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Constraints Oriented Approaches in Advancing Spatial Data Infrastructure: Case of Southern African Customs Union.

By

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PLAGIARISM DECLARATION

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ABSTRACT

Spatial data infrastructure (SDI) concept has made in-roads in a number of economies across the world, but Africa, on average is reported as lagging behind in implementation. This status has been confirmed through a number of continental SDI Assessments done in Africa. Africa SDI Assessments average its development as slow, which is problematic considering the fourth industrial revolution where; technology, communication, information and connectivity are the main enablers of political and socio-economic development. The problem of slow SDI development in Africa has acted as a catalyst for this study, with the five Southern African Customs Union (SACU) countries forming the scope for the investigations. This study focussed on investigating SACU countries SDIs and the associated sub-region with the aim of fostering on-going improvement. To do that, the prevailing SDI assessments in Africa were reviewed and utilised to propose a seven stepped constraint-oriented methodological approach as a means for guiding SDI development and progression within SACU. Management theories being; *Theory of Constraints (TOC) and Due Diligence (DD)* were utilised alongside the well-known SDI assessments of *State of play (SoP)* and *Readiness Index (RI)* to propose SDI On-Going Improvement Framework (SDIOGIF). This framework as suggested, has been enhanced using study data collected through documents, websites, workshops, interviews and questionnaires relating to SDIs within the SACU countries. Results from these instruments are revealing fundamental disparities in SDI implementations among study case countries, especially SDI aspects relating to legal frameworks and organisational setups. Some countries possess SDI legal frameworks and others don't. In addition, these countries are found to base SDIs on varying institutional sectors such as; Surveying and Mapping (Geoinformation), Statistics, Environmental and Information Technology Agencies. Studying these countries' SDIs, helped in establishing context-based constraints in their advancement. Through inductive reasoning, these constraints are aggregated as; macro-environment, organisation, legal, marketing, financial, management, informational and technology. They are designed into SDIOGIF, to guide country specific SDI improvements and their comparative analysis performed as a pre-cursor to establishing the proposed SACU Regional SDI which is currently non-existent.

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ACRONYMS

ANZLIC	Australia New Zealand Land Information Council
CEGGIM:	Committee of Experts on Global Geospatial Information Management
ESRI:	Environmental Scientific Research Institute
EU:	European Union
EUROGI:	European Umbrella Organization for Geographic Information
FGDC:	Federal Geospatial Data Committee
FIG:	International Federation of Surveyors
GIS:	Geographical Information Systems
GSDI:	Global Spatial Data Infrastructure
GPS:	Global Positioning Systems
ICT:	Information Communication Technologies
ICA:	International Cartographic Association
INSPIRE:	Infrastructure for Spatial Information in the European Community
ISGM:	International Steering Committee for Global Mapping
ISO-TC211:	International Standards Organisation Technical Committee for Geographic information/Geomatics
ISPRS:	International Society for Photogrammetry and Remote Sensing
OGC:	Open Geospatial Consortium
NASA:	National Aeronautics and Space Administration
PCGIAP:	Permanent Committee on GIS Infrastructure for Asia and the Pacific
SACU:	South African Customs Union
USA:	United States of America
UN-GGIM:	United Nations-Global Geospatial Information Management
SDI:	Spatial Data Infrastructure
SDIOGIF	Spatial Data Infrastructure On-Going Improvement Framework

Chapter 1 : General Introduction

1.1 Introduction

This study is about looking at advancement in Spatial Data Infrastructures (SDIs) in the context of individual countries forming the Southern African Customs Union (SACU) and as region. In the study, the purpose is to advance constraints as agents that can slow or keep dormant the development of SDI in a jurisdiction. The study will identify constraints that are associated with SDI developments in SACU, and then relate them with the Theory of Constraints (TOC), as a viable approach towards SDI On-Going Improvement (SDIOGI) in its implementation. TOC is premised on the belief that, real systems do have constraints associated with them, which act as bottlenecks or hindrance to system development (Rand, 2000; Rahman, 2012; Şimşit, Günay and Vayvay, 2014). According to Şimşit *et al* (2014), TOC can be defined as "a management philosophy which is focused on the weakest ring(s) in the chain to improve the performance of systems." This study contends that although SDI assessments have been done to gauge the status of development in African countries, no studies have been done to show their underlying constraints and how they can be exploited to foster improved implementation. As such SDI assessments have tended to show implementation of SDIs in Africa as slow without exposing their clear cause and effect in the context of the countries assessed. This study was instituted and pursued under the presumption that, if the constraints are identified and understood they can be dealt with in the process of SDI implementation. Therefore, the study was coined to investigate and report on SDI constraints in SACU and propose a constraint-oriented approach to facilitate SDI implementation programs.

In this introduction, a succinct background is put forward as to why this study is required and justification is given in the context of increasing urbanisation in Africa. For conceptualisation, the study draws from previous research in particular SDI State of Play in Africa (Makanga and Smit, 2010) read with SDI Readiness Index in Africa (Mwange, Mulaku and Siriba, 2016). Through this chapter, the study conceptualisation is expressed through research aims, objectives, questions and hypothesis. The constraints are buttressed with the help of a short review of literature to expose the constraints and their implications thereof, as gaps needing comprehensive investigations in SDI discourse. A preview of the methodology followed in this study is given, showing how the objectives of the study were made to reside in it and the

limitations thereon are identified. This introduction chapter then articulates how the whole thesis write-up is going to look like and it closes with a conclusion.

