overcomes identified barriers. The protocol was demonstrated and evaluated using the PPU to fulfil objective 5 of this research.

The findings of the EAI-SDI, PPU and the NGDI-|CF evaluations were synergised and a new SDI Augmentation Framework (SDI-AF) was developed to fulfil objectives6 and 7. The framework provides a platform within which the novel SDI Data Access Protocol can flourish and be sustained. The SDI-AF was validated by industry experts to fulfil Objective 7. The updated and final SDI-AF is presented in Section 9.5.

## 10.3 FUTURE WORK

Future research work should be directed to deploying the SDI-AF in practice from level 1 to 3 (SDI data access protocol, SDI governance protocol and the SDI continuous assessment protocol) to develop a full blown SDI. In Nigeria for instance, efforts could be directed at integrating existing Health Information System and Land Information System hubs, as well as the GIS centres existing in some of the states within Nigeria to create a clearinghouse. The scope of this research did not enable further experimentation on the framework. However, a number of critical factors were recommended to enable seamless implementation in practice (See section 9.5.2).

## 10.4 CHAPTER SUMMARY

This research sufficiently answered the research questions and fulfilled the research aim and objectives defined in this study. The research concludes with the contribution of two novel developments to benefit SDI adoption globally. It contributed a novel SDI Data Access Protocol as well as the new SDI Augmentation Framework. Both contributions were adequately validated with the suggested improvements incorporated and presented in this research.

# 11 REFERENCES

Abraham, R., Aier, S., and Winter, R. (2014) 'Fail Early, Fail often: Towards Coherent Feedback Loops in Design Science Research Evaluation'

Aderoju, O. M., Dias, A. G., and Guimarães, R. (2016) 'Geospatial Technology as a Tool in Municipal Solid Waste Management and Monitoring in Nigeria.'. *Journal of Solid Waste Technology & Management* 42 (1)

Adesola, O. A., Adesodun, A. I., and Adekola, D. R. (2014) 'Impact of Oil Revenue on Economic Development in Nigeria [1981–2012]'. *Journal of Social and Development Sciences* 5 (2), 73-78

Agbaje, G. I., Ingersoil, M., and Mochamuk, J. (eds.) (2008) *GSDI-10 Conference, Trinidad*. 'National Geospatial Data Infrastructure (NGDI): An Enabler for Socio-Economic Improvement in Nigeria'

Agbaje, G. I., Akinyede, J., United Nations. Economic and Social Council, and United Nations. Economic Commission for Africa (2005) 'NGDI Development in Nigeria: Policy Issues on Information Access and Information Dissemination'. *COI-IV United Nations Economic for Africa, Geo-Information Subcommittee, Addis Ababa*

Agbaje, G., Azeez, A., Oyediran, K. A., and Stewart, J. (2014) 'Holding a National Summit to Improve Health Outcomes through Health and Mapping Sector Collaboration in the Development of National Geospatial Data Infrastructure: The Nigerian Strategy'. *Journal of Health Informatics in Developing Countries* 8 (1)

Aghedo, I. and Osumah, O. (2014) 'Insurgency in Nigeria: A Comparative Study of Niger Delta and Boko Haram Uprisings'. *Journal of Asian and African Studies*, 0021909614520726

Agunbiade, M. E., Rajabifard, A., and Bennett, R. (2014) 'Inter-Agency Land Administration in Australia: What Scope for Integrating Policies, Processes and Data Infrastructures for Housing Production?'. *Journal of Spatial Science* 59 (1), 121-136

Ahmad, A., Javaid, U., Javed, M. A., Ahmad, S. R., Jaffri, M. A., and Ashfaq, M. (2016) 'Landfill Sites Identification using GIS and Multi-Criteria Method: A Case Study of Intermediate City of Punjab, Pakistan'. *Journal of Geographic Information System* 8 (01), 40

Aji, A., Wang, F., Vo, H., Lee, R., Liu, Q., Zhang, X., and Saltz, J. (2013) 'Hadoop GIS: A High Performance Spatial Data Warehousing System Over Mapreduce'. *Proceedings of the VLDB Endowment* 6 (11), 1009-1020

Ajmi, M., Hamza, M., Labiadh, M., Yermani, M., Khatra, N. B., Al-Thubaiti, A., Moharrem, I., and El Arrim, A. (2014) 'Setting Up a Spatial Data Infrastructure (SDI) for the ROSELT/OSS Network'. *Journal of Geographic Information System* 6 (2), 150

Akinwale, Y. O. and Akinbami, J. K. (2016) 'Economic Evaluation of Nigerian Marginal Oil and Gas Field using Financial Simulation Analysis'. *International Journal of Energy Economics and Policy* 6 (3)

Akpan, N. S. and Akpabio, E. M. (2003) 'Youth Restiveness and Violence in the Niger Delta Region of Nigeria: Implications and Suggested Solutions'. *International Journal of Development Issues* 2 (2), 37-58

Allwood, C. M. (2012) 'The Distinction between Qualitative and Quantitative Research Methods is Problematic'. *Quality & Quantity* 46 (5), 1417-1429

Ambituuni, A., Amezaga, J., and Emeseh, E. (2014) 'Analysis of Safety and Environmental Regulations for Downstream Petroleum Industry Operations in Nigeria: Problems and Prospects'. *Environmental Development* 9 (0), 43-60

Andrews, M., Pritchett, L., and Woolcock, M. (2013) 'Escaping Capability Traps through Problem Driven Iterative Adaptation (PDIA)'. *World Development* 51, 234-244

Anifowose, A., Bamisaye, O., and Odeyemi, I. (2006) 'Establishing a Solid Mineral Database for a Part of Southwestern Nigeria'. *Geospatial Application Papers*, 1-3

Anifowose, B., Lawler, D., Horst, D., and Chapman, L. (2014) 'Evaluating Interdiction of Oil Pipelines at River Crossings using Environmental Impact Assessments'. *Area* 46 (1), 4-17

Anifowose, B., Lawler, D., van der Horst, D., and Chapman, L. (eds.) (2011) *SPE European Health Safety and Environmental Conference in Oil and Gas Exploration and Production*. 'Assessing the Quality of Oil and Gas Project Environmental Impact Statements (EIS)-A Preface': Society of Petroleum Engineers

Anifowose, B., Lawler, D. M., van der Horst, D., and Chapman, L. (2012) 'Attacks on Oil Transport Pipelines in Nigeria: A Quantitative Exploration and Possible Explanation of Observed Patterns'. *Applied Geography* 32 (2), 636-651

Antony, J., Malik, A., and Blumenfeld, S. (2012) 'Six Sigma, Quality Management Systems and the Development of Organisational Learning Capability: Evidence from Four Business Process Outsourcing Organisations in India'. *International Journal of Quality & Reliability Management* 29 (1), 71-91

Anyanwu, C. U. (ed.) (2012) *Nd Annual Meeting of the International Association for Impact Assessment, Centro De Congresso Da Alfândega, Porto–Portugal*. 'The Oil Industry and the Nigerian Environment'

Appiah-Opoku, S. (2001) 'Environmental Impact Assessment in Developing Countries: The Case of Ghana'. *Environmental Impact Assessment Review* 21 (1), 59-71

Apulu, I., Latham, A., and Moreton, R. (2011) 'Factors Affecting the Effective Utilisation and Adoption of Sophisticated ICT Solutions: Case Studies of SMEs in Lagos, Nigeria'. *J of Systems and Info Tech* 13 (2), 125-143

Ayanlade, A., Orimoogunje, I., and Borisade, P. (2008) 'Geospatial Data Infrastructure for Sustainable Development in Sub-Saharan Countries'. *International Journal of Digital Earth* 1 (3), 247-258

Ayeni, O., Kufoniyi, O., and JO, A. (eds.) (2003) *Proceeding of the Technical Session of the 38th Annual General Conference and Meeting of Nigeria Institution of Surveyors, Lokoja, Kogi State, Nigeria*. 'Towards a National Geospatial Information Policy for Nigeria'

Bakar, A. A., Idris, N., Hamdan, A. R., Othman, Z., Nazari, M. Z. A., and Zainudin, S. (eds.) (2011) *Electrical Engineering and Informatics (ICEEI), 2011 International Conference On*. 'Classification Models for Outbreak Detection in Oil and Gas Pollution Area': IEEE

Balaji, S. and Murugaiyan, M. S. (2012) 'Waterfall Vs. V-Model Vs. Agile: A Comparative Study on SDLC'. *International Journal of Information Technology and Business Management* 2 (1), 26-30

Barrow, C. (2002) 'Evaluating the Social Impacts of Environmental Change and the Environmental Impacts of Social Change: An Introductory Review of Social Impact Assessment'. *International Journal of Environmental Studies* 59 (2), 185-195

Batcheller, J. K. (2008) 'Automating Geospatial Metadata generation—An Integrated Data Management and Documentation Approach'. *Computers & Geosciences* 34 (4), 387-398

Beck, R., Weber, S., and Gregory, R. W. (2013) 'Theory-Generating Design Science Research'. *Information Systems Frontiers* 15 (4), 637-651

Bendassolli, P. F. (ed.) (2013) *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*. 'Theory Building in Qualitative Research: Reconsidering the Problem of Induction'

Betey, C. B. and Godfred, E. (2013) 'Environmental Impact Assessment and Sustainable Development in Africa: A Critical Review'. *Environment and Natural Resources Research* 3 (2), 37

Bhardwaj, S., Jain, L., and Jain, S. (2010) 'Cloud Computing: A Study of Infrastructure as a Service (IAAS)'. *International Journal of Engineering and Information Technology* 2 (1), 60-63

Bhat, M. A., Shah, R. M., and Ahmad, B. (2011) 'Cloud Computing: A Solution to Geographical Information Systems (GIS)'. *International Journal on Computer Science & Engineering* 3 (2), 594-600

Bokhari, S. M. A., Azam, F., and Abbas, M. (2015) 'Limitations of Service Oriented Architecture and its Combination with Cloud Computing'. *Bahria University Journal of Information & Communication Technology* 8 (1), 7

Bolloju, N., Schneider, C., and Sugumaran, V. (2012) 'A Knowledge-Based System for Improving the Consistency between Object Models and use Case Narratives'. *Expert Systems with Applications* 39 (10), 9398-9410

Botta, A., de Donato, W., Persico, V., and Pescapé, A. (2016) *Integration of Cloud Computing and Internet of Things: A Survey* [online] . available from <http://www.sciencedirect.com/science/article/pii/S0167739X15003015>

Brender, N. and Markov, I. (2013) 'Risk Perception and Risk Management in Cloud Computing: Results from a Case Study of Swiss Companies'. *International Journal of Information Management* 33 (5), 726-733

Buyya, R., Ranjan, R., and Calheiros, R. N. (eds.) (2010) *International Conference on Algorithms and Architectures for Parallel Processing*. 'Intercloud: Utility-Oriented Federation of Cloud Computing Environments for Scaling of Application Services': Springer

Campagna, M., Ivanov, K., and Massa, P. (eds.) (2014) *Accepted) Proceedings of the 17th AGILE Conference on Geographic Information Science Connecting a Digital Europe through Location and Place*. 'Orchestrating the Spatial Planning Process: From Business Process Management to 2nd Generation Planning Support Systems'

Charland, A. and Leroux, B. (2011) 'Mobile Application Development: Web Vs. Native'. *Communications of the ACM* 54 (5), 49-53

Chauhan, R. and Singh, A. (2011) 'A Consistent Approach for Structurally Interoperable Data Layer'. *Www.Excelpublish.Com*, 3

Chen, H., Chiang, R. H., and Storey, V. C. (2012) 'Business Intelligence and Analytics: From Big Data to Big Impact.'. *MIS Quarterly* 36 (4), 1165-1188

Cheng, B. H. C. and Atlee, J. M. (eds.) (2007) *Future of Software Engineering, 2007. FOSE '07*. 'Research Directions in Requirements Engineering'

Chittock, D. G. and Hughey, K. F. D. (2011) 'A Review of International Practice in the Design of Voluntary Pollution Prevention Programs'. *Journal of Cleaner Production* 19 (5), 542-551

Church, R. L. (2002) 'Geographical Information Systems and Location Science'. *Computers & Operations Research* 29 (6), 541-562

Cinquini, L., Crichton, D., Mattmann, C., Harney, J., Shipman, G., Wang, F., Ananthakrishnan, R., Miller, N., Denvil, S., and Morgan, M. (2014) 'The Earth System Grid Federation: An Open Infrastructure for Access to Distributed Geospatial Data'. *Future Generation Computer Systems* 36, 400-417

Closa, G., Masó, J., Proß, B., and Pons, X. (2017) 'W3C PROV to Describe Provenance at the Dataset, Feature and Attribute Levels in a Distributed Environment'. *Computers, Environment and Urban Systems* 64, 103-117

Coleman, D. J., Rajabifard, A., and Kolodziej, K. W. (2016) 'Expanding the SDI Environment: Comparing Current Spatial Data Infrastructure with Emerging Indoor Location-Based Services'. *International Journal of Digital Earth* 9 (6), 629-647

Coleman, D. J. (ed.) (2010) *GSDI 12 World Conference*. 'Volunteered Geographic Information in Spatial Data Infrastructure: An Early Look at Opportunities and Constraints'

Coleman, D. J. and McLaughlin, J. (1998) 'Defining Global Geospatial Data Infrastructure (GGDI): Components, Stakeholders and Interfaces'. *Geomatica-Ottawa-* 52, 129-143

Craglia, M., Pavanello, L., and Smith, R. (2010) 'The use of Spatial Data for the Preparation of Environmental Reports in Europe'. *European Commission Joint Research Centre Institute for Environment and Sustainability, Ispra, Italy, Available at: Http://Ies.Jrc.Ec.Europa.Eu/Uploads/SDI/Publications/JRC_technical% 20report_2009% 20EIA-SEA% 20survey.Pdf*

Craglia, M. and Campagna, M. (2009) 'Advanced Regional Spatial Data Infrastructures in Europe'. *Luxembourg: Office for Official Publications of the European Communities*

Creswell, J. W. (2013) *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*.: Sage Publications, Incorporated

Crompvoets, J., Bregt, A., Rajabifard, A., and Williamson, I. (2004) 'Assessing the Worldwide Developments of National Spatial Data Clearinghouses'. *International Journal of Geographical Information Science* 18 (7), 665-689

Cruz, E. F., Machado, R. J., and Santos, M. Y. (eds.) (2014) *Computational Science and its Applications (ICCSA), 2014 14th International Conference On*. 'On the Decomposition of use Cases for the Refinement of Software Requirements'

da Silva, C. N., da Silva, João Marcio Palheta, Chagas, C. A. N., and Castro, C. J. N. (2014) 'The Cartography and the Spatial Representations: Search by Perfect Map'. *Journal of Geographic Information System* 6 (06), 624

Dahunsi, F. and Owoseni, T. (2015) 'Cloud Computing in Nigeria: The Cloud Ecosystem Perspective'. *Nigerian Journal of Technology* 34 (1), 209-216

D'Amore, F., Cinnirella, S., and Pirrone, N. (2012) 'ICT Methodologies and Spatial Data Infrastructure for Air Quality Information Management'. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 5 (6), 1761-1771

De Alfonso, C., Caballer, M., Alvarruiz, F., and Moltó, G. (2013) 'An Economic and Energy-Aware Analysis of the Viability of Outsourcing Cluster Computing to a Cloud'. *Future Generation Computer Systems* 29 (3), 704-712

de Andrade, F. G., Baptista, C. d. S., and Leite Jr, F. L. (2011) 'Using Federated Catalogs to Improve Semantic Integration among Spatial Data Infrastructures'. *Transactions in GIS* 15 (5), 707-722

de Assunção, M. D., di Costanzo, A., and Buyya, R. (2010) 'A Cost-Benefit Analysis of using Cloud Computing to Extend the Capacity of Clusters'. *Cluster Computing* 13 (3), 335-347

De Massis, A. and Kotlar, J. (2014) 'The Case Study Method in Family Business Research: Guidelines for Qualitative Scholarship'. *Journal of Family Business Strategy* 5 (1), 15-29

DeGloria, S. D., Beaudette, D. E., Irons, J. R., Libohova, Z., O'Neill, P. E., Owens, P. R., Schoeneberger, P. J., West, L. T., and Wysocki, D. A. (2014) 'Emergent Imaging and Geospatial Technologies for Soil Investigations'

Delgado Fernández, T., Lance, K., and Buck, M. (2005) 'Assessing an SDI Readiness Index, from Pharaohs to Geoinformatics, FIG Working Week 2005 and 8th International Conference on Global Spatial Data Infrastructure'. *April, Cairo, Egypt*

Dessers, E., Van Hootegem, G., Crompvoets, J., and Hendriks, P. H. (2010) 'Developing Spatially-Enabled Business Processes: The Role of Organisational Structures'. *Spatially Enabling Society.Research, Emerging Trends, and Critical Assessment*, 41-54

Devillers, R., Stein, A., Bédard, Y., Chrisman, N., Fisher, P., and Shi, W. (2010) 'Thirty Years of Research on Spatial Data Quality: Achievements, Failures, and Opportunities'. *Transactions in GIS* 14 (4), 387-400

Di, L., Shao, Y., and Kang, L. (2013) 'Implementation of Geospatial Data Provenance in a Web Service Workflow Environment with ISO 19115 and ISO 19115-2 Lineage Model'. *IEEE Transactions on Geoscience and Remote Sensing* 51 (11), 5082-5089

Díaz, L., Bröring, A., McInerney, D., Libertá, G., and Foerster, T. (2013) 'Publishing Sensor Observations into Geospatial Information Infrastructures: A use Case in Fire Danger Assessment'. *Environmental Modelling & Software* 48 (0), 65-80

Dittmar, J. E. (2011) 'Information Technology and Economic Change: The Impact of the Printing Press'. *The Quarterly Journal of Economics* 126 (3), 1133-1172

Dogo, E. M., Salami, A., and Salman, S. (2013) 'Feasibility Analysis of Critical Factors Affecting Cloud Computing in Nigeria'. *International Journal of Cloud Computing and Services Science* 2 (4), 276

Dow, S., Siddiky, I. A., and Ahmmad, Y. K. (2013) 'Cross-Border Oil and Gas Pipelines and Cross-Border Waterways: A Comparison between the Two Legal Regimes'. *The Journal of World Energy Law & Business* 6 (2), 107-128

Drira, R., Warin, B., and Laroussi, M. (2011) 'Contextualisation of Reusable Learning Systems: Theoretical and Practical Analysis, Approach and Case Study'. *International Journal of Learning Technology* 6 (4), 362-383

Ebegbulem, J., Ekpe, D., and Adejumo, T. O. (2013) 'Oil Exploration and Poverty in the Niger Delta Region of Nigeria: A Critical Analysis'. *International Journal of Business and Social Science* 4 (3), 279-287

Echefu, N. and Akpofure, E. (2002) 'Environmental Impact Assessment in Nigeria: Regulatory Background and Procedural Framework'. *EIA Training Resource Manual*

Eko, S. A., Utting, C. A., and Onun, E. U. (2013) 'Beyond Oil: Dual-Imperatives for Diversifying the Nigerian Economy'. *Journal of Management and Strategy* 4 (3), 81

Elenwo, E. I. and Akankali, J. A. (2014) 'Environmental Policies and Strategies in Nigeria Oil and Gas Industry: Gains, Challenges and Prospects'. *Natural Resources* 5 (14), 884

Elwood, S. (2008) 'Grassroots Groups as Stakeholders in Spatial Data Infrastructures: Challenges and Opportunities for Local Data Development and Sharing'. *International Journal of Geographical Information Science* 22 (1), 71-90

Elwood, S., Goodchild, M. F., and Sui, D. Z. (2012) 'Researching Volunteered Geographic Information: Spatial Data, Geographic Research, and New Social Practice'. *Annals of the Association of American Geographers* 102 (3), 571-590

Emmanuel, A. O. and Babatunde, A. W. (2009) 'Poverty, Oil Exploration and Niger Delta Crisis: The Response of the Youth'. *African Journal of Political Science and International Relations* 3 (5), 224-232

Eneh, O. C. (2011) 'Managing Nigeria's Environment: The Unresolved Issues.'. *Journal of Environmental Science & Technology* 4 (3)

European Commission (2016) *Report from the Commission to the Council and the European Parliament on the Implementation of Directive 2007/2/EC of March 2007 Establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) Pursuant to Article 23*. Brussels: European Commission

Ezeoha, A., Igwe, A., Onyeke, C., and Uche, C. (2016) 'Relevance Lost? the Petroleum Equalization Fund in Nigeria'. *Energy for Sustainable Development* 31, 152-162

Federal Geographic Data Committee (2013) *National Spatial Data Infrastructure Strategic Plan 2014–2016*

Fedra, K. (1999) 'Urban Environmental Management: Monitoring, GIS, and Modeling'. *Computers, Environment and Urban Systems* 23 (6), 443-457

Feng, C. (2013) 'Mapping Geospatial Metadata to Open Provenance Model'. *IEEE Transactions on Geoscience and Remote Sensing* 51 (11), 5073-5081

Fernández, T. D., Cuba, K. L., and Margaret, B. (eds.) (2005) *FIG Working Week*. 'Assessing an SDI Readiness Index'

Folkeson, L., Antonson, H., and Helldin, J. O. (2013) 'Planners’ Views on Cumulative Effects. A Focus-Group Study Concerning Transport Infrastructure Planning in Sweden'. *Land use Policy* 30 (1), 243-253

Frynas, J. G. (2012) 'Corporate Social Responsibility Or Government Regulation? Evidence on Oil Spill Prevention'. *Ecology and Society* 17 (4)

Frynas, J. G., Beck, M. P., and Mellahi, K. (2000) 'Maintaining Corporate Dominance After Decolonization: The ‘first Mover Advantage’of Shell- BP in Nigeria'. *Review of African Political Economy* 27 (85), 407-425

Garrido, J. and Requena, I. (2011) 'Proposal of Ontology for Environmental Impact Assessment: An Application with Knowledge Mobilization'. *Expert Systems with Applications* 38 (3), 2462-2472

Georgiadou, Y., Puri, S. K., and Sahay, S. (2005) 'Towards a Potential Research Agenda to Guide the Implementation of Spatial Data Infrastructures—A Case Study from India'. *International Journal of Geographical Information Science* 19 (10), 1113-1130

Ghaemia, A., Samadzadeganb, F., Rajabifardc, A., and Yadegarib, M. (eds.) (2010) *GSDI 12 World Conference-Realizing Spatially Enabled Societies*. 'Implementing a Municipal SDI with Service Oriented Architecture'

Giuliani, G., Lacroix, P., Guigoz, Y., Roncella, R., Bigagli, L., Santoro, M., Mazzetti, P., Nativi, S., Ray, N., and Lehmann, A. (2016) 'Bringing GEOSS Services into Practice: A Capacity Building Resource on Spatial Data Infrastructures (SDI)'. *Transactions in GIS*

Giuliani, G., Dubois, A., and Lacroix, P. M. A. (2013) 'Testing OGC Web Feature and Coverage Service Performance: Towards Efficient Delivery of Geospatial Data'. *Journal of Spatial Information Science* 7, 1-23

Giuliani, G., Ray, N., and Lehmann, A. (2011) 'Grid-Enabled Spatial Data Infrastructure for Environmental Sciences: Challenges and Opportunities'. *Future Generation Computer Systems* 27 (3), 292-303

Glasson, J., Therivel, R., and Chadwick, A. (2013) *Introduction to Environmental Impact Assessment*.: Routledge

Gontier, M., Mörtberg, U., and Balfors, B. (2010) 'Comparing GIS-Based Habitat Models for Applications in EIA and SEA'. *Environmental Impact Assessment Review* 30 (1), 8-18

González, A., Gilmer, A., Foley, R., Sweeney, J., and Fry, J. (2011) 'Applying Geographic Information Systems to Support Strategic Environmental Assessment: Opportunities and Limitations in the Context of Irish Land-use Plans'. *Environmental Impact Assessment Review* 31 (3), 368-381

Goodall, J. L., Horsburgh, J. S., Whiteaker, T. L., Maidment, D. R., and Zaslavsky, I. (2008) 'A First Approach to Web Services for the National Water Information System'. *Environmental Modelling and Software* 23 (4), 404-411

Goodchild, M. F. (2014) 'Twenty Years of Progress: GIScience in 2010'. *Journal of Spatial Information Science* (1), 3-20

Goodchild, M. F. (2011) 'Formalizing Place in Geographic Information Systems'. in *Communities, Neighborhoods, and Health*. ed. by Anon: Springer, 21-33

Gotschol, A., De Giovanni, P., and Esposito Vinzi, V. (2014) 'Is Environmental Management an Economically Sustainable Business?'. *Journal of Environmental Management* 144 (0), 73-82

Gotway, C. A. and Young, L. J. (2002) 'Combining Incompatible Spatial Data'. *Journal of the American Statistical Association* 97 (458), 632-648

Grant, D. (2016) 'Business Analysis Techniques in Business Reengineering'. *Business Process Management Journal* 22 (1), 75-88

Grus, Ł, Castelein, W., Crompvoets, J., Overduin, T., Loenen, B. v., Groenestijn, A. v., Rajabifard, A., and Bregt, A. K. (2011) 'An Assessment View to Evaluate Whether Spatial Data Infrastructures Meet their Goals'. *Computers, Environment and Urban Systems* 35 (3), 217-229

Gunay, A., Akcay, O., and Altan, M. O. (2014) 'Building a Semantic Based Public Transportation Geoportal Compliant with the INSPIRE Transport Network Data Theme'. *Earth Science Informatics* 7 (1), 25-37

Gupta, S., Saxena, K., and Saini, A. (eds.) (2016) *Proceedings of the 2016 International Conference on Industrial Engineering and Operations Management, Kuala Lumpur, Malaysia*. 'Towards Risk Managed Cloud Adoption: A Conceptual Framework'

Harding, J. (2013) 'Usability of Geographic Information – Factors Identified from Qualitative Analysis of Task-Focused User Interviews'. *Applied Ergonomics* 44 (6), 940-947

Hart, T. C. and Zandbergen, P. A. (2013) 'Reference Data and Geocoding Quality: Examining Completeness and Positional Accuracy of Street Geocoded Crime Incidents'. *Policing* 36 (2), 263-294

Hartmann, P. (2015) 'Marine Spatial Data Infrastructure in the Baltic'. *The International Hydrographic Review* (12)

Harvey, F., Jones, J., Scheider, S., Iwaniak, A., Kaczmarek, I., Łukowicz, J., and Strzelecki, M. (2014) 'Little Steps Towards Big Goals. using Linked Data to Develop Next Generation Spatial Data Infrastructures (Aka SDI 3.0)'. *Connecting a Digital Europe through Location and Place. Proceedings of the AGILE'2014 International Conference on Geographic Information Science, Castellón, June, 3-6, 2014.*

Harvey, F., Iwaniak, A., Coetzee, S., and Cooper, A. K. (2012) 'SDI Past, Present and Future: A Review and Status Assessment'. *Spatial Enabling Government, Industry and Citizens*

Heinma, K. and Põder, T. (2010) 'Effectiveness of Environmental Impact Assessment System in Estonia'. *Environmental Impact Assessment Review* 30 (4), 272-277

Hese, S. and Schmullius, C. (2009) 'High Spatial Resolution Image Object Classification for Terrestrial Oil Spill Contamination Mapping in West Siberia'. *International Journal of Applied Earth Observation and Geoinformation* 11 (2), 130-141

Hilson, G. (2012) 'Corporate Social Responsibility in the Extractive Industries: Experiences from Developing Countries'. *Resources Policy* 37 (2), 131-137

IAIA (1999) *Principles of Environmental Impact Assessment Best Practice* : International Association for Impact Assessment

Idiri, B. and Napoli, A. (eds.) (2013) *Proceedings Or the 6th International Workshop on Information Fusion and Geographic Information Systems: Environmental and Urban Challenges-IF&GIS'2013*. 'The Geographical Decision-Making Chain: Formalization and Application to Maritime Risk Analysis'

Idrees, M. O., Saeidi, V., Yusuf, Y. A., and Shariff, A. (2012) 'Comparing Approaches and Strategies for NSDI Implementation between the Developed and Developing World'. *Article Under Review for the International Journal of Spatial Data Infrastructures Research*

Ihonvbere, J. O. (1994) 'The State and Environmental Degradation in Nigeria: A Study of the 1988 Toxic Waste Dump in Koko'. *Journal of Environmental Systems* 23 (3), 207-227

Ingelson, A. and Nwapi, C. (2014) 'Environmental Impact Assessment Process for Oil, Gas and Mining Projects in Nigeria: A Critical Analysis'. *Gas and Mining Projects in Nigeria: A Critical Analysis* 10 (1)

Izquierdo-Sotorrío, E., Holgado-Tello, F. P., and Carrasco, M. Á (2016) 'Incremental Validity and Informant Effect from a Multi-Method Perspective: Assessing Relations between Parental Acceptance and Children's Behavioral Problems'. *Frontiers in Psychology* 7, 664

Jacobson, I. (2003) 'Use Cases and Aspects - Working Seamlessly Together'. *Journal of Object Technology* 2 (4), 7-28

Jacobson, I. (1999) *The Unified Software Development Process*. Reading, Mass ; Harlow, England: Reading, Mass ; Harlow, England : Addison-Wesley

James, P., Jankowska, M., Marx, C., Hart, J. E., Berrigan, D., Kerr, J., Hurvitz, P. M., Hipp, J. A., and Laden, F. (2016) '"Spatial Energetics": Integrating Data from GPS, Accelerometry, and GIS to Address Obesity and Inactivity'. *American Journal of Preventive Medicine* 51 (5), 792-800