1.2 Background to study

Geospatial data had been put on a firm political and socio-economics pedestals in 1994 by President Clinton of the USA through the Executive Order 12906. Following this executive order, Spatial Data Infrastructures (SDI) have been vigorously pursued across the globe. The emergence of SDIs has influenced a number of publications revealing the fundamentals of spatial data in several fields (Warnest, Rajabifard and Williamson, 2003; Rajabifard, 2002; Davies, 2003; Crompvoets *et al*, 2008, Eds; Makanga and Smit, 2010; Okuku, Bregt and Grus, 2014; Mwange, Mulaku & Siriba, 2016). The revelation has now made it conventionally accepted that 80% of data in any economy is spatial data (Rajabifard, 2002; Budic and Pinto, 1999; Lemmens, 2001). The accepted abundance and importance of spatial data has meant that it be studied more as an inter-disciplinary phenomenon so as to develop systems that make its use in economies ampler. These studies have firmly led to conceptualisation of spatial data as an infrastructure which is buildable with the help of the modern geospatial technologies, telecommunications and the internet.

The advancement of SDIs since the mid-1990s has led to a number of useful comprehensive documents such as SDI Cookbook (Nebert, 2004) and The SDI Assessment Framework (Crompvoets *et al* 2008, Eds). According to Nebert (2004), SDI occurs at various levels of place ranging from corporate, local, national, regional and global. In line with SDI classifications by Nebert (2004), the South African Customs Union (SACU) countries and region SDIs have been put under the microscope in this study, in order to understand their development status and their major constraints.

The SACU itself is a long standing regional economic block dating back to 1910 made of neighbourly countries of South Africa, Botswana, Namibia, Lesotho and Swaziland (Gibb, 2006). Each SACU union member, has like most countries across the world strived towards development of SDIs at national levels. The SACU member countries SDIs have featured among those of other African countries reviewed by Makanga and Smit (2010) following the INSPIRE State of Play (SoP) methodology with the following results summaries;

- South Africa was reported as having a coordinating body, a legal framework which has been confirmed as the Spatial Data Infrastructure Act of 2003. Though political support was reported, the SDI did not have a clearinghouse, adequate funding and the stakeholders' participation was low.
- Botswana had a coordinating body but then lacked in legal framework, financial support, political support, stakeholder participation and clearinghouse.
- Namibia did not have anything in all the parameters.
- Lesotho was reported as having a coordinating body but lacking a legal framework, political support, financial support and clearinghouse but with reasonable stakeholder participation.
- Swaziland (now called 'Kingdom of eSwatini') was reported as having no formal coordinating body but with a good financial support. Other parameters such as legal framework, financial support and clearinghouse were all lacking.

These countries, in the recent years were still on an upward struggle to establishing National Spatial Data Infrastructures (NSDI). For instance, Siebritz and Fourie (2015) reveals that South Africa was struggling with coordination issues. Namibia began NSDI following the SDI mandate being incorporated into the Statistics Act in 2011. As further enhancement, Namibian SDI Committee was set and it has since compiled and finalised a policy in 2015 which has largely supported the commencement of Namibian SDI (Mudabeti and Longhorn, 2016). Other countries up to now are still not having much happening in terms of NSDI. The SACU SDIs have relatively been slow in implementation process and that is why this study was seeking to understand what could have constrained their development and suggest methods of advancing them.

These countries and their SDIs have offered a fertile ground for this study to germinate and flourish into a number of theoretical considerations, for instance, The Theory of Constraints (TOC). The research findings are compared among these countries and benchmarking framework proposed. The results are also compared with well documented SDI efforts such as INSPIRE of the European Union and USA-NSDI. The slowness concerns of these SDIs have offered a platform for them to be studied within the frameworks of existing study on GIS and early SDIs assimilations into organisations and nations (Rajabifard, 2002; Warnest *et al*, 2003; Nebert, 2004; Crompvoets *et al*, 2008, Eds). In overall, constraints have been recognised

as a major concern in SACU countries SDI advancement, as such, a method based on TOC is proposed as an intervention for improved implementation in Chapter 3 and with the help from study results, it is enhanced in Chapter 7. This method is referred to as SDI On-going Improvement Framework (SDIOGIF).

1.3 Research Premise

This study has taken into consideration the trends in world populations growth and dynamics, especially in Africa (Cohen, 2003; Alexandratos and Bruinsma, 2012). According to these authors global population growth in the next coming 50 years was predicted to grow by around 3 billion and become largely urbanite. The growth was envisaged to affect Africa more with population densities moving from around 26 people/km2 to as high as 60 people/km2, (Cohen, 2003). According to Cohen (2006) the growth and urbanisation are attributed to a number of dynamics such as: rural-urban migration, urban cities experiencing natural growth in populations and assimilating peri-urban villages to cities. The picture of growth and urbanisation is presented in table 1.1 following Cohen (2006).

Table 1.1: Urban population size and distribution by major geographic area, 1950 - 2030. (Source: Cohen, 2006)

Region	1950	1975	2000	2030
Total Population (Millions)				
World	2,519	4,068	6,071	8,130
More Developed Regions[a]	813	1,047	1,194	1,242
Less Developed Regions[b]	280	3,021	4,877	6,888
Rural Population (Millions of Inhabitants)				
World	1,786	2,552	3,214	3,185
More Developed Regions	386	344	311	228
Less Developed Regions	1,400	2,208	2,902	2,958
Urban Population (Millions of Inhabitants)				
World	733	1,516	2,857	4,945
More Developed Regions	427	703	882	1,015
Less Developed Regions	306	813	1,974	3,930
Percentage of Population Living in Urban Areas				
World	29.1	37.3	47.1	60.8
More Developed Regions	52.5	67.2	73.9	81.7
Less Developed Regions	17.9	26.9	40.5	57.1
Distribution of The World's Urban Population				
(World)	100	100	100	100
More Developed Regions	58.3	46.4	30.9	20.5
Less Developed Regions	41.7	53.6	69.1	79.5

From table 1.1, all African countries reside in the category 'Les Developed Regions', which is portrayed with very significant temporal growths. For example, the city of Johannesburg is said to have experienced a population growth by 1.25 million between the period 1996 and

2007 (van Huyssteen and Botha, 2008). These growths directly affect ecosystems, their inter-dependencies and sustainability, as such the use of the involved spaces need better management systems for the benefit of the inhabitants. To undertake better management of the growth and urbanisation African countries need to integrate, share and exchange geospatial data more. Geospatial data conducive platforms need to be established in a structured manner to facilitate the stated activities. A platform that has been advanced for supporting geospatial data integration, sharing and exchange is known as SDI, which grew in popularity between 1990 and 2000. SDIs have been advanced as a means to integration, sharing and exchange of information generated by the various geospatial technology sensors and methods. SDI concept has been popularised by the USA Federal Geospatial Data Committee (FGDC) and the European Union INSPIRE, (Hjelmager et al, 2008). The SDIs of USA and Europe Union represent federated and regional efforts in '*More Developed Regions*' category as per table 1.1 and they are considered fundamental in giving impetus to studying SDIs in the context of regions such as SACU.

Around the year 2000, SDI implementation had taken a more global outlook albeit its successes recorded in a number of African jurisdictions as slow, challenged and disorganised (Makanga and Smit 2010; Mwange *et al*, 2016, Guigoz *et al*, 2017). A closer look at literature on SDI implementation in five SACU countries, a sub-region of Africa, confirms it as slow. This study has attributed the slowness in SDI implementation to inherent constraints which act as bottlenecks and blockages in progression. According to Makanga and Smit (2010) SDI activities within all SACU countries were back then, still in their early stages and generally slow in development. The "early stages" status of SDI in Africa was recently confirmed by other studies for instance Mwange *et al* (2016) and Guigoz *et al* (2017). In addition to them being in early stages and their slowness, SDI coordination challenges have been identified in the South African SDI, (Siebritz and Fourie, 2015). In order to improve and reshape SDIs (Delgado Fernandez et al, 2005; Grus et al, 2007; Grus et al 2008; Okuku et al, 2014) have all alluded to the usefulness of studying SDIs developments coupled with their assessments. Based on this, there is need to investigate and conceptualise SDI development and assessment in SACU countries. The results from the investigation will be evaluated, analysed and used to reshape SACU SDIs for the future and foster a plan for the development of Regional SACU-SDI.

The selected countries SDIs are considered suitable for this study because they belong to countries of a long-established economic system known as South African Customs Union (SACU). This point is framed along the principle of the European Union (EU) SDI model, INSPIRE. EU as an economic block has taken the lead in establishing Regional SDI, hence others can learn from it in order to realise the importance of interconnectedness in territories in terms of social, political, economic and environmental requirements and decision-making. In case of SACU the interconnectedness is readily realised through, their shared international boundaries which runs along a number of their major rivers. In graphical format these countries can be routinely subjected to Tobler's first law of geography which states that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). Depicting from Tobler (1970), the relationships which come to mind for SACU countries, include the rivers (international boundaries) and the hydrological systems as shared resources, the boarders and related activities, transboundary conservation strategies, transportation networks and geodetic network integration. In recognition of these inter-relations, the SACU shared economic interest, will through SDI be aligned with environmental management and coined into an objective for a Regional SACU SDI.

1.4 Research Conceptualisation

From the early 1990s SDIs have been researched and advanced as a solution to geospatial data integration, sharing and exchange but from the review of Makanga and Smit (2010) read with Mwange *et al*, (2016), African countries are still struggling with SDIs. Lack of properly developed SDIs in Africa is problematic in today's fast technological advancement and increasing geospatial stakeholder community. The evidence in the literature seems to be pointing towards poor coordination and constraints as major problems affecting lack of SDI development (Siebritz and Fourie, 2015). Constraints associated with NSDIs were considered in this study to be major gaps which must be investigated especially within African countries context as means to fostering SDIs implementation. Well-developed SDIs in Africa are going to be vital in managing growing population settlements and urbanisation as alluded to in section 1.3. For this reason, the constraints in this study are contextualised with respect to SDI developments in SACU countries and the regional grouping. In so doing, the constraints associated with the SDIs of the SACU countries are identified and ways of managing them suggested in such a manner that they support positive NSDI advancement. Knowing these

constraints and exploiting them can lead the SACU countries to come up with more focussed SDI programs and shaping a way towards Regional SDI integration.