Janowicz, K., Schade, S., Bröring, A., Keßler, C., Maué, P., and Stasch, C. (2010) 'Semantic Enablement for Spatial Data Infrastructures'. *Transactions in GIS* 14 (2), 111-129

Jay, S., Alves, F. L., O'Mahony, C., Gomez, M., Rooney, A., Almodovar, M., Gee, K., de Vivero, J. L. S., Gonçalves, J. M. S., da Luz Fernandes, M., Tello, O., Twomey, S., Prado, I., Fonseca, C., Bentes, L., Henriques, G., and Campos, A. (2016) 'Transboundary Dimensions of Marine Spatial Planning: Fostering Inter-Jurisdictional Relations and Governance'. *Marine Policy* 65, 85-96

Jeffery, K.,G and Asserson, A. (eds.) (2016) *Smart Descriptions & Smarter Vocabularies (SDSVoc) Workshop*. 'Position Paper: Why CERIF? ' at CWI Amsterdam. https://www.w3.org/2016/11/sdsvoc/SDSVoc16_paper_15

Kabir, S. Z. and Momtaz, S. (2012) 'The Quality of Environmental Impact Statements and Environmental Impact Assessment Practice in Bangladesh'. *Impact Assessment and Project Appraisal* 30 (2), 94-99

Kalantari, M., Rajabifard, A., Olfat, H., and Williamson, I. (2014) 'Geospatial Metadata 2.0 – an Approach for Volunteered Geographic Information'. *Computers, Environment and Urban Systems* 48, 35-48

Kansou, K. and Bredeweg, B. (2014) 'Hypothesis Assessment with Qualitative Reasoning: Modelling the Fontestorbes Fountain'. *Ecological Informatics* 19, 71-89

Keene, M. and Pullin, A. S. (2011) 'Realizing an Effectiveness Revolution in Environmental Management'. *Journal of Environmental Management* 92 (9), 2130-2135

Khalili, N. R. and Duecker, S. (2013) 'Application of Multi-Criteria Decision Analysis in Design of Sustainable Environmental Management System Framework'. *Journal of Cleaner Production* 47, 188-198

Khanlari, G., Abdilor, Y., and Babazadeh, R. (2014) 'Landslide Hazards Zonation using GIS in Khoramabad, Iran'. *Journal of Geotechnical Geology* 9 (4), 343-352

Kim, J. (2015) 'Convergence Strategies for Spatial Data Industry Based on Industry Value Chain Analysis'. *Indian Journal of Science and Technology* 8 (19)

Kokalj, Ž, Pehani, P., Goodchild, H., Gaffney, V., and Oštir, K. (2013) 'Crossing Borders: A Multi-Layer GIS Mapping Framework for the Cultural Management of the Mundo Maya Region'. in *Visual Heritage in the Digital Age*. ed. by Anon: Springer, 169-182

Kolb, T. L., Blukacz-Richards, E. A., Muir, A. M., Claramunt, R. M., Koops, M. A., Taylor, W. W., Sutton, T. M., Arts, M. T., and Bissel, E. (2013) 'How to Manage Data to Enhance their Potential for Synthesis, Preservation, Sharing, and Reuse—A Great Lakes Case Study'. *Fisheries* 38 (2), 52-64

Koornneef, J., Ramírez, A., Turkenburg, W., and Faaij, A. (2012) 'The Environmental Impact and Risk Assessment of CO2 Capture, Transport and Storage – an Evaluation of the Knowledge Base'. *Progress in Energy and Combustion Science* 38 (1), 62-86

Krivokapic-Skoko, B. and O’neill, G. (2011) 'Beyond the Qualitative–quantitative Distinction: Some Innovative Methods for Business and Management Research'. *International Journal of Multiple Research Approaches* 5 (3), 290-300

Kuechler, W. and Vaishnavi, V. (2012) 'A Framework for Theory Development in Design Science Research: Multiple Perspectives'. *Journal of the Association for Information Systems* 13 (6), 395-423

Kufoniyi, O. and Agbaje, G. I. (2005) 'National Geospatial Data Infrastructure Development in Nigeria: The Journey so Far'. *From Pharaohs to Geoinformatics FIG Working Week*

Lacerda, D., Dresch, A., Proença, A., and Antunes, J. J. (2013) 'Design Science Research: Método De Pesquisa Para a Engenharia De Produção'. *Gestão & Produção* 20 (4), 741-761

Latre, M. Á, Lopez-Pellicer, F. J., Nogueras-Iso, J., Béjar, R., Zarazaga-Soria, F. J., and Muro-Medrano, P. R. (2013) 'Spatial Data Infrastructures for Environmental E-Government Services: The Case of Water Abstractions Authorisations'. *Environmental Modelling & Software* 48 (0), 81-92

Lawal, A. M., Bouzarovski, S., and Clark, J. (2013) 'Public Participation in EIA: The Case of West African Gas Pipeline and Tank Farm Projects in Nigeria'. *Impact Assessment and Project Appraisal* 31 (3), 226-231

Lebo, T., Sahoo, S., McGuinness, D., Belhajjame, K., Cheney, J., Corsar, D., Garijo, D., Soiland-Reyes, S., Zednik, S., and Zhao, J. (2013) 'Prov-O: The Prov Ontology'. *W3C Recommendation* 30

Leitner, P. and Cito, J. (2016) 'Patterns in the Chaos—a Study of Performance Variation and Predictability in Public Iaas Clouds'. *ACM Transactions on Internet Technology (TOIT)* 16 (3), 15

Leitner, P., Inzinger, C., Hummer, W., Satzger, B., and Dustdar, S. (eds.) (2012) *Service-Oriented Computing and Applications (SOCA), 2012 5th IEEE International Conference On*. 'Application-Level Performance Monitoring of Cloud Services Based on the Complex Event Processing Paradigm': IEEE

Leonard, H. J. and Morell, D. (1981) 'Emergence of Environmental Concern in Developing Countries: A Political Perspective'. *Stan.J.Int'L L.* 17, 281

Li, W., Yang, C., Nebert, D., Raskin, R., Houser, P., Wu, H., and Li, Z. (2011) 'Semantic-Based Web Service Discovery and Chaining for Building an Arctic Spatial Data Infrastructure'. *Computers & Geosciences* 37 (11), 1752-1762

Lundvall, B. (2016) 'Is there a Technological Fix for the Current Global Stagnation?: A Response to Daniele Archibugi, Blade Runner Economics: Will Innovation Lead the Economic Recovery?'. *Research Policy*

Maguire, D. J. and Longley, P. A. (2005) 'The Emergence of Geoportals and their Role in Spatial Data Infrastructures'. *Computers, Environment and Urban Systems* 29 (1), 3-14

Makanga, P. and Smit, J. (2010) 'A Review of the Status of Spatial Data Infrastructure Implementation in Africa'. *South African Computer Journal* (45), 18-25

Malik, A., Maciejewski, R., Jang, Y., Oliveros, S., Yang, Y., Maule, B., White, M., and Ebert, D. S. (2012) 'A Visual Analytics Process for Maritime Response, Resource Allocation and Risk Assessment'. *Information Visualization*

Manfré, L. A., Hirata, E., Silva, J. B., Shinohara, E. J., Giannotti, M. A., Larocca, A. P. C., and Quintanilha, J. A. (2012) 'An Analysis of Geospatial Technologies for Risk and Natural Disaster Management'. *ISPRS International Journal of Geo-Information* 1 (2), 166-185

Marchant, A. P., Banks, V. J., Royse, K. R., and Quigley, S. P. (2013) 'The Development of a GIS Methodology to Assess the Potential for Water Resource Contamination due to New Development in the 2012 Olympic Park Site, London'. *Computers & Geosciences* 51, 206-215

Marston, S., Li, Z., Bandyopadhyay, S., Zhang, J., and Ghalsasi, A. (2011) *Cloud Computing — the Business Perspective* [online] . available from <http://www.sciencedirect.com/science/article/pii/S0167923610002393>

Mas'ud, A. A., Vernyuy Wirba, A., Muhammad-Sukki, F., Mas'ud, I. A., Munir, A. B., and Md Yunus, N. (2015) 'An Assessment of Renewable Energy Readiness in Africa: Case Study of Nigeria and Cameroon'. *Renewable and Sustainable Energy Reviews* 51, 775-784

Masser, I., Rajabifard, A., and Williamson, I. (2008) 'Spatially Enabling Governments through SDI Implementation'. *International Journal of Geographical Information Science* 22 (1), 5-20

Massoud, M. A., Fayad, R., Kamleh, R., and El-Fadel, M. (2010) 'Environmental Management System (ISO 14001) Certification in Developing Countries: Challenges and Implementation Strategies 1'. *Environmental Science & Technology* 44 (6), 1884-1887

Maurer, M., Emeakaroha, V. C., Brandic, I., and Altmann, J. (2012) 'Cost–benefit Analysis of an SLA Mapping Approach for Defining Standardized Cloud Computing Goods'. *Future Generation Computer Systems* 28 (1), 39-47

Mayer, P., Klarl, A., Hennicker, R., Puviani, M., Tiezzi, F., Pugliese, R., Keznikl, J., and Bureš, T. (eds.) (2013) *Self-Adaptation and Self-Organizing Systems Workshops (SASOW), 2013 IEEE 7th International Conference On*. 'The Autonomic Cloud: A Vision of Voluntary, Peer-2-Peer Cloud Computing': IEEE

McDougall, K., Rajabifard, A., and Williamson, I. P. (2007) 'A Mixed-Method Approach for Evaluating Spatial Data Sharing Partnerships for Spatial Data Infrastructure Development'. *Research and Theory in Advancing Spatial Data Infrastructure Concepts, Redlands, California, USA: ESRI Press, at: Http://Gsdidocs.Org/Gsdiconf/GSDI-9/Papers/TS22.3paper.Pdf*

Mehmi, S., Sangal, A. L., Verma, H. K., and Parmar, K. (2016) 'Economic Viability of Smart Grid Cloud in India'. *International Journal of Grid and Distributed Computing* 9 (2), 61-72

Mettler, T., Eurich, M., and Winter, R. (2014) 'On the use of Experiments in Design Science Research: A Proposition of an Evaluation Framework.'. *Cais* 34, 10

Miah, S. J., Kerr, D., and Liisa, v. H. (2014) 'A Collective Artefact Design of Decision Support Systems: Design Science Research Perspective'. *Info Technology & People* 27 (3), 259-279

Michelsen, O., Cherubini, F., and Strømman, A. H. (2012) 'Impact Assessment of Biodiversity and Carbon Pools from Land use and Land use Changes in Life Cycle Assessment, Exemplified with Forestry Operations in Norway'. *Journal of Industrial Ecology* 16 (2), 231-242

Misra, S. C. and Mondal, A. (2011) 'Identification of a Company's Suitability for the Adoption of Cloud Computing and Modelling its Corresponding Return on Investment'. *Mathematical and Computer Modelling* 53 (3-4), 504-521

Missier, P., Belhajjame, K., and Cheney, J. (eds.) (2013) *Proceedings of the 16th International Conference on Extending Database Technology*. 'The W3C PROV Family of Specifications for Modelling Provenance Metadata': ACM

Mithas, S. and Rust, R. T. (2016) 'How Information Technology Strategy and Investments Influence Firm Performance: Conjectures and Empirical Evidence'. *Mis Quarterly* 40 (1), 223-245

Mithas, S., Tafti, A., Bardhan, I., and Goh, J. M. (2012) 'Information Technology and Firm Profitability: Mechanisms and Empirical Evidence'. *Mis Quarterly* 36 (1), 205-224

Mohammadi, H., Rajabifard, A., and Williamson, I. P. (2010) 'Development of an Interoperable Tool to Facilitate Spatial Data Integration in the Context of SDI'. *International Journal of Geographical Information Science* 24 (4), 487-505

Moja, S. J. and Mnguni, S. N. (2014) 'The Effect of Poor Environmental Impact Assessment (EIA) Implementation on the Wellbeing of the KwaMathukuza Community, Newcastle Municipality in South Africa'. *Journal of Agricultural Science* 6 (10), p18

Morgan, R. K. (2012) 'Environmental Impact Assessment: The State of the Art'. *Impact Assessment and Project Appraisal* 30 (1), 5-14

Morrison-Saunders, A., Pope, J., Gunn, J. A., Bond, A., and Retief, F. (2014) 'Strengthening Impact Assessment: A Call for Integration and Focus'. *Impact Assessment and Project Appraisal* 32 (1), 2-8

Morrison-Saunders, A. and Retief, F. (2012) 'Walking the Sustainability Assessment Talk — Progressing the Practice of Environmental Impact Assessment (EIA)'. *Environmental Impact Assessment Review* 36 (0), 34-41

Musa, G. J., Chiang, P., Sylk, T., Bavley, R., Keating, W., Lakew, B., Tsou, H., and Hoven, C. W. (2013) 'Use of GIS Mapping as a Public Health Tool--from Cholera to Cancer'. *Health Services Insights* 6, 111

Mwenda, A. N., Bregt, A. K., and Ligtenberg, A. (2013) 'Spatial Information during Public Participation within Environmental Impact Assessment in Kenya'. *Impact Assessment and Project Appraisal* 31 (4), 261-270

Nativi, S., Craglia, M., and Pearlman, J. (2013) 'Earth Science Infrastructures Interoperability: The Brokering Approach'. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 6 (3), 1118-1129

Nawrocka, D. and Parker, T. (2009) 'Finding the Connection: Environmental Management Systems and Environmental Performance'. *Journal of Cleaner Production* 17 (6), 601-607

Newman, Isadore, Benz,Carolyn R., (2006) *Qualitative-Quantitative Research Methodology : Exploring the Interactive Continuum*. Carbondale, Ill. [u.a.: Southern Illinois Univ. Press

Nowduri, S. (2011) 'Management Information Systems and Business Decision Making: Review, Analysis, and Recommendations'. *Journal of Management and Marketing Research Management Information Systems and Business Decision Making, Bloomsburg University of Pennsylvania*

Nushi, B., Van Loenen, B., Besemer, J., and Crompvoets, J. (eds.) (2012) *Global Geospatial Conference 2012, Spatially Enabling Government, Industry of Citiziens: Research and Development Perspectives, Quebec City, Canada, may 14-17, 2012*. 'Multiview SDI Assessment of Kosovo (2007-2010): Developing a Solid Base to Support SDI Strategy Development': GSDI Association Press

Nwankwo, B. O. (2015) 'The Politics of Conflict Over Oil in the Niger Delta Region of Nigeria: A Review of the Corporate Social Responsibility Strategies of the Oil Companies'. *American Journal of Educational Research* 3 (4), 383-392

Nwankwo, C. and Ogagarue, D. (2011) 'Effects of Gas Flaring on Surface and Ground Waters in Delta State, Nigeria'. *Journal of Geology and Mining Research* 3 (5), 131-136

Nwilo, P. and Osanwuta, D. (eds.) (2004) *Proceedings FIG Working Week*. 'National Spatial Data Infrastructure for Nigeria–Issues to be Considered'