1.4.1 Research Aim

This research aims to investigate, assess and understand the development of SDIs within SACU. In addition, National SDI progression plan in each country is suggested and a framework for a Regional SDI proposed.

1.4.2 Research Objectives

The aim of the study is further realised through the following objectives;

I. *To review SDI discourses and propose a constraint oriented methodological approach as a road map of advancing its development and progression*
II. *To investigate SDIs found in the five SACU countries in order to identify their state of development*
III. *To investigate and describe variables that constitute constraints that could have slowed Spatial Data Infrastructure Development in SACU countries*
IV. *To carry out a comparative analysis of the state of development of SACU countries SDIs to suggest possible benchmarking and propose a framework for regional SACU SDI.*

1.4.3 Research Questions

The following questions are going to be answered in depth;

I. Why are SDI implementations slow in SACU and how could they be fast paced?
II. Why have SACU countries not successfully adapted SDI development drives from elsewhere?
III. In case of SACU Countries, who are the main players in the development of national and/or regional spatial data infrastructure and how should they interact to ensure its SDI realisation?
IV. How can the critical success and failure factors of a spatial data infrastructure be managed?

In order to answer the above questions, SDI development and assessment are conceptualised by critically examining and responding to the items in Table 1.2 within frameworks of the Theory of Constraints (TOC). TOC and its proposed application to SDI is going to be elaborated in Chapter 3. Arguably, there is need to understand that in reality, there are a bundle of constraints that are associated with the initial SDIs inputs, through processes and outputs and all these needs to be controlled in manner that will ensure temporal progression.

Table 1.2: The Conceptual Framework

Inputs	**SDI Processes**	**Outputs**	**Control**
What are the inputs of an SDI and how are they organised for its development?	What are the processes that produce SDI and how are they deployed in the environment of its development to ensure success?	What are the outputs of a SDI in terms of products, benefits and opportunities they create?	How is the whole process controlled and what feedback mechanism are used in continuing SDI development?

Inputs to development of any public infrastructure like SDI are very vital to its actual implementation, efficiency and effectiveness. Studying infrastructure traits and their lack of effectiveness in developing countries Rioja (2003, p. 136) made and interesting conclusion by stating that "*neglect of operations and maintenance in developing countries may be one of the causes of ineffective infrastructure*". The work of Rioja (2003) was specifically done in the context of Latin America largely focussing on irrigation, road and power network infrastructures. In this study, the interest is to understand the inputs of SDIs in SACU within the frameworks of TOC. Inputs in an operational environment have been recognised by Kruger (2012, p139) as "*money, materials, machines, manpower, management, markets and messages*". These inputs need to be considered in the context of SDI as constrained singularly and/or collectively leading to slow and disorganised development.

For inputs to be productive, they have to be subjected to a varied number of processes. Processes here addresses the fundamental steps that are required in ensuring a smooth proposition and implementation of SDI. This largely spells out the organisational perspectives and influences to SDI development. Inter-organisational remits and partnerships in SDI development as a shared resource are paramount in its actual implementation. If the processes are constrained in a number of ways, for example; structure, clarity, commitments, coordination, roles and mandate, just to mention a few, then success in SDI development become farfetched.

If inputs are constrained then outputs get adversely affected. This can be appreciated from Rioja (2003, p. 127) when saying that "*an inefficient infrastructure network is costly to a country in terms of loss of potential output*". Looking back at the quoted work of Makanga and Smit (2010) read with Mwange et al (2016) and Guigoz et al (2017) it could be inferred that most SDIs in Africa are inefficient and have continuously failed to provide requisite outputs in keeping with their intended objectives and goals.

SDIs are developed as public interventions to share geospatial information and facilitate evidence-based decision making in distributed environments, and their advancement need to be reviewed and controlled to improve implementation approaches. The control mechanism is therefore edged on SDI Assessment proposed by various scholars (Crompvoets and Bregt, 2004; Kok and Van Lonen, 2005; Delgado-Fernández et al, 2005; Annoni and Craglia, 2005; Grus, Crompvoets and Bregt, 2007; Vandenbroucke, Janssen and Van Orshoven, 2008; Vandenbroucke et al, 2013), and interfaced with some management theoretical considerations aimed at on-going improvement. It is for this reason that the TOC has been presumed and justified to be a fitting theoretical consideration in this study as will be elaborated in more detail in Chapter 3.

1.4.4 Research Hypothesis

The pace of SDI development within the SACU countries is directly related with the legal framework as a fundamental underlying constraint to implementation (The process of moving an idea from concept to reality). This hypothesis is born out of the fact that the SDI concept was acknowledged within these countries since the mid-1990s (FAO and SEK, 2001; Makanga and Smit, 2010), but to date, it has not been pursued with enough rigour to yield required outputs in most of them, e.g. lack of comprehensive geoportals with adequate accessibility for all stakeholders.

1.5 A Synopsis on SDI Literature

Spatial Data Infrastructure (SDI) is a phrase used to denote a collection of technologies, policies and institutional arrangements that facilitate the availability of and access of spatial

data and services (Nebert, 2004; Rajabifard, 2002). It is further defined as a complex evolving phenomenon with enablement capabilities in building new communities referred to as "*spatially enabled societies*" (Rajabifard et al, 2007; Rajabifard, 2010). It provides a basis for spatial data discovery, evaluation and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia and by citizens in general (Nebert, 2004). Nebert (2004) has articulated SDI on the basis of its accepted fundamental constructs being: Organisations, Legal Framework, People, Technical Standards, Access Networks, Fundamental Datasets and Services. The SDI concept itself, has been subjected to studies in various fronts, for instance; its development on the basis of hierarchies (Rajabifard, 2002); as a complex system (Grus, Crompvoets and Bregt, 2006); considered along the Reference Model for Open Distributed Processing (Hjelmager *et al*, 2008); requiring Multiview approaches in its assessment (Crompvoets *et al*, 2008, Eds) and its governance has been put under microscope as agent in its development (Crompvoets *et al*, 2018).

A number of international and regional organisations have through research and practice continuously pursued the SDI concept by proposing its processes and standards for development. Examples of these organisations include; International Standards Organisation-Technical Committee of Geoinformation (ISO-TC 211); Open Geospatial Consortium (OGC), International Steering Committee for Global Mapping (ISGM), European Umbrella Organization for Geographic Information (EUROGI), International Federation of Surveyors (FIG); International Society of Photogrammetry and Remote Sensing (ISPRS), Global Spatial Data Infrastructure (GSDI), International Cartography Association (ICA), United Nations Geospatial Information Management (UN-GGIM). ISO-TC 211 and OGC have crafted various standards to geomatics and geoinformation management while GSDI has directly advocated SDI concept development. EUROGI is a typical regional organisation based in Europe, which focussed on issues of data qualities and in transiting National Mapping Agencies (NMAs) held data into SDIs (Jakobsson and Vauglin, 2001). ISGM, FIG, ISPRS, ICA are traditional organisations which bring together various geomatics experts together on topical subjects. For instance, FIG played a central role in the Bogor Declaration of 1996 in which National SDIs were advanced as means to tapping from existing topographical and cadastral datasets of nations (FIG, 1996). The works of these organisations have found a lot of acceptance and utilisation in most developed countries, while in developing countries they do get acknowledged but are seldom used. This study realises that lack of wholesale use and application of SDI and related methods in developing countries could be due to disparities in a

number of areas such as technology, management, expertise, culture, policies, legislation, tenure systems and nationwide appreciation of SDIs, (Delgado Fernández et al, 2005). Through this study, the disparities are sought while SACU and its member states are used as an investigative platform.

Origins of the SDI concept is largely associated with USA following the presidential Order in 1994 which was seeking for geospatial data to be collated and aggregated to make it more useful, accessible and discoverable to citizens (Clinton, 1994). This led to the assignment of the Federal Geographic Data Committee (FGDC) which has been responsible for the development of major USA SDIs and the Geoportal One Stop, (Goodchild, Fu and Rich, 2007). Other notable SDIs developments had also emerged in a number of European countries and the European Union. In the European Union, following SDI directive issued in 2007, SDI known as INSPIRE was started as conglomeration of SDIs of member countries (Craglia and Campagna, 2009, Eds). Remaining regions of the globe, also attempted SDI developments nationally and regionally and examples include Australian National SDI and Asia-Pacific SDI (Rajabifard, 2002). The African region joined the SDI bandwagon at the turn of the century. But on average it appears that the African community as a whole has struggled with development of SDIs, (Makanga and Smit 2010; Mwange *et al*, 2016, Guigoz *et al*, 2017).

After development of early SDIs, it emerged that they needed to be assessed in order to review and improve them, (Delgado Fernández *et al*, 2005; Lance, 2008). Various SDI assessment frameworks have been coined to check their nature, performance and usefulness within communities where they have been established within. The assessment frameworks have been developed and used in various regions and jurisdictions, for example the following;

- The SDI Readiness Index was started with Cuban SDI (Delgado Fernández *et al*, 2005) and it contains some useful expositions on SDI development constraints.
- The clearinghouses suitability assessments studies were done across the world, (Crompvoets *et al*, 2006).
- Giff (2006) followed by Giff and Crompvoets (2008) have all devised the SDI performance-based assessment which seeks to justify SDI development by revealing its past record and delivery on key objectives of its creation.

- Within SACU, Makanga and Smit (2010) following the State of Play method have done an assessment aimed at evaluating implementation issues in African SDIs. The result of which revealed that generally African countries continue to struggle with SDI.
- A more recent study in the African region has been done by Mwange *et al* (2016) focussing on the aspect of SDI Readiness following the principles set out in Delgado Fernández *et al* (2005).
- SDI assessment frameworks are many and a number of them can be found in a comprehensive SDI framework called 'Multi-View Framework to Assess SDIs' which is a more than 400-page compiled document, (J. Crompvoets, A. Rajabifard, B. Van Loenen and T. Delgado Fernández, 2008, Eds).