Ogbazi, J. U. (2013) 'Alternative Planning Approaches and the Sustainable Cities Programme in Nigeria'. *Habitat International* 40, 109-118

Ogunba, O. A. (2004) 'EIA Systems in Nigeria: Evolution, Current Practice and Shortcomings'. *Environmental Impact Assessment Review* 24 (6), 643-660

Ogunleye, E. K. (2008) 'Natural Resource Abundance in Nigeria: From Dependence to Development'. *Resources Policy* 33 (3), 168-174

Okuku, J., Bregt, A., and Grus, L. (2014) 'Assessing the Development of Kenya National Spatial Data Infrastructure (KNSDI)'. *South African Journal of Geomatics* 3 (1), 95-112

Okuku, J., Bregt, A., and Grus, L. (2013) 'Assessing the Development of Kenya National Spatial Data Infrastructure (KNSDI)'. *South African Journal of Geomatics* 3 (1), 95-112

Oliveira, T., Thomas, M., and Espadanal, M. (2014) 'Assessing the Determinants of Cloud Computing Adoption: An Analysis of the Manufacturing and Services Sectors'. *Information & Management* 51 (5), 497-510

Olugbenga, E. O. (2016) 'A Comparative Study of Public Policy and the Environment: The Cases of Nigeria, Egypt and South Africa'. *Academy of Social Science Journal* 1 (1)

Onu, B., Trevor, P., Suresh, S., and Ebie, S. (2012) 'Solid Waste Management: A Critique of Nigeria's Waste Management Policy'. *The International Journal of Knowledge, Culture and Change Management* 11 (4)

Onwuegbuzie, A. J., Frels, R. K., and Hwang, E. (2016) 'Mapping Saldaňa's Coding Methods Onto the Literature Review Process'. *Journal of Educational Issues* 2 (1), 130-150

Ortiz, S. (2011) 'The Problem with Cloud-Computing Standardization'. *Computer* 44 (7), 13-16

Östlund, U., Kidd, L., Wengström, Y., and Rowa-Dewar, N. (2011) 'Combining Qualitative and Quantitative Research within Mixed Method Research Designs: A Methodological Review'. *International Journal of Nursing Studies* 48 (3), 369-383

Paki, F. A. and Ebienfa, K. I. (2011) 'Oil and Development Deficit in Africa: The Failure of Intervention Agencies in Nigeria's Niger Delta'. *International Journal of Business and Social Science* 2 (8)

Pandey, D., Suman, U., and Ramani, A. K. (eds.) (2010) *Advances in Recent Technologies in Communication and Computing (ARTCom), 2010 International Conference On*. 'An Effective Requirement Engineering Process Model for Software Development and Requirements Management'

Panigrahi, J. K. and Amirapu, S. (2012) 'An Assessment of EIA System in India'. *Environmental Impact Assessment Review* 35 (0), 23-36

Paudyal, D. R., McDougall, K., and Apan, A. (2011) 'Spatial Data Infrastructure Convergence: Building Spatial Data Infrastructure Bridges to Address Climate Change'. *Geoinformatics for Climate Change Studies*, 377-392

Percivall, G. (2010) 'The Application of Open Standards to Enhance the Interoperability of Geoscience Information'. *International Journal of Digital Earth* 3 (S1), 14-30

Pôças, I., Gonçalves, J., Marcos, B., Alonso, J., Castro, P., and Honrado, J. P. (2014) 'Evaluating the Fitness for use of Spatial Data Sets to Promote Quality in Ecological Assessment and Monitoring'. *International Journal of Geographical Information Science* 28 (11), 2356-2371

Power, M., Marlon, J., Bartlein, P., and Harrison, S. (2010) 'Fire History and the Global Charcoal Database: A New Tool for Hypothesis Testing and Data Exploration'. *Palaeogeography, Palaeoclimatology, Palaeoecology* 291 (1), 52-59

Proctor, E. K., Powell, B. J., and McMillen, J. C. (2013) 'Implementation Strategies: Recommendations for Specifying and Reporting'. *Implementation Science* 8 (1), 139

Putra, T. Y. D., Trias, A., and de Vries, W. (2011) 'A Local Spatial Data Infrastructure to Support the Merapi Volcanic Risk Management: A Case Study at Sleman Regency, Indonesia'. *Indonesian Journal of Geography* 43 (1)

Qureshi, M. R. J. and Hussain, S. A. (2008) 'A Reusable Software Component-Based Development Process Model'. *Advances in Engineering Software* 39 (2), 88-94

Rafique, K., Tareen, A. W., Saeed, M., Wu, J., and Qureshi, S. S. (eds.) (2011) *Broadband Network and Multimedia Technology (IC-BNMT), 2011 4th IEEE International Conference On*. 'Cloud Computing Economics Opportunities and Challenges': IEEE

Rajabifard, A., Kalantari, M., and Binns, A. (2009) 'SDI and Metadata Entry and Updating Tools'. *SDI Convergence*, 121

Rajabifard, A., Binns, A., Masser, I., and Williamson, I. (2006) 'The Role of Sub- national Government and the Private Sector in Future Spatial Data Infrastructures'. *International Journal of Geographical Information Science* 20 (7), 727-741

Rajabifard, A., Williamson, I., and Feeney, M. F. (2003) *Developing Spatial Data Infrastructures: From Concept to Reality*.: Taylor & Francis

Rajabifard, A., Feeney, M. F., and Williamson, I. P. (2002) 'Future Directions for SDI Development'. *International Journal of Applied Earth Observation and Geoinformation* 4 (1), 11-22

Rajabifard, A. and Williamson, I. P. (eds.) (2001) *GEOMATICS'80 Conference, Teheran, Iran*. 'Spatial Data Infrastructures: Concept, SDI Hierarchy and Future Directions'

Ramirez, J. R. (1996) 'Spatial Data Revision: Toward an Integrated Solution using New Technolgies'. *International Archives of Photogrammetry and Remote Sensing* 31, 677-683

Rattray, N. (2006) 'A User-Centered Model for Community-Based Web-GIS'. *URISA, the Journal of Urban and Regional Information Systems Association* 18 (2), 25-34

Rautenbach, V., Coetzee, S., and Iwaniak, A. (2013) 'Orchestrating OGC Web Services to Produce Thematic Maps in a Spatial Information Infrastructure'. *Computers, Environment and Urban Systems* 37 (0), 107-120

Ray, N., Lacroix, P. M. A., Giuliani, G., Upla, P., Rajabifard, A., and Jensen, D. (2016) 'Open Spatial Data Infrastructures for the Sustainable Development of the Extractives Sector: Promises and Challenges'

Reichman, O. J., Jones, M. B., and Schildhauer, M. P. (2011) 'Challenges and Opportunities of Open Data in Ecology'. *Science (New York, N.Y.)* 331 (6018), 703-705

Robinson, J. O. (2013) 'Environmental Education and Sustainable Development in Nigeria: Breaking the Missing Link'. *International Journal of Education and Research* 1 (5), 1-6

Ryoo, H., Kim, S., Kim, J., and Li, K. (eds.) (2017) *Free and Open Source Software for Geospatial (FOSS4G) Conference Proceedings*. 'Development of an Extension of GeoServer for Handling 3D Spatial Data'

Sánchez, L. E. and Hacking, T. (2002) 'An Approach to Linking Environmental Impact Assessment and Environmental Management Systems'. *Impact Assessment and Project Appraisal* 20 (1), 25-38

Sánchez-Lozano, J. M., Teruel-Solano, J., Soto-Elvira, P. L., and Socorro García-Cascales, M. (2013) 'Geographical Information Systems (GIS) and Multi-Criteria Decision Making (MCDM) Methods for the Evaluation of Solar Farms Locations: Case Study in South-Eastern Spain'. *Renewable and Sustainable Energy Reviews* 24, 544-556

Sangodoyin, A. Y. and Ipadeola, S. F. (2000) 'Hazardous Wastes Assessing the Efficacy of Structures and Approaches to Management in Nigeria'. *Environmental Management and Health* 11 (1), 39-46

Sarkis, J., Gonzalez-Torre, P., and Adenso-Diaz, B. (2010) 'Stakeholder Pressure and the Adoption of Environmental Practices: The Mediating Effect of Training'. *Journal of Operations Management* 28 (2), 163-176

Sarma, P., Owens, J., Chen, W., and Wen, X. (eds.) (2015) *SPE Reservoir Simulation Symposium*. 'Massively Distributed Simulation and Optimization on Commercial Compute Clouds': Society of Petroleum Engineers

Savic, D., da Silva, A. R., Vlajic, S., Lazarevic, S., Stanojevic, V., Antovic, I., and Milic, M. (eds.) (2012) *Quality of Information and Communications Technology (QUATIC), 2012 Eighth International Conference on The*. 'Use Case Specification at Different Levels of Abstraction': IEEE

Sein, M., Henfridsson, O., Purao, S., Rossi, M., and Lindgren, R. (2011) 'Action Design Research'. *MIS Quarterly* 35 (1), 37-37-56

Shahiduzzaman, M. and Alam, K. (2014) 'Information Technology and its Changing Roles to Economic Growth and Productivity in Australia'. *Telecommunications Policy* 38 (2), 125-135

Shao, B. B. M. and Lin, W. T. (2016) 'Assessing Output Performance of Information Technology Service Industries: Productivity, Innovation and Catch-Up'. *International Journal of Production Economics* 172, 43-53

Shiode, S. and Shiode, N. (2013) 'Network-Based Space-Time Search-Window Technique for Hotspot Detection of Street-Level Crime Incidents'. *International Journal of Geographical Information Science* 27 (5), 866-882

Simpson, C. L. and Novak, L. L. (2013a) 'Place Matters: The Problems and Possibilities of Spatial Data in Electronic Health Records'. *AMIA ...Annual Symposium Proceedings.AMIA Symposium* 2013, 1303-1311

Simpson, C. L. and Novak, L. L. (2013b) 'Place Matters: The Problems and Possibilities of Spatial Data in Electronic Health Records'. *AMIA ...Annual Symposium Proceedings.AMIA Symposium* 2013, 1303-1311

Sinha, A. and Paradkar, A. (eds.) (2010) *Web Services (ICWS), 2010 IEEE International Conference On*. 'Use Cases to Process Specifications in Business Process Modeling Notation'

Soh, C. and Markus, M. L. (eds.) (1995) *Icis*. 'How IT Creates Business Value: A Process Theory Synthesis': Citeseer

Solomon, O. B., Opawole, A., and Olusegun, E. A. (2012) 'Critical Success Factors in Public- private Partnership (PPP) on Infrastructure Delivery in Nigeria'. *J of Facilities Management* 10 (3), 212-225

Steenbruggen, J., Borzacchiello, M. T., Nijkamp, P., and Scholten, H. (2013) 'Mobile Phone Data from GSM Networks for Traffic Parameter and Urban Spatial Pattern Assessment: A Review of Applications and Opportunities'. *GeoJournal* 78 (2), 223-243

Steiniger, S. and Hunter, A. J. (2012) 'Free and Open Source GIS Software for Building a Spatial Data Infrastructure'. *Geospatial Free and Open Source Software in the 21st Century*, 247-261

Sultan, N. A. (2011) 'Reaching for the “cloud”: How SMEs can Manage'. *International Journal of Information Management* 31 (3), 272-278

Sutanta, H., Rajabifard, A., and Bishop, I. D. (2010) 'Integrating Spatial Planning and Disaster Risk Reduction at the Local Level in the Context of Spatially Enabled Government'. *Spatially Enabling Society: Research, Emerging Trends and Critical Assessment*, 205-218

Takon, N., Ali, S., Saeed, M., Hussain, J., Akinbileje, T. Y., Nwaozuzu, E. E., Dozie, I. N., Kibiiy, J., Koskei, K., and Sitters, C. (2014) 'Distribution of Oil Revenue to Niger Delta of Nigeria in Post-2000: Is the Debate how Fairly the Federal Government has Redistributed Oil Revenue?'. *International Journal of Development and Sustainability* 3 (4), 586-607

Tavares, G., Zsigraiová, Z., and Semiao, V. (2011) 'Multi-Criteria GIS-Based Siting of an Incineration Plant for Municipal Solid Waste'. *Waste Management* 31 (9), 1960-1972

Teixeira, L., Ferreira, C., and Santos, B. S. (2012) 'User-Centered Requirements Engineering in Health Information Systems: A Study in the Hemophilia Field'. *Computer Methods and Programs in Biomedicine* 106 (3), 160-174

Thiruchelvam, M., Kumar, S., and Visvanathan, C. (2003) 'Policy Options to Promote Energy Efficient and Environmentally Sound Technologies in Small- and Medium-Scale Industries'. *Energy Policy* 31 (10), 977-987

Tonchovska, R. and Adlington, G. (2011a) 'Spatial Data Infrastructure and Inspire in Global Dimension'. *Land Tenure Journal* (1)

Tonchovska, R. and Adlington, G. (2011b) 'Spatial Data Infrastructure and Inspire in Global Dimension'. *Land Tenure Journal* (1)

Trapp, N., Schneider, U. A., McCallum, I., Fritz, S., Schill, C., Borzacchiello, M. T., Heumesser, C., and Craglia, M. (2014) 'A Meta- Analysis on the Return on Investment of Geospatial Data and Systems: A Multi- Country Perspective'. *Transactions in GIS*

Trilles, S., Juan, P., Diaz, L., Arago, P., and Huerta, J. (2013) 'Integration of Environmental Models in Spatial Data Infrastructures: A use Case in Wildfire Risk Prediction'

Tsang, E. W. K. (2014) 'Case Studies and Generalization in Information Systems Research: A Critical Realist Perspective'. *The Journal of Strategic Information Systems* 23 (2), 174-186

Tumba, A. G. and Ahmad, A. (2014) 'Geographic Information System and Spatial Data Infrastructure: A Developing Societies' Perception'. *Universal Journal of Geoscience* 2 (3), 85-92

Vaez, S. and Rajabifard, A. (2012) 'Seamless SDI Design by using UML Modelling'. *International Journal of Spatial Data Infrastructures Research* 7, 207-207-224

Vandenbroucke, D., Dessers, E., Crompvoets, J., Bregt, A. K., and Van Orshoven, J. (2013) 'A Methodology to Assess the Performance of Spatial Data Infrastructures in the Context of Work Processes'. *Computers, Environment and Urban Systems* 38 (0), 58-66

Vandenbroucke, D., Crompvoets, J., Vancauwenberghe, G., Dessers, E., and Van Orshoven, J. (2009) 'A Network Perspective on Spatial Data Infrastructures: Application to the Sub-National SDI of Flanders (Belgium)'. *Transactions in GIS* 13, 105-122

Vanderhaegen, M. and Muro, E. (2005) 'Contribution of a European Spatial Data Infrastructure to the Effectiveness of EIA and SEA Studies'. *Environmental Impact Assessment Review* 25 (2), 123-142

Venkatesh, V., Brown, S. A., and Bala, H. (2013) 'Bridging the Qualitative-Quantitative Divide: Guidelines for Conducting Mixed Methods Research in Information Systems'. *MIS Quarterly* 37 (1), 21-54