SDIs have also been found to be dynamic and subject to changes over a period of time, (Delgado Fernández *et al*, 2005). But in SDI assessment it is possible to come across several constraints which hamper development. The basic constraints can come in the following forms; technical, political, social and technological. Examples of technical constraints are highly data related and they are; availability and appropriate geodetic reference systems to allow for perfect data integration as captured by United Nations (2015a); uncertainty in GI as elaborated by MacEachren *et al* (2005) and Goodchild (2001); metadata and data lineage problems as captured by Wayne (2001) then later supported by Meeks and Dasguptas (2004). Political constraints can be related to legal requirements and enactments, (Murakami, 2008); data privacy and security, (Boxall, 2005) and lack of political support and funding as captured earlier in Makanga and Smit (2010). The social constraints address the internal activities, interactions and participation of those responsible for SDI program such as individuals, firms and communities as a social system in the process of implementation, (Rajabifard 2002). Technological constraints occur because technology is continually advancing with a wide dynamic structure. The constraints can be in the form of access channels, resistance, lack of resources, capacities in skilled personnel.

Deriving from the preceding literature review, it is fundamental to identify weaknesses, gaps and any form of misconception that can get associated with an SDI. Makanga and Smit (2010), has alluded to the progression of SACU countries SDIs as critical and needing speed-up interventions, therefore developing country focussed assessments is viewed as a good thing for them in the short term. But over a long-term, dedicated roadmaps for their progression may

ensure that they continue to stay on course and in the passage of time lead to development of Regional SACU SDI. All these must be done by considering what Rajabifard (2002) has defined as product-driven and process-driven SDIs within and across hierarchies. The product-driven SDI focus mostly on data integration while the process-driven SDIs seeks to integrate the whole operational environment by taking into consideration processes, users/stakeholders, partnerships and any other relevant and emerging issues. These SDI types are found at different hierarchical levels (corporate, local, national, regional and global).

1.6 Research Methodology and Analysis

In Chapter 3, the study takes into consideration a quantitative tone based on existing SDI assessments carried out in Africa by Makanga and Smit (2010) intertwined with Mwange et al (2016). This is followed through by an inductive or qualitative study approach covering chapter 4, 5, 6 and 7. Documents and records were reviewed, existing SACU country efforts and internet sites were visited and described, questionnaires were administered and interviews conducted with relevant authorities to identify why SDIs development in SACU have been slow. The results are processed and analysed with constraints in mind. The analysis involves comparisons, benchmarking and consideration of SDI constraints following a cyclic pattern that is able to support SDI development and assessment. The method developed is further used to support a proposal for a SACU Regional SDI framework.

To understand problems associated with SDIs development, SACU as region, an economic block was used as an area of study. This was to allow problems to be investigated at micro (country) and macro (SACU) levels to proffer solutions, comparisons and benchmarking. Tackling SDIs' problems at SACU level is considered relevant to the proposition of a Regional SACU-SDI and offers an opportunity to instituting its studies, which are currently non-existent. This methodological framework has been designed to directly proffer solutions to the research aims and objectives outlined in 1.3.2. How this study progressed is summarised in table 1.3 whereby it is shown that the objectives have been designed to strictly reside in the methodology. It has to be noted that, table 1.3 take into consideration all the objectives of the study and align them with a data collection approach and an analytical framework so as to proffer solutions for the identified problem.

Table 1.3: The Research Methodological Framework

OBJECTIVE 1	OBJECTIVE 2	OBJECTIVE 3	OBJECTIVE 4
Data acquisition Methodology for the objective			
Constraint-oriented methodological approach through desktop study and review of existing work by other authors.	SDIs and state of development in the five SACU through Country documents, websites, records, questionnaire and interviews.	Variables that constituting constraints in SACU countries SDIs by collating responses, reviewing country documents, websites.	Comparison, benchmarking and regional SACU SDI proposal through RM-ODP. Using organisation, data and mandate as the basis for regional SDI road map for SACU
Data Discussion and Analysis			
Analysis Aligning SDI with the Theory of Constraints and proposition for SDI Ongoing Improvement (SDIOGI)	The state of development, achievements made and challenges being experienced. Solutions being proffered.	Outlining and describing the SDI constraints for each country context	Comparisons to best practice: European INSPIRE Initiative. Enhancing the SDIOGI as a tool and framework in SDI implementations.

The data collection approach in particular has generally followed the theoretical sampling method so as to reach relevant audience and obtain datasets. For instance, the samples of the study have been influenced by the following;

- General Review of literature; desktop studies and internet searches
- SACU countries legislations
- Spatial Data Infrastructure Efforts e.g. South African SDI Documents and its Website
- Various data sets from SDI implementing organisations (internet searches and physical visit) e.g. cadastral, country boundaries and river data sets
- Questionnaires (Internet and physical visits)
- Interviews (physical visits to selected agencies and companies)
- Workshops (country SDI workshops)

All these data channels and the realisation of their analysis are described comprehensively in chapter 5, 6 and 7. Document analysis approach has been widely used to extract and analyse results from several SDI documents and internet sites.

1.7 Research Contribution and Limitations

The study contributions and limitations are intertwined and they are briefly referred to in this subsection to emphasize their importance and continued consideration in the study process.

They are going to be extensively covered through the methodology and data chapters of the research which are chapter 3, 4, 5, 6 and 7.

1.7.1 Contribution

This study contributes to SDI discourses by emphasizing the role of constraints in its implementation. The study focuses on the five SACU countries by pursuing understanding of their SDI efforts in more depth, identifying the associated weak links and suggest ways that can be followed to improve. An implementation approach named SDI On-Going Improvement (SDIOGI) is proposed as a tool and framework to constructing SDI as a corporate, multi-sectoral and hierarchical endeavour. This study is believed to have contributed to knowledge and advancing new ways of looking at improving SDI implementations within SACU countries and proposing a structure for SACU Regional SDI.