Vescoukis, V., Doulamis, N., and Karagiorgou, S. (2012) 'A Service Oriented Architecture for Decision Support Systems in Environmental Crisis Management'. *Future Generation Computer Systems* 28 (3), 593-604

Visconti, P., Di Marco, M., Alvarez- Romero, J., Januchowski- Hartley, S., Pressey, R., Weeks, R., and Rondinini, C. (2013) 'Effects of Errors and Gaps in Spatial Data Sets on Assessment of Conservation Progress'. *Conservation Biology* 27 (5), 1000-1010

Volante, J. N., Alcaraz-Segura, D., Mosciaro, M. J., Viglizzo, E. F., and Paruelo, J. M. (2012) 'Ecosystem Functional Changes Associated with Land Clearing in NW Argentina'. *Agriculture, Ecosystems & Environment* 154, 12-22

Wang, X. V. and Xu, X. W. (2013) 'An Interoperable Solution for Cloud Manufacturing'. *Robotics and Computer-Integrated Manufacturing* 29 (4), 232-247

Waters, J., Powers, B. J., and Ceruti, M. G. (2009) 'Global Interoperability using Semantics, Standards, Science and Technology (GIS3T)'. *Computer Standards & Interfaces* 31 (6), 1158-1166

Watson, R. T., Boudreau, M., and Chen, A. J. (2010) 'Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS Community'. *MIS Quarterly*, 23-38

Whaiduzzaman, M., Sookhak, M., Gani, A., and Buyya, R. (2014) 'A Survey on Vehicular Cloud Computing'. *Journal of Network and Computer Applications* 40, 325-344

Wilson, G. (2014) 'The Nigerian State and Oil Theft in the Niger Delta Region of Nigeria'. *Journal of Sustainable Development in Africa* 16 (1), 69-81

Wisdom, J. P., Cavaleri, M. A., Onwuegbuzie, A. J., and Green, C. A. (2012) 'Methodological Reporting in Qualitative, Quantitative, and Mixed Methods Health Services Research Articles'. *Health Services Research* 47 (2), 721-745

Woolf, A., Cramer, R., Gutierrez, M., Dam, K. K. v., Kondapalli, S., Latham, S., Lawrence, B., Lowry, R., and O'Neill, K. (2005) 'Standards- based Data Interoperability in the Climate Sciences'. *Meteorological Applications* 12 (1), 9-22

Xia, J. (2012) 'Metrics to Measure Open Geospatial Data Quality'. *J.Issues Sci.Technol.Librarianship*

Yang, Y., Shang, S., and Jiang, L. (2012) 'Remote Sensing Temporal and Spatial Patterns of Evapotranspiration and the Responses to Water Management in a Large Irrigation District of North China'. *Agricultural and Forest Meteorology* 164, 112-122

Yin, R. K. (2013) *Case Study Research: Design and Methods*.: Sage publications

Zakaria, S., Rey, G., Mohamed, E., Lavirotte, S., Abdelaziz, E. F., and Tigli, J. (2015) 'Smart Geographic Object: Toward a New Understanding of GIS Technology in Ubiquitous Computing'. *arXiv Preprint arXiv:1506.01943*

Zerneke, J. L., Buckland, M. K., and Carl, K. (2013) 'Temporally Dynamic Maps: The Electronic Cultural Atlas Initiative Experience'. *Human IT: Journal for Information Technology Studies as a Human Science* 8 (3)

Zhang, W., Wang, W., and Wang, S. (2014) 'Environmental Performance Evaluation of Implementing EMS (ISO 14001) in the Coating Industry: Case Study of a Shanghai Coating Firm'. *Journal of Cleaner Production* 64, 205-217

Zhang, Y., Zhang, Y., Gao, Y., Zhang, H., Cao, J., Cai, J., and Kong, X. (2011) 'Water Pollution Control Technology and Strategy for River–lake Systems: A Case Study in Gehu Lake and Taige Canal'. *Ecotoxicology* 20 (5), 1154-1159

Zhu, Q., Cordeiro, J., and Sarkis, J. (2013) 'Institutional Pressures, Dynamic Capabilities and Environmental Management Systems: Investigating the ISO 9000–Environmental Management System Implementation Linkage'. *Journal of Environmental Management* 114, 232-242

# APPENDICES

## APPENDIX I
## THE EIA-SDI QUESTIONNAIRE

**A SURVEY ON THE SPECIFIC EIA ACTIVITIES ON-GOING IN NIGERIA AND THE CURRENT USE OF SPATIAL DATA AS INPUTS TO EIA REPORTS**

**Part 1: Specific EIA Activities in your Organisation**

*This section comprises of questions about your organisation, the type of EIA activities on-going in your organisation, as well as its spatial distribution, to help us decipher the variation of EIA activities across Nigeria*

1. In which of the geopolitical zones of Nigeria is your organisation primarily based?
   *(Select an answer)*
   - o South-West Zone (Ekiti, Lagos, Ogun, Ondo, Oshun, and Oyo)
   - o South-South Zone (Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, and Rivers)
   - o South-East Zone (Abia, Anambra, Ebonyi, Enugu, and Imo)
   - o North-West Zone (Kaduna, Kano, Katsina, Jigawa, Kebbi, Sokoto, and Zamfara)
   - o North-Central Zone (Benue, Kogi, Kwara, Nassarawa, Niger, and Plateau)
   - o North-East Zone (Adamawa, Bauchi, Bornu, Gombe, Taraba, and Yobe)

2. Does your organisation carry out and prepare formal Environmental Impact Assessment (EIA) statements or contribute to Environmental Analysis?
   *(Select all that apply)*
   - o Carry out and prepare formal EIA statements
   - o Contribute to Environmental Analysis
   - o None of the Above / Not applicable (End of Survey)

3. Your organisation may work in more than one geopolitical zone of Nigeria. Please select where your organisation carries out EIA or contributes to Environmental Analysis?
   *(Select all that apply)*
   - o South-West Zone
   - o South-South Zone
   - o South-East Zone
   - o North-West Zone
   - o North-Central Zone
   - o North-East Zone

4. For what kind of project/plans does your organisation carry out Environmental Impact Assessments (EIA)?
   *(Select all that apply)*
   - o Oil and gas exploration
   - o Environmental health
   - o Agriculture and Food industry
   - o Extractive industry
   - o Mineral industry
   - o Chemical industry
   - o Textile; leather; wood and paper industries
   - o Disposal of waste
   - o Tourism and leisure
   - o Construction
   - o Energy Industry
   - o Non-oil and gas / Energy industry (Solar, wind, hydroelectric)
   - o Aquaculture and fisheries
   - o Oil and gas production

- Oil and gas transportation
- Other (Please specify) ________________________________________________________________

***In order to establish a baseline against which improvements to EIA activities can be measured, we will like to know the following information:***

5. How many people in your organisation are involved full-time in EIA activities including EIA report preparation?
   *(Kindly select one of the following)*
   - 1-5
   - 6-10
   - 11-20
   - 21-50
   - >50

6. What is the average time needed/taken by your organisation to complete an entire Environmental Impact Assessment (EIA) activity?
   *(Kindly select one of the following)*
   - <2 weeks
   - 2 weeks - 1 month
   - 1 month - 3 months
   - 3 month - 6 months
   - 6 month - 1 year
   - 1 year - 2 year
   - 2 years

7. Please provide an estimate of the number of environmental impact assessments your organisation carries out yearly
   (*Kindly select one of the following)*
   - 1-5
   - 6-10
   - 11-25
   - 26-50
   - 51-100
   - 101-500
   - >500

8. What is your annual turnover for carrying out Environmental Impact Assessments (EIAs)?
   *(Kindly select one of the following)*
   - <20 million NGN
   - 20 million to 50 million NGN
   - 50 million to 100 million NGN
   - 100 million to 200 million NGN
   - 200 million to 300 million NGN
   - 30 million to 400 million NGN
   - >400 million NGN

9. Do you have experience with cross-border EIAs?
   *(Please choose only one of the following)*
   - Yes
   - No

**Part 2: Current Use of Spatial Data as Inputs to EIA Reporting**

*In this section we would like to know about your experience with the use of spatial data when preparing EIA reports (Spatial data refers to data that define a location and can be directly or indirectly referenced or attributed to a certain location on earth)*

10. Please indicate which spatial data is frequently used by your organisation for preparing EIA reports *(Select all that apply)*
    - o Addresses
    - o Administrative units
    - o Agricultural and aquaculture facilities
    - o Area management, restriction, regulation zones and reporting units
    - o Atmospheric conditions
    - o Bio-geographical regions
    - o Buildings
    - o Cadastral parcels
    - o Coordinate reference systems
    - o Elevation
    - o Energy resources
    - o Environmental monitoring facilities
    - o Geographical grid systems
    - o Geographical names
    - o Geology
    - o Habitats and biotopes
    - o Human health and safety
    - o Hydrography
    - o Land cover
    - o Land use
    - o Meteorological geographical features
    - o Mineral resources
    - o Natural risk zones
    - o Oceanographic geographical features
    - o Orthoimagery
    - o Population distribution - demography
    - o Production and industrial facilities
    - o Protected sites
    - o Species distribution
    - o Statistical units
    - o Transport networks
    - o Utility and governmental services
    - o Other (please specify)___________________________________________

11. What are your sources of spatial data? *(Select all that apply)*

    - o Environmental Protection Agencies
    - o Mapping agencies
    - o Geological surveys
    - o National maritime administration
    - o Cadastral
    - o Land registration
    - o Other land administration organisations
    - o Local authorities/local government
    - o Utilities
    - o Private data producers
    - o We produce spatial data for our EIAs
    - o Other (please specify): ________________________________________________________________

12. Do you find the current sources of spatial data sufficient for EIA reporting? *(Select one of the following)*

- Yes
- No

Please give reasons ______________________________________

13. Does your organisation engage in predictive modelling of impacts?
*(Select one of the following)*
    - Yes
    - No

    Please give reasons
    ____________________________________________________________________________

14. Will access to spatial data help address the problem of non-testable and non-auditable predictions?
*(Select one of the following)*
    - Yes
    - No

    Please give reasons
    ____________________________________________________________________________

15. What type of EIA activity does your organisation utilise spatial data for?
*(Select all that apply)*
    - Visualisation/presentation of impacts
    - Identification of impacts
    - Simple analysis/forecasting of impacts
    - Complex analysis/forecasting of impacts, using modelling and scenario analysis etc.
    - Other (*please specify*)
    ________________________________________________________________________________

16. Does the access to spatial data make EIA reporting more efficient?
*(Kindly select one of the following)*
    - Very efficient
    - Efficient
    - Moderately efficient
    - Less efficient
    - Inefficient

17. Does your organisation reuse spatial data that was acquired for one EIA report to produce other EIA reports?
*(Select one of the following)*
    - Yes
    - No

18. Will you say spatial data are difficult to use?
*(Select one of the following)*

- Yes
- No

**Please answer the follow-on question for Question 19**

If you answered yes to Question 19 above, please indicate the type of problems you or your organisation are currently experiencing
(S*elect all that apply)*

- Finding it
- Accessing it
- Integrating it with other data
- Its quality
- Its cost

- None of the above
- Other (*please specify)*

  ______________________________________________________________________

19. How do the problems affect the preparation of EIA reporting in Nigeria?
    *(Select all that apply)*
    - Lower level of accuracy when describing impacts
    - Higher uncertainty of impacts
    - Higher costs of studies
    - Takes more time
    - Other (*please specify)*

    ______________________________________________________________________

20. Please suggest ways to overcome these problems

______________________________________________________________________

**Part 3: Current Level of the Use of NGDI Procedures and Protocols in the Oil and Gas Industry**
*In this section, we would like to know the factors that constrain the use of Geospatial Data in Nigeria.*

21. Are you familiar with the National Spatial Data Infrastructure (NGDI) in Nigeria?
    *(Kindly select one of the following)*
    - Yes
    - No

22. Do you have adequate access to data from the Nigerian NGDI?
    *(Kindly select one of the following)*
    - Yes
    - No

    If your answer to 23 above was No, what do you think is the cause of the inaccessibility of NDSI data?

    ______________________________________________________________________

23. Do you agree that the state of the Nigerian NGDI affects the quality of data used for EIA and subsequently the effectiveness of EIA reports in the oil and gas sector?
    *(Kindly select one of the following)*
    - Yes
    - No

24. Will you say that current protocols and procedures in the Nigerian NGDI are sufficient enough to support the geospatial data needs of EIA practitioners in the oil and gas sector?
    *(Kindly select one of the following)*
    - Yes
    - No

25. Rate how effective you feel the current NGDI procedures and protocols are in Nigeria?
    *(Kindly select one of the following)*
    - Very effective
    - Effective
    - Moderately effective
    - Less effective
    - Ineffective

26. Please give reasons for your answer to **Question 26** above

    ______________________________________________________________________

27. Can you please suggest ways you think the issues you raised on **Question 26** can be resolved?

    ______________________________________________________________________

**Part 4: Effect of NGDI on Working Practices of EIA Practitioners**

*This section will enable us decipher the level of effect NGDI has on the performance of EIA practitioners.*

28. Will you say the EIA carried out in the Nigerian oil and gas sector are done in strict adherence to industry best practices?
    (*Kindly select one of the following)*
    - o Yes
    - o No

29. Do you think the dual EIA jurisdiction is an effective approach for managing environmental impacts in the oil and gas industry?
    (*Kindly select one of the following)*
    - o Yes
    - o No

    Please give reasons_____________________________________________

30. What do you think are the key issues with conducting an EIA in the Nigerian oil and gas sector, and give reasons?

    ________________________________________________________________________________

31. Who do you consider as the primary source of the issues stated in **Question 31** above?
    (*Select all that apply)*
    - o Government
    - o EIA practitioners
    - o Oil and gas operators
    - o All of the above

32. Kindly state reasons for your answer to **Question 32** above

    ________________________________________________________________________________

33. To what extent do you think these issues affect the quality of EIA conducted in the oil and gas sector?
    (*Kindly select one of the following)*
    - o To a great extent
    - o To a considerable extent
    - o To a moderate extent
    - o To a slight extent
    - o Not at all

34. Do you agree to the notion that an adequately updated NGDI will have no significant influence on the way EIA is being carried out in the Nigerian oil and gas sector?
    *(Select one of the following)*
    - o Yes
    - o No

35. Please give reasons for your answer to **Question35** above

________________________________________________________________________________

36. What factors do you feel can improve the current situation

________________________________________________________________________________

**THANK YOU**

Your responses have been recorded in our database. Your input is highly valued and we sincerely appreciate the time you have taken out of your busy schedule to partake in this research survey.

# APPENDIX II
# THE NGDI-CF EVALUATION INTERVIEW QUESTIONS

**Determining User Experience and Technical Proficiency (Know-how) of Respondents**

*This section comprises of questions about your organisation, your technical proficiency, and the current issues bothering on spatial data use*

1. *Can you confirm your level of technical proficiency with computers and GIS applications? (Kindly select one of the following)*
    - o *Expert*
    - o *Intermediary*
    - o *Starter*

2. Please state the name of your organisation.

    ______________________________________________

    a) Select the appropriate category your organisation belongs to.
    - o Spatial data end user
    - o Spatial data provider
    - o Spatial policy maker

3. Kindly describe the type of task you utilise GIS and geospatial data for?

    ______________________________________________

4. What problems do you currently face with the access and use of spatial data for you work?

    ______________________________________________

    a) Are there any particular problems with the use of the accessed spatial data with GIS?

    ______________________________________________

5. Kindly confirm your familiarity with the Nigerian geospatial data infrastructure (NGDI)
    - o Very familiar
    - o Familiar
    - o Unsure
    - o Unfamiliar
    - o Very unfamiliar

6. How would you describe the NGDI development in Nigeria with regards to providing spatial data for environmental management protocols? And why?

    ______________________________________________

7. Can you highlight some of the protocols employed in the management of the NGDI for data dissemination? Stating the current structure, routes and corresponding rules.

    ______________________________________________

8. In the first part of this research, 90.80% of the respondents asserted that the current protocols in the NGDI were not sufficient to support geospatial data needs.

    a) Do you agree with this statement? *(Kindly select one of the following)*
    - o Strongly agree
    - o Agree
    - o Unsure
    - o Disagree
    - o Strongly disagree

    b) Please provides reasons for your answer to 8a)

______________________________________________________________________

9. Can you highlight some of the factors limiting the current NGDI? Can you also state some factors you consider critical to successfully implementing the current NGDI?

______________________________________________________________________

10. As a follow-up to question 9 above, can you please indicate your level of agreement with the following statements; please discuss any additional comments.

| | Strongly agree | Agree | Unsure | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| The low technological proficiency of the end user is responsible for the reduced SDI implementation | | | | | |
| Unclear protocol for data sharing limits the implementation of SDI partnership arrangements in Nigeria | | | | | |
| There is a very clear protocol for data access through the NGDI | | | | | |
| It is very easy to find and access suitable data through the NGDI | | | | | |
| The user interface/infrastructure for the NGDI clearing house is not easily accessible to end users | | | | | |
| The cost of accessing data from the NGDI is reasonable. | | | | | |
| I can access interoperable spatial data from the NGDI easily | | | | | |
| Data from the NGDI are obsolete as they are not frequently updated. | | | | | |
| Data from the NGDI are not accurate or interoperable with other data so it causes challenges during analysis | | | | | |
| I am very willing to participate in a spatial data sharing partnership within the NGDI | | | | | |
| Lack of adequate funding limits the advancement of the NGDI in Nigeria | | | | | |

11. What processes or protocols do you think can be implemented to achieve the following?
    a) Improve the access to the NGDI in Nigeria
    ______________________________________________________________________
    b) Improve the quality of data resident in the NGDI
    ______________________________________________________________________
    c) Encourage partnership arrangements where end users can contribute to updating the database thus making it more robust and less obsolete?
    ______________________________________________________________________

12. A number of problems were identified during the course of the prototype development have been highlighted below. In a scale of 1 – 5, where 1 is connotes the issue with utmost importance, please rank the top five most important issue. These have been grouped based on the components of an SDI as shown below;

| Category | Issue | Rank |
|---|---|---|
| Standards | Inconsistent scales and reference systems | |
| | Integrating data of standards with little or no interoperability | |
| Policy | Lack of open spatial data policy in Nigeria | |
| | Inexistent partnership arrangement | |
| | Restricted data sources | |
| Access Network | Ease of access | |
| | Usability and interoperability of accessed datasets | |
| Data | Access to Nigerian datasets | |
| | Quality of accessed data | |
| | Cost of accessing data | |
| | Query data and handling requests | |
| People | Technical proficiency | |
| | Availability of technical documentation | |
| | Awareness of data/SDI existence | |

13. Kindly discuss these issues and highlight any other issue(s) you think may pose as a limitation.

    ________________________________________

14. a) Does the prototype demonstrate how an effective NGDI could improve spatial data access for environmental management protocols like EIA? And why

    ________________________________________

    b) Based on your answer to question 14a) above, in a scale of 1 – 5, where 1 is the highest score, how would you rate the proposed idea?
    - 1
    - 2
    - 3
    - 4
    - 5

15. What problems do you see with the proposed idea?

    ________________________________________

16. Please provide general comments on any additions or modifications you would like to see in an SDI data access web application that might help with the development of a more useful system?

    ________________________________________

**THANK YOU SO MUCH FOR YOUR TIME.**

Your responses have been recorded in our database. Your input is highly valued and we sincerely appreciate the time you have taken out of your busy schedule to partake in this research survey.

- Please indicate if you would like me to keep in touch.

a) Yesb) No

# APPENDIX III
# THE PROTOTYPE PERFORMANCE AND USER EVALUATION SCRIPT

**Evaluation Tasks**

1. What processes or protocols do you think can be implemented to encourage partnership arrangements where end users can contribute to updating the database thus making it more robust and less obsolete?
2.

*In this section you would be required to go through a number of tasks in the developed prototype after which you would answer questions on the usability, applicability and reliability of the prototype.*

The prototype development involved the configuration of an SDI (GDI) demo from which an interoperable GIS web application was deployed to enable spatial data access, utilization and dissemination. It is hoped that building on the prototype would also create/enhance spatial data sharing partnerships among stakeholders to improve NGDI adoption and also maintain NGDI data. The following steps include a number of tasks aimed for evaluating the prototype to identify areas of improvement and highlight its wider application towards contributing to the emergent NGDI in Nigeria.

1. Open a web browser, log on to http://52.30.157.153/demo/index.html or log on to the local host version via the computer provided. Perform the following operations;
   a. Click on 'search' using the plugin at the bottom of the demo window. Click to 'integrate' one or more layer into the web map.
   b. Explore the map. Select a feature and view the attributes of any point selected by clicking on the (i) identify tool to view the feature info.
   c. For data sharing, click on 'share'. Complete the form to share interoperable datasets to the database.
2. *On the web app user interface, perform the following operations;*
   a. *Use the "" and "delete" button at the bottom of the web app window to edit selected features and click on "save" to save the outcome.*

   b. *Click on export to export the attribute of the selected feature*.

3. To download data for analysis using any GIS software of your choice, log on to, http://52.30.157.153:8080/geoserver/web/?wicket:bookmarkablePage=:org.geoserver.web.demo.MapPreviewPage

i) Copy the WMS/WFS url and import it into a GIS application of your choice for analysis.
ii) To view the data online, copy the WMS url following the steps from the Layer preview panel and perform the following tasks;

   a. Open a notepad or notepad++
   b. Enter the extjs gpl cdn and the leaflet.js script as provided below

```
<html>
<head>
<title>A Leaflet map!</title>
<link rel="stylesheet" href="http://cdn.leafletjs.com/leaflet/v0.7.7/leaflet.css" />
<script src="http://cdn.leafletjs.com/leaflet/v0.7.7/leaflet.js"></script>
</body>
</html>
```

   c. Enter the wms url you copied from the geoserver layer preview page
   d. Save the resultant page as .html
   e. Open the html page and explore the exported map

**Prototype Performance and User Satisfaction**

*In this section, we would like to assess the prototype performance and user satisfaction based on* ***ISO 9241-210 usability standard.***

1. Do you feel the design is based upon explicit understanding of users, tasks and environments?
   *(Kindly select one of the following)*
   - Very effective
   - Effective
   - Unsure
   - Less effective
   - Ineffective
2. Do you feel the prototype is an effective demonstration for accessing spatial data access from an SDI?
   *(Kindly select one of the following)*
   - Very effective
   - Effective
   - Unsure
   - Less effective
   - Ineffective
3. Do you think that the instructions and prompts in the user-interface are helpful?
   *(Kindly select one of the following)*
   - Very helpful
   - Helpful
   - Unsure
   - Less helpful
   - Very unhelpful
4. Do you agree that the system is presented in a clear and understandable manner?
   *(Kindly select one of the following)*
   - Strongly Agree
   - Agree
   - Unsure
   - Disagree
   - Strongly Disagree
5. Would you say it was easy to go through the evaluation tasks on the prototype?
   *(Kindly select one of the following)*
   - Very easy
   - Easy
   - Unsure
   - Hard
   - Very hard
6. Are you satisfied with using the prototype?
   *(Kindly select one of the following)*
   - Very satisfied

- Satisfied
- Unsure
- Dissatisfied
- Very Dissatisfied

7. Would you recommend the prototype and data access protocols to your colleagues? (*Kindly select one of the following)*
   - Very likely
   - Likely
   - Unsure
   - Not likely
   - Not at all
8. Do you think the proposed cloud-based SDI data access and sharing solution would help improve SDI adoption? And why?

   ______________________________________________________________

9. From the iterative prototype development, 'share', 'save', 'search', delete', and 'create' functions were proposed. The current prototype includes only the 'share' (partnership arrangements) and 'search' (access data) functions which are sufficient for this demonstration. Do you think the current 'search' and 'share' function as well as the proposed 'create', 'delete', 'save' functions would help, and why?

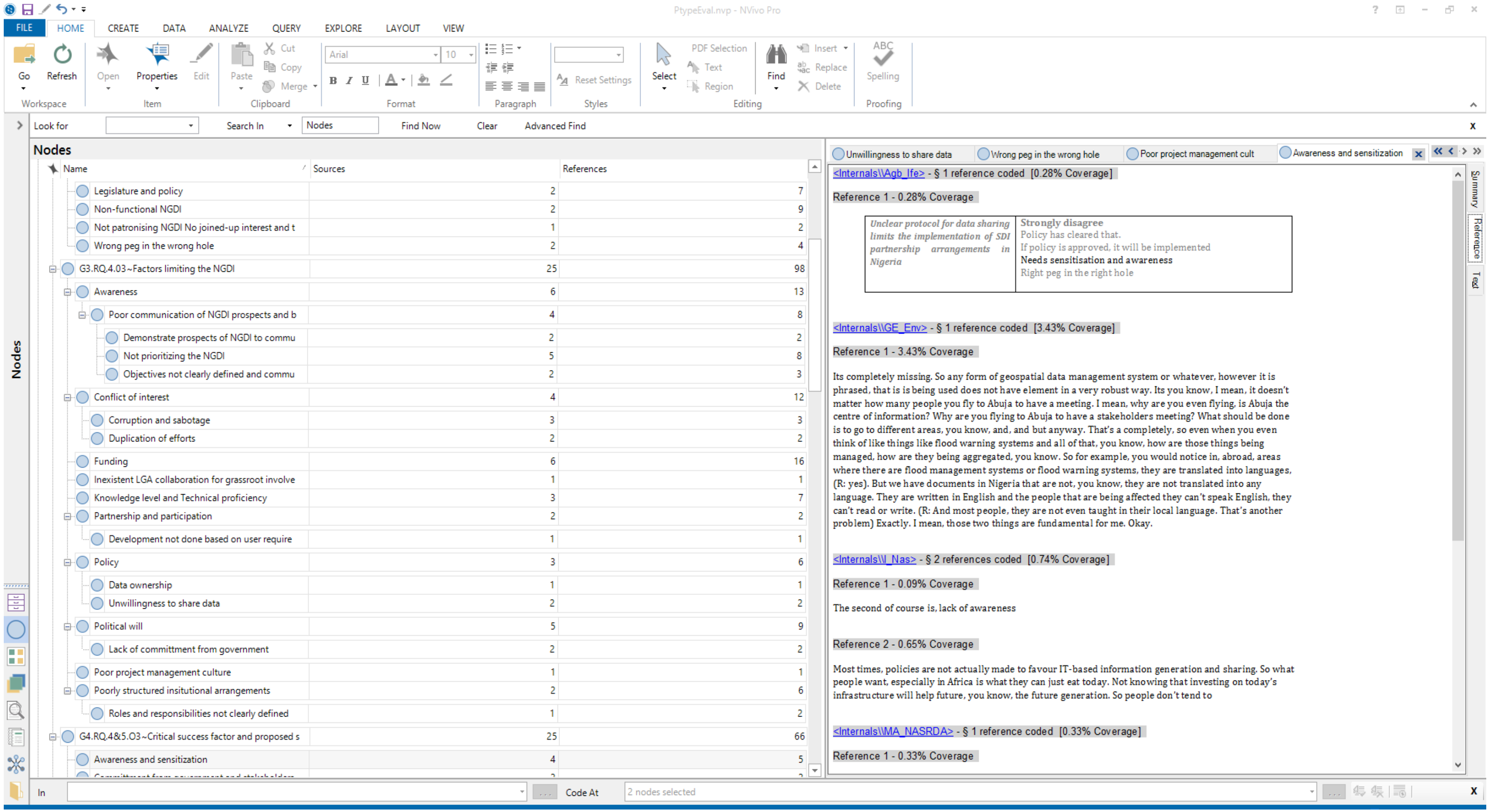
   ______________________________________________________________

10. Do you agree that development of this prototype address the concerns of accessing NGDI data highlighted in Part 1 of the questionnaire above?
    - Strongly Agree
    - Agree
    - Unsure
    - Disagree
    - Strongly Disagree

11. Please indicate how the use of this prototype affected your ability to perform the following tasks; (*Kindly tick as appropriate)*

| | Strongly Agree | Agree | Unsure | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| I was able to find suitable spatial data via the prototype | | | | | |
| The access links provided me with relevant resources | | | | | |
| The user-interface of the web application provided me access to download spatial data | | | | | |
| The interface supports partnership arrangement, as I was able to upload spatial data for others to access | | | | | |
| The interface supports data analysis as I was able to explore the features of the data and analyse the data | | | | | |
| The interface supports data updating to overcome the issues of data redundancy as I was able to update and delete obsolete/incorrect data with the right permissions | | | | | |

# APPENDIX IV
# EXAMPLE OF QUALITATIVE DATA CODING IN NVIVO



# APPENDIX V
# PROGRAM CODE FOR THE PROTOTYPE LANDING PAGE

```
Ext.Loader.setConfig({
   enabled: true,
   disableCaching: false,
   paths: {
            GeoExt: "../geoext2-2.1.0/src/GeoExt",
            Ext: "../ext-4.2.1.883/src"
   }
}) ;
```