The study output is expected to benefit the focussing and development of SDIs in the SACU countries if adopted. It is also expected to contribute to knowledge by helping us understand why adoption of SDI concept and development of the same has been slow in the region. It will in addition put forward solutions and make recommendations that can be followed to improve SDI progression and use. It will also give currency to development of Regional SACU-SDIs, improvement of collaboration, regional integration not only in trade but also in land and environmental management. Last but not least, the study is expected to foster SDI research in the region as it will be shown in the recommendations in Chapter 8. The proposed approach can be used beyond SACU by any SDI implementing institutions and jurisdictions across the world.

1.7.2 Limitations and Bias

Scope of this research is the SACU countries SDI development and their assessment. Comprehensive study of SDI of the five countries proved to be a far reach due to time constraints and other factors beyond the command of the researcher. Carrying in-depth studies in the context of the involved countries had limitations, especially due to time constraints, finance and geographic spacing between the main centres of data collection being Gaborone (Botswana), Maseru (Lesotho), Pretoria (South Africa), Windhoek (Namibia) and Mbabane

(Kingdom of eSwatini). Mbabane could not even be visited during study fieldwork data collection, because the authorities who were believed to be main stakeholders in SDI matters did not respond to collaborative requests made. The Mbabane example is a typical factor beyond the command of the researcher.

The other limitations are related with SDI trends and discourses. For instance, the current work by UN-GGIM, OGC, ISOTC211, FGDC, INSPIRE Committee and many more are considered useful in supporting analysis in this study, but their activities may not all be comprehensively utilised due to several limitations. These committees are made up of experts from across the globe and it is not easy to reach all of them and be aware of all their new activities. The researcher is a Professional Land Surveyor of Botswana origin and this is considered as a possible contributory factor to personal bias. But then utilising triangulation in the research processes by using several research instruments is considered to have gone a long way in mitigating bias.

1.8 Thesis Outline

In this thesis, Chapter 1 forms an introduction laid out to elaborate the background to the study and its motivation through research justification, problem statement, research objectives, methodological summary of the research and specification of its scope. This is connected with a widely articulated review of relevant literature to SDIs in Chapter 2. This literature review is used to reveal where and when the SDI concept germinated across the globe. From the review, an articulation of the various discourses associated with SDI at various levels of organisation and place are done.

The articulated literature connects into Chapter 3 where a formulation of SDIOGI is proposed. In Chapter 3, SDI implementation is aligned with the TOC to show how constraints can be identified and exploited from inception, execution and review. In Chapter 3, the SDIOGI is proposed and illustrated following a quantitative inquiry on constraints using results of previous studies. In Chapter 4 a qualitative study approach based on questionnaire, interviews, reports and records on country SDIs is formulated.

The results of the data obtained by the methods employed in the fieldwork are reported and analysed by comprehensively interrogating SDI activities of the various countries forming SACU in Chapter 5 and 6. In Chapter 5, SDIs of countries without SDI legal frameworks are reported with their development status gauged and constraints noted. In Chapter 6, SACU countries with SDI legal framework are reported. The results and responses of Chapter 5 and 6 are collated into a comparative framework of the countries and linked with a proposition for the development of a Regional SACU-SDI road map in Chapter 7.

A conclusion to research in line with the aims, objectives and research questions is provided along recommendations in Chapter 8. The recommendations are done to identify further research with interest in advancing the SDI narratives in SACU, then expanding the same concepts to bigger regions such as South African Development Community (SADC) and the whole continent.

1.9 Conclusion

This chapter has given an introduction of the topic of study by way of looking at urbanisation in Africa as an important indicator of why aggregated geospatial information will be important in aiding major-decisions in Africa. Therefore, effectively arguing for development of such systems in the form of what has been conceptualised as SDIs. This chapter has identified gaps in SDIs development by referring to previous studies which were done to review SDIs in Africa by Makanga and Smit (2010) read with Mwange *et al* (2016). The gaps identified clearly point to slow speed in development of SDI concept in the African continent. Therefore, an aim was coined to seek to understand what could be attributed to slow SDI development within the African countries. To make an attempt at investigating the aim, objectives and questions, a presumption was advanced which indicate that constraints are possible inhibiting factors to SDI advancements. To be able to study the constraints within the time limitations of this study, five (5) countries in Southern Africa which are in the review by Makanga and Smit (2010) are sampled.

Chapter 2 : Spatial Data Infrastructures and Discourses

2.1 Introduction

Spatial Data Infrastructures (SDIs) are multi-data inclusive systems which are seeking to improve on governance, decision-making, technological embracement and the overall use of spatial data in the political and socio-economic aspirations of local, national, regional and global communities (Masser, 1998; Rajabifard *et al* 2001; Crompvoets *et al*, 2018). The motive of SDIs is to primarily foster geospatial data distribution, exchange and sharing across multiple organisations at micro and macro level (Rajabifard, 2002). Several nations of the world have adopted this concept for implementation and have had varied experiences ranging from success up to near failure. The gap between success and failure is quite enormous and continues to provide a fertile ground for carrying out SDIs related studies at all levels of the involved communities.