The index.htm code;

```
<html>
<head>
<!-- Set the title for the homepage -->
<title>SDI Access Demo</title>

<!-- Load Ext -->
            <script type="text/javascript" src="../ext-4.2.1.883/examples/shared/include-ext.js"></script>
<script type="text/javascript" src="../ext-4.2.1.883/examples/shared/options-toolbar.js"></script>
<script language="JavaScript" SRC="mysdi.js"></script>
            <link rel="stylesheet" type="text/css" href="../ext-4.2.1.883/examples/shared/example.css">

<!-- Load Openlayers -->
<script src="../OpenLayers-2.13.1/OpenLayers.js"></script>

<!-- Load our modules loader.js and map.js -->
<script type="text/javascript" src="loader.js"></script>
            <script type="text/javascript" src="map1.js"></script>

            <style type="text/css">
      .legend {
         padding-left: 18px;
      }
      .x-tree-elbow, .x-tree-elbow-end {
         width: 3px !important;
      }
      .gx-tree-layer-icon {
         display: none !important;
      }
      button,
.buttons a {
   cursor: pointer;
   font-size: 9.75pt;  /* maximum size in WebKit to get native look buttons without using zoom */
   -moz-user-select: none;
   -webkit-user-select: none;
   -webkit-tap-highlight-color: transparent;
}
.buttons a {
   margin: 2px;
   padding: 3px 6px 3px;
   border: 2px outset buttonface;
   background-color: buttonface;
   color: buttontext;
   text-align: center;
   text-decoration: none;
   -webkit-appearance: button;
}
button img,
.buttons a img {
   -webkit-user-drag: none;
   -ms-user-drag: none;
}
.buttons form {
   display: inline;
   display: inline-block;
```

```
}
</style>

</head>
<body>
<div id="desc">
<h1>Spatial Data Integration(SDI) Access Demonstration</h1>
<h2> Find and download data from other sources or publish your data for sharing</h2>
<a href="action1.htm"><button type="button" style="width:100px; height:30px; background-
color:lightblue">Search</button></a>
<a href="action2.htm"><button type="button" style="width:100px; height:30px; background-
color:lightblue">Share</button></a>
<p>......
</div>
</body>
</html>
```

And the map.js code;

```
Ext.require([
    'Ext.container.Viewport',
    'Ext.layout.container.Border',
    'GeoExt.tree.Panel',
    'Ext.tree.plugin.TreeViewDragDrop',
    'GeoExt.panel.Map',
    'GeoExt.tree.OverlayLayerContainer',
    'GeoExt.tree.BaseLayerContainer',
    'GeoExt.data.LayerTreeModel',
    'GeoExt.tree.View',
 ]);
var mapPanel, tree;

Ext.application({
    name: 'Tree',
    launch: function() {
                // create a map panel with some layers that we will show in our layer tree
        // below.
        mapPanel = Ext.create('GeoExt.panel.Map', {
            border: true,
            region: "center",
            // we do not want all overlays, to try the OverlayLayerContainer
            map: {allOverlays: false},
            center: [8, 10],
            zoom: 10,
                                layers: [

                var wms = new OpenLayers.Layer.WMS(
                                                "OpenLayers WMS - Basic",
                                                "http://vmap0.tiles.osgeo.org/wms/vmap0",
                    {layers: 'basic'},
                ),
                new OpenLayers.Layer.WMS("Administrative Areas",
                    "http://52.18.169.105:8080/geoserver/tubo/wms?", {
                        layers: "Adm",
                        transparent: true,
                        format: "image/png"
                    }, {
                        isBaseLayer: false,
                        resolutions: [
                            1.40625,
                            0.703125,
                            0.3515625,
                            0.17578125,
                            0.087890625,
                            0.0439453125,
                            0.02197265625,
                            0.010986328125,
                            0.0054931640625
                        ],
```

```
            buffer: 0
        }
    ),
                                    new OpenLayers.Layer.WMS("Oil and Gas Fields",
        "http://52.18.169.105:8080/geoserver/tubo/wms?",
        {
            layers: 'OilAndGasFields',
            format: 'image/png',
            transparent: true
        },
        {
            singleTile: true,
            visibility: false
        }
    ),

    new OpenLayers.Layer.WMS("Landuse",
        "http://52.18.169.105:8080/geoserver/tubo/wms?", {
            layers: "Landuse",
            transparent: true,
            format: "image/png"
        }, {
            isBaseLayer: false,
            buffer: 0
        }
    ),
    new OpenLayers.Layer.WMS("Mineral Deposits",
        "http://52.18.169.105:8080/geoserver/tubo/wms?",
        {
            layers: 'mineral_deposits',
            format: 'image/png',
            transparent: true
        },
        {
            singleTile: true,
            visibility: false
        }
    ),

    // create a group layer (with several layers in the "layers" param)
    // to show how the LayerParamLoader works
    new OpenLayers.Layer.WMS("sdi_access_demo (Group Layer)",
        "http://52.18.169.105:8080/geoserver/tubo/wms?", {
            layers: [
                "tubo:mineral_deposits",
                "tubo:OilAndGasFields",
    "tubo:WaterLines",
    "tubo:Landuse",
                "tubo:SurfaceGeology",
                "tubo:LGAs",
    "tubo:Adm",
                                                ],
            transparent: true,
            format: "image/gif"
        }, {
            isBaseLayer: false,
            buffer: 0,
            // exclude this layer from layer container nodes
            displayInLayerSwitcher: false,
            visibility: false
        }
    )
  ]
});

 // create our own layer node UI class, using the TreeNodeUIEventMixin
//var LayerNodeUI = Ext.extend(GeoExt.tree.LayerNodeUI, new GeoExt.tree.TreeNodeUIEventMixin());
```

```
/*var treeConfig = [
    {nodeType: 'gx_layercontainer', layerStore: map.layers}
{
    nodeType: "gx_baselayercontainer"
}, {
    nodeType: "gx_overlaylayercontainer",
    expanded: true,
    // render the nodes inside this container with a radio button,
    // and assign them the group "foo".
    loader: {
        baseAttrs: {
            radioGroup: "foo",
            uiProvider: "layernodeui"
        }
    }
}, {
    nodeType: "gx_layer",
    layer: "tubo (Group Layer)",
    isLeaf: false,
    // create subnodes for the layers in the LAYERS param. If we assign
    // a loader to a LayerNode and do not provide a loader class, a
    // LayerParamLoader will be assumed.
    loader: {
        param: "LAYERS"
    }
}];
var wfs = new OpenLayers.Layer.Vector(
    "Stavros Features",
    {
        strategies: [new OpenLayers.Strategy.Fixed()]
        , projection: new OpenLayers.Projection("EPSG:4326")
        , protocol: new OpenLayers.Protocol.WFS({
            version: "1.1.0",
            url: "http://52.18.169.105:8080/geoserver/wfs",
            featurePrefix: 'tubo', //geoserver worspace name
            featureType: "mineral_deposits", //geoserver Layer Name
            featureNS: "http://52.18.169.105:8080/geoserver/tubo", // Edit Workspace Namespace URI
            geometryName: "bounds" // field in Feature Type details with type "Geometry"
        })
    });*/

var store = Ext.create('Ext.data.TreeStore', {
    model: 'GeoExt.data.LayerTreeModel',
    root: {
        expanded: true,
        children: [
            {
                plugins: [{
                    ptype: 'gx_layercontainer',
                    store: mapPanel.layers
                }],
                expanded: true
            }, {
                plugins: ['gx_baselayercontainer'],
                expanded: true,
                text: "Base Maps"
            }, {
                plugins: ['gx_overlaylayercontainer'],
                expanded: true
            }
        ]
    }
});

var layer;
```

```
        // create the tree with the configuration from above
        tree = Ext.create('GeoExt.tree.Panel', {
            border: true,
            region: "west",
            title: "Layers",
            width: 250,
            split: true,
            collapsible: true,
            collapseMode: "mini",
            autoScroll: true,
            store: store,
            rootVisible: false,
            lines: false,
            tbar: [{
                text: "remove",
                handler: function() {
                    layer = mapPanel.map.layers[2];
                    mapPanel.map.removeLayer(layer);
                }
            }, {
                text: "add",
                handler: function() {
                    mapPanel.map.addLayer(layer);
                }}
            ]
        });

        Ext.create('Ext.Viewport', {
            layout: "fit",
            hideBorders: true,
            items: {
                layout: "border",
                deferredRender: false,
                items: [mapPanel, tree, {
                    contentEl: "desc",
                    region: "south",
                    bodyStyle: {"padding": "5px"},
                    collapsible: true,
                    collapseMode: "mini",
                    split: true,
                    width: 200,
                    title: "Description"
                }]
            }
        });

        Ext.create('Ext.Viewport', {
            layout: "fit",
            hideBorders: true,
            items: {
                layout: "border",
                deferredRender: false,
                items: [mapPanel, tree, {
                    contentEl: "desc",
                    region: "south",
                    bodyStyle: { "padding": "5px" },
                    collapsible: true,
                    collapseMode: "mini",
                    split: false,
                    width: 200,
                    title: "Hello"
                }]
            }
        });
    }
})
```

# APPENDIX VI
# FRAMEWORK (SDI-AF) VALIDATION INSTRUMENT

### SDI AUGMENTATION FRAMEWORK VALIDATION

Thank you for discussing your experience of SDI and the NGDI with me earlier in the year and helping me to evaluate the core part of my proposal for an SDI Architecture. Following your feedback I have now created an Augmentation Framework for SDI, designed to help SDI stakeholders put in place the appropriate instruments to increase likelihood of a successful implementation of SDI. I would appreciate very much if you could help me evaluate this by providing me with your comments on my proposal.

This document is written out as follows:

1. Introduction of the SDI Augmentation Framework
2. Components of the SDI Augmentation Framework
3. Validation Questions

I would like you to consider carefully the description and case for the SDI Augmentation Framework that I have presented and answer the question.

### 1.0. INTRODUCTION OF THE SDI AUGMENTATION FRAMEWORK

The SDI Augmentation framework was designed from the results of three empirical studies conducted in this research; EIA-SDI case, the PPU and the NGDI-CF. These studies surveyed stakeholders in the field of environmental management in Nigeria. The EIA-SDI case assessed the problems bothering spatial data use in Environment Impact Assessments (EIA) reporting and the prospects of an effective Spatial Data Infrastructure (SDI) in alleviating the problems. The Prototype Performance and User evaluation (PPU) evaluated the validity and usability of the prototype solution (SDI Data Access Protocol) developed in this research. And the NGDI-CF assessed the factors critical to improving the National Geospatial Data Infrastructure (NGDI) in Nigeria. Chief of the problems underlined from these studies were; access, cost, data accuracy, data availability and data quality. Though there has been some progress made with the development NGDI draft policy and institutional arrangements, the policy is yet to be passed into law and the NGDI clearinghouse is yet to be implemented. The absence of the clearinghouse impedes the access to the NGDI (makes it inaccessible) thus making it insufficient to support geospatial data needs. To address this problem the SDI augmentation framework puts forward a bottom-up approach for the implementation of SDIs using a scalable distributed SDI data access protocol as shown in figure 1.1 below.

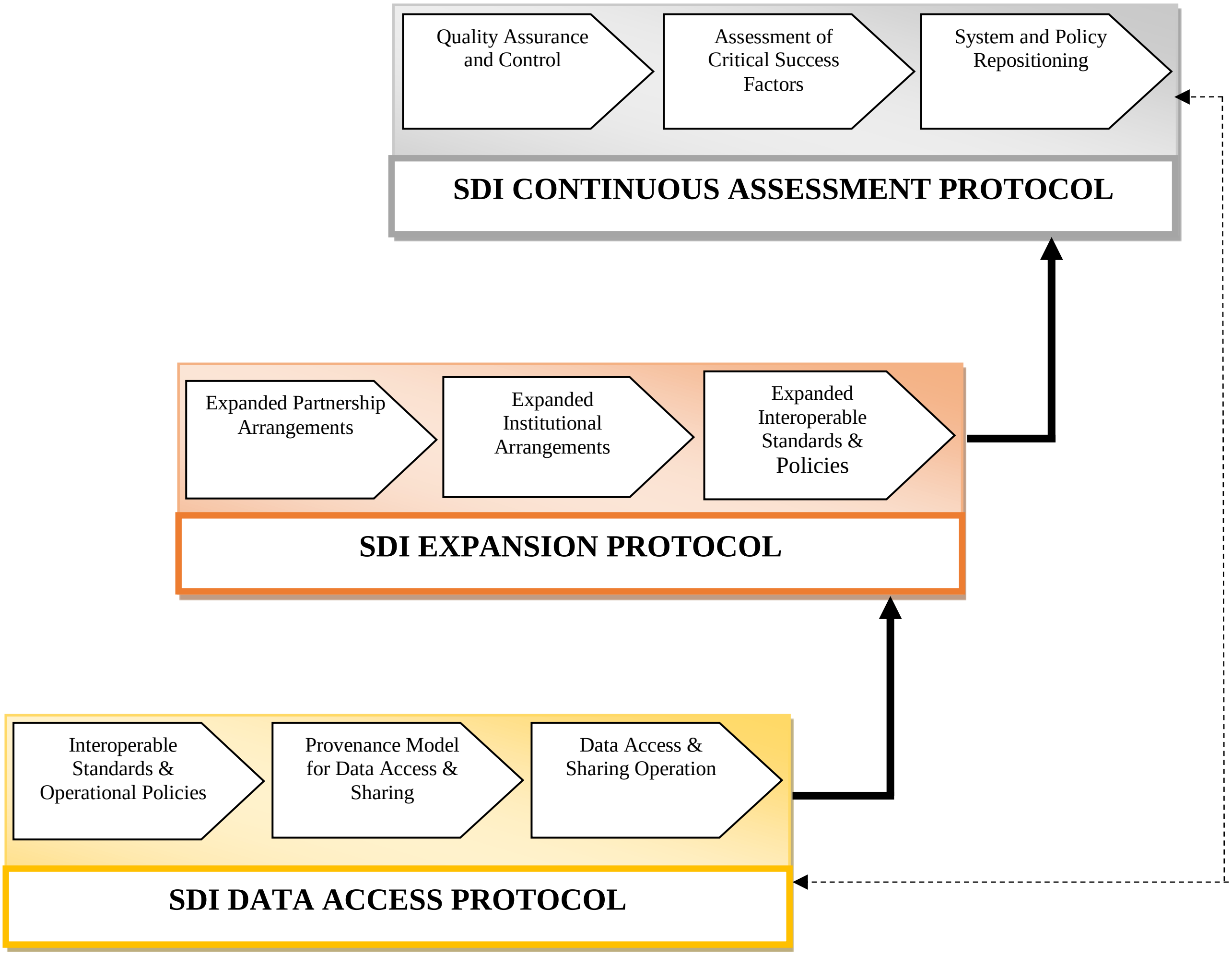



Figure 1: SDI Augmentation Framework

We contend that one of the main problems in the advancement of SDI has been the emphasis on a centralised, top-down approach and argue that a scalable, bottom-up, distributed approach, which could progress alongside a top-down approach, would offer more opportunity to exploit available spatial data to the benefit of local economies. In developing countries like Nigeria, the issue of a clearing house has shown to be problematic. Clearing houses are expensive to implement, require cooperation from many parties, and good underlying technical infrastructure across the regions covered. These aspects have been more problematic in Nigeria because of security in some areas, economic issues, lack of robust, reliable, pervasive underlying infrastructure and multi-level jurisdiction. Other developing countries suffer with similar problems.This framework addresses this need by developing a bottom-up data access protocol based on web services as an alternative to the centralised approach, to create a new type of SDI which can be built up gradually and be user-driven. That is, the framework matures from the SDI data access protocol into the expanded SDI in the SDI expansion protocol which then matures into the full blown SDI that is reviewed and updated bi-annually using the SDI continuous assessment protocol.

The components of the framework are presented in section 2 below.

# 2.0. COMPONENTS OF THE SDI AUGMENTATION FRAMEWORK

## 2.1. SDI DATA ACCESS PROTOCOL

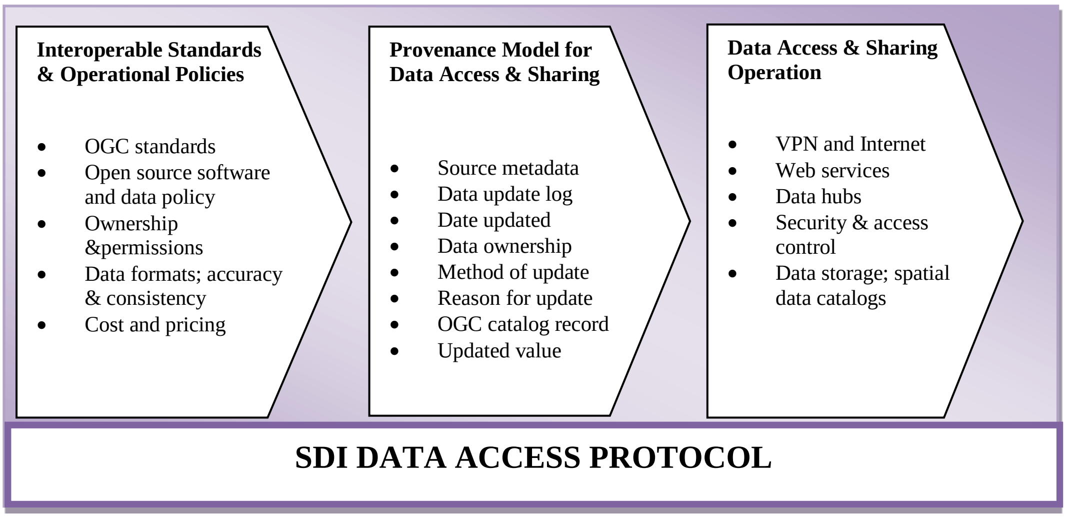



Figure 2: SDI Data Access Protocol

The framework is built on the basis of the data access protocol. It comprises of three key areas. The interoperable standards and operational policies are important to the seamless access and sharing accurate, compatible, consistent and quality data. It also includes agreements for data ownership and permissions for access control. It utilises open source software and thus the open source policy. To support quality of data in a bottom–up approach a provenance model has been included for data access and sharing in the data access protocol. The provenance model enables the recording of a provenance link to a previous catalog entry (or entries) from which the queried entry is derived. It assumes a catalog entry for each ancestor data set.

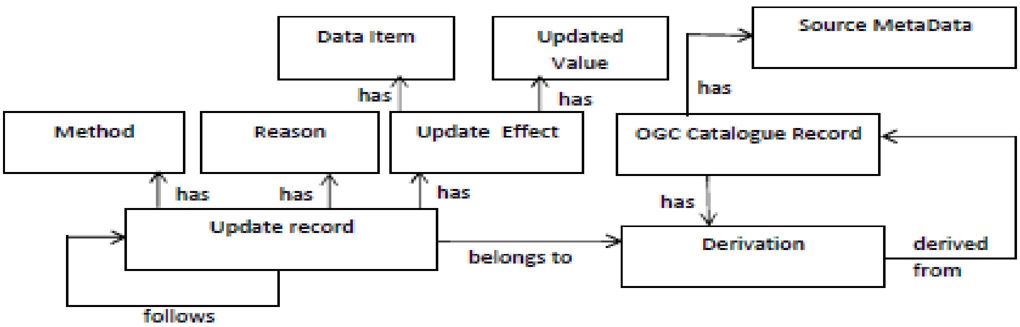



Figure 3: Provenance model

The provenance method ensures the maintenance of an acceptable quality level in the distributed, scalable approach as it ensures information is provided about the provenance of the data set. This will include items such as its ownership, its history in terms of how it was derived and its update log hence it is different and more valuable than just having metadata records which is the current practice. Users can then decide how far to trust the data provided according to their application needs. Similarly access control can be specified at various levels, from publicly accessible to group-limited in the expanded SDI (level 2: SDI expansion protocol). In the latter case, (SDI expansion protocol) potential users would need to apply for access to the data and if successful would be assigned to an access group.

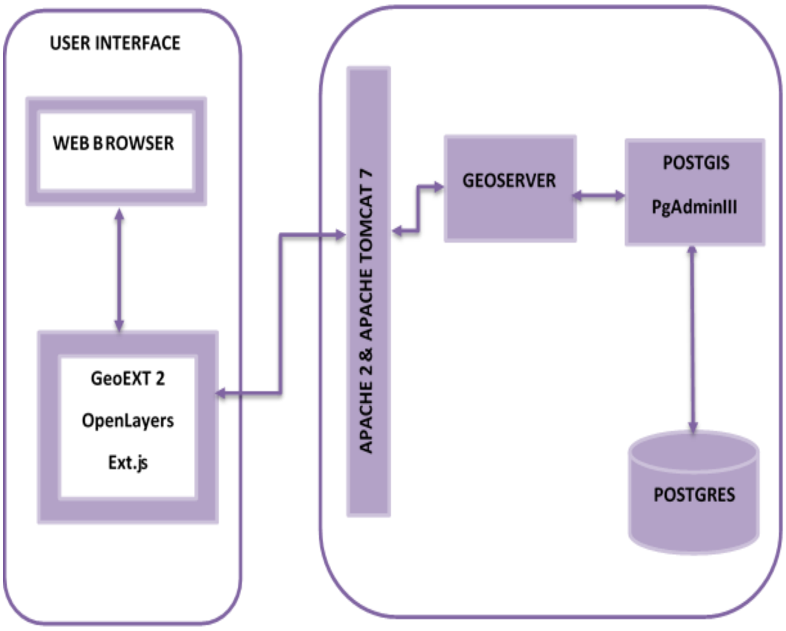



Figure 4: Data access operation

For the development of the data access and sharing operation, SDI Various software and components were coupled together to create a flexible web-based system to store, process and transfer spatial data to enable easy access and sharing, thus increasing the usability of the prototype to prospective users. The resulting system realises the Data Sharing Protocol. The whole system was implemented for demonstration purposes on an Amazon Web Services virtual machine.

The Data Access Protocol supports spatial data providers and consumers. Providers can choose to restrict access or make data publicly available through the possibility of assigning access controls to data sets. Consumers need to run client software such as Java Open Layers which allows display of linked geographical data sets.

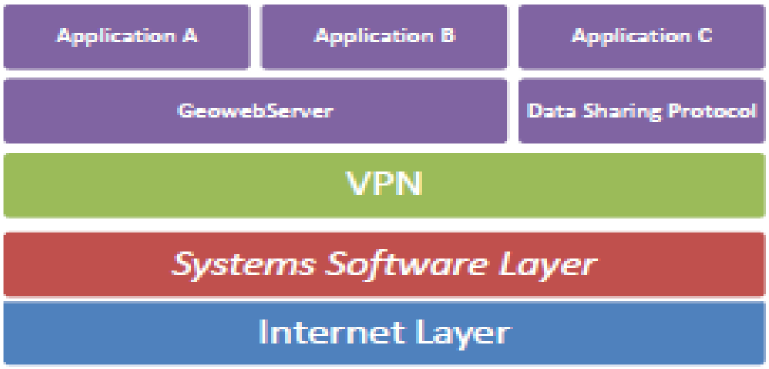



Figure 5: System Architecture of the Data Access and Sharing Operation

Providers need to run data base and web server software capable of handling spatial data. In the prototype, Geoserver was used with OGC standards Web Map Service (WMS) and Web Feature Service (WFS) for the data sets.

The internet is assumed as the underlying connection but VPNs can be established for applications requiring increased security. A unique feature of the Data Access Protocol is the addition of the provenance facility which can be used to enable consumers to see where the data comes from and its update history. Extra security can be implemented through access control.

### 2.2. SDI EXPANSION PROTOCOL

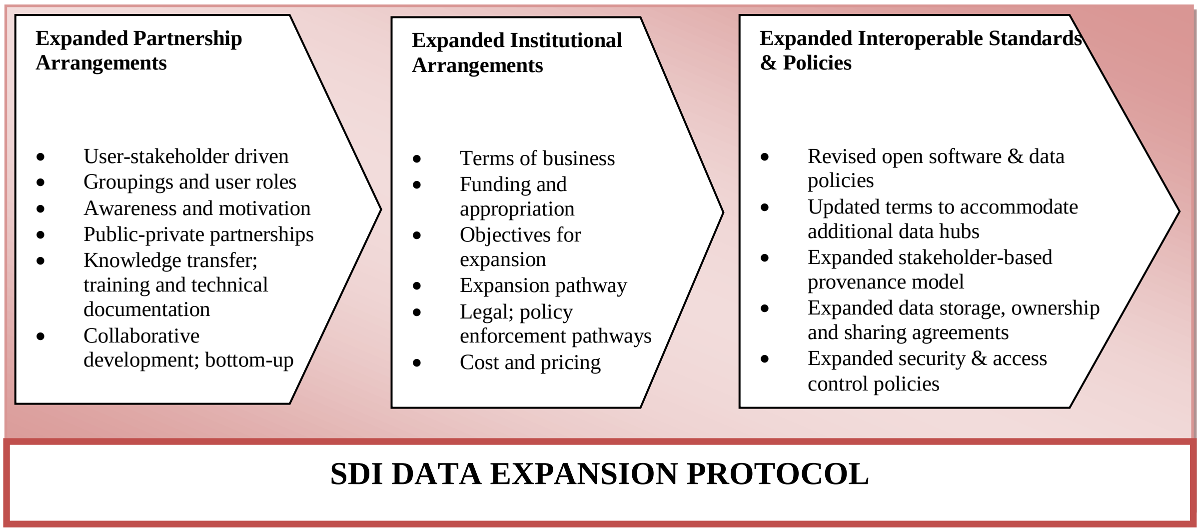



Figure 6: SDI Expansion Protocol

The SDI expansion protocol is the second level of the framework. At this level it is assumed that the SDI data access protocol has been established with the data access operation, institutional arrangements and provenance model. At this level, the SDI expands to create a centralised "clearinghouse" by through the establishment of partnerships and the collaborative networks. The collaborative partners create individual data access protocols which are then aligned to form a regional or national harvester.


Figure 7: Network Architecture of the Data Access protocol Expansion

A region sets up a server and runs the Data Access Protocol. An available harvesting service accesses all the servers in the network within a particular region to harvest the catalogs and thereby create a regional catalog that holds all the metadata for a region in one place. Additional services that the region might apply are data cleansing, enhanced quality checks and additional information provision. Additional services that could be applied at a national level are translation services between standards. This is addressed by the expanded institutional arrangements, as well as the expanded interoperable standards and policies.

**2.3. SDI CONTINUOUS ASSESSMENT PROTOCOL**

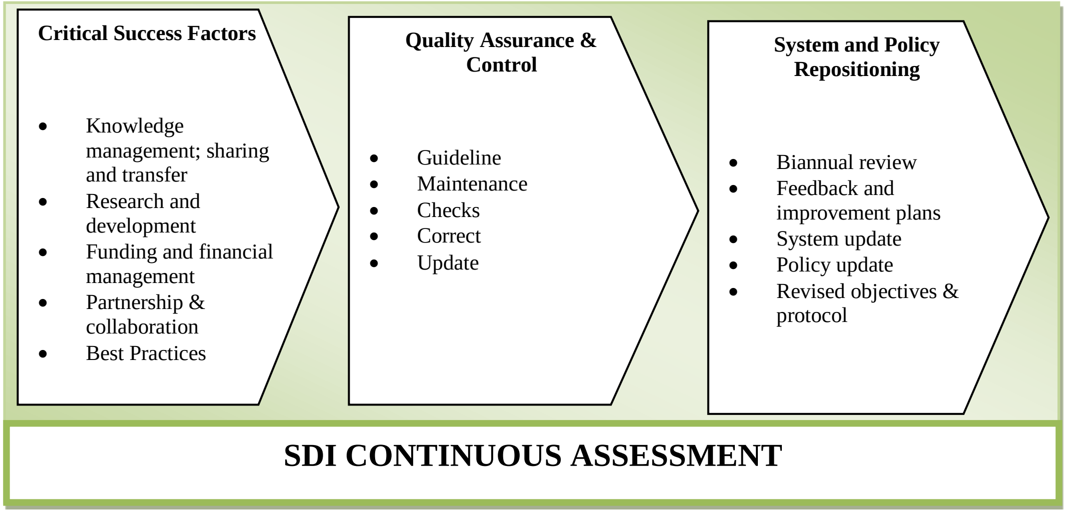



Figure 7: SDI Continuous Assessment

This is the third and final level of the framework. It tackles the problem of infrastructural failure due to non-fulfilment of objectives, obsolete technology, outdated protocols, and the inability of the infrastructure to address prevailing challenges over time. It comprises of three key areas. The critical success factors were recommended to enable the framework thrive. These factors have been defined from the assessed problems and in their absence the framework may not achieve effectiveness. Knowledge management is important to ensure steady sharing and transfer of best practices across all partners, and also to ensure the synergy of the people, process (SDI expansion protocol) and the technology (SDI Data Access Protocol). Research and development is also prioritised to ensure the system is up to date and sufficient to tackle current challenges. Funding and financial management is also highlighted as a critical success factor because the lack of funds, as well as the appropriation of available funds, has been highlighted as hindering the deployment of infrastructures globally. Quality assurance and control was included to ensure timely monitoring of processes to ensure quick fixes where necessary.  And the system and policy repositioning is to ensure the comprehensive review and update of the entire system for optimum effectiveness.

## 3.0. VALIDATION QUESTIONS

1. Kindly assess and comment on the SDI Augmentation Framework presented in figure 1?
2. Kindly comment on the feasibility and validity framework?
3. What is your take on the proposed bottom-up approach advocated by this framework instead of the typical top-bottom approach?
4. Do you think the provenance enabled, scalable, bottom-up distributed approach for SDI data access over a web would hasten SDI implementation as suggested by the framework?
5. Do you agree that the development of individual hubs and its subsequent expansion can be harmonised organically over time to develop a central NGDI clearinghouse that would be readily accessible?
6. Do you think the framework is sufficient and inclusive of the components (figure 2, 6 and 8) necessary for augmenting SDI adoption?
7. Kindly highlight the components, stages or links you think should be added to the framework or expanded within the framework to improve its feasibility in practice? Also highlights components, stages or links you think should be removed from the framework.
8. Is the framework clear and understandable to follow or replicate in practice?
9. Do you think this framework can provide economic and environmental benefits as suggested?
10. Do you think the framework would amplify the legislation and enforcement of a user-driven policy and objectives for SDI implementation?
11. Do you think this approach will heighten awareness, as well as amplify participation and partnership and therefore, aid the full implementation of the NGDI?
12. What are your final remarks?

**5**