The line of research that can be carried out in SDI are enormous and complex, and they can take the form of improving the already built systems, aggregating and focusing silo efforts to starting anew failed ones. It is recognised that efforts to establish SDIs have been started across several African countries but the efforts have remained slow and fail to keep up with the ever-changing geospatial technology, information needs, stakeholders and the associated methods. This slowness is suggestive that research should reconceptualise SDI within the African countries' realm. In so doing, research need to look deeply into underlying constraints, as responsible for slowing progression and come up with solutions towards improvement in delivery of SDIs in Africa. The African continent is made up of several countries with varying legal frameworks which could have a direct impact on SDIs development. In consideration of that, the study has selected to focus on five (5) countries which are making the Southern African Custom Union (SACU).

In order to study SDI implementation in SACU, reviewing of literature relating to SDI frameworks and contexts is done. The frameworks here include SDI Cookbooks and Assessments Frameworks. The context includes local, national, regional and global SDIs Such as country SDIs; for example, INSPIRE, FGDC, Australian SDI, Asian-Pacific, African and South American SDIs. The literature reviewed in line with the foregoing will help in exposing what the major inputs of SDI are and how they have to be organised towards a successful implementation. It is in the interest of this study, to review SDI literature by looking into the

origins of SDI concept so as to shed light on its fundamental issues such as political, economic and technological influences. Describing the SDI components should further expose us to the accepted discourses which have formed the bulk of past investigations into this concept. The components are then focussed on the developments aspects as they have been perceived and attempted by various communities across the globe. Developments of SDIs across many communities has led to their assessment in order to relate its success or lack thereof. The review of the literature then veers into directions that SDI had been taking as a way to making an appropriate opening to why this particular study is necessary to be carried out. A conclusion is then drawn to give direction to the next chapter.

2.2 SDI concept

For the purposes of this section and the entire study, it is considered necessary to describe the SDI concept in terms of its emergence. In so doing, the origins of SDIs concept are traced by its emergence in terms of place and time. The aspects of place and time are noted in Coleman and MacLoughlin (1998, p. 134) when they say;

> *"The early 1990's, the concept of spatial data infrastructure (SDI) development was being proposed in support of accelerating geographic information exchange standards efforts, selected national mapping programs and the establishment of nation-wide spatial information networks in the United States [Mapping Sciences Committee, 1993], the United Kingdom [Rhind, 1992], Canada [McLaughlin, 1991] and the European Community [EUROGI, 1996]*".

This reference and the references thereon swiftly reveal where, when and by who, regarding the SDI concept germination across the globe. The conceptual origins are followed here with succinct definitions of the concept. Furthermore, the concept is discussed within the frameworks of political and technological influences. The representation and parlance of presentation of spatial data, is then elaborated in view of the impact of information and communication technology (ICT). Deriving from the ICTs, the perspectives and general momentum that SDIs have taken are elaborated as a way to ending this section.

2.2.1 SDI Emergence

SDI origins, can be traced to the continent of North America, especially in the United states of America and Canada (Robinson, 2008). A closer look at SDI emergence in these countries suggest a long, tedious and documented process which have often been politically and

technically driven. As it will be elaborated in 2.4.2, SDI development in USA is heavily linked with a long-standing geographic data handling structure which has morphed through various stages of existence beginning from 1840 to today (Robinson, 2008). Canadian SDI on another hand can be traced to the early 1960s in connection to the work of integrated mapping highly associated with Roger Tomlinson who is refereed as the father of geographical information systems (Coleman and McLaughlin, 1998; Masser, 1999; Scott and Rajabifard, 2017). As elaborated in Coleman and McLaughlin (1998), the global trends have largely followed these two nations with European Union countries working through a conglomeration called European Umbrella Organisation for Geographic Information (EUROGI), while in Australia SDI has emerged through the works of Australia New Zealand Land Information Council (ANZLIC).

The realisation is that NSDI developments have largely been influenced by the continued strive to collect geospatial data and the enhancement brought about by technological advancements and impacts on the methods used. The increase has been steady since 1993 and according to Grus, Crompvoets and Bregt (2006) following Crompvoets (2004), the number of NSDI projects across the world in 2002 were already above 100. It is very important to note that Grus et al (2006) alluded to the differing nature of all these NSDIs because of country perspectives. By the turn of the year 2000 these NSDIs were effectively divided into two temporal categories named "*First and Second-generation SDIs*", (Masser, 1999; Rajabifard, 2002; Rajabifard et.al., 2003). First generation NSDIs were those started in the early 1990s up to 2000 and they were generally dubbed as product-oriented because their focus was around building robust databases hence, they were highly data and technology driven. After the year 2000 the tone changed towards the second-generation SDIs which were highly process driven and having wider approach towards interfacing producers and users of the system, (Grus et al, 2006; Rajabifard et al, 2006). The evolvement of SDI had also been acknowledged to have led to reconceptualization and third-generation SDI (Rajabifard, 2007; Rajabifard, 2010; Cooper *et al*, 2011). SDIs in various jurisdictions have been government mandated, but some have grown independently driven more by innovativeness. Table 2.1 has been collated to decipher and appreciate how the two fundamental driving forces have influenced SDI development in some countries. Most of the examples used in table 2.1 are those which appeared largely in the first-generation SDI list with a lot of discourses which can be said to have influenced SDI elsewhere, e.g. The United States of America with its presidential Executive Order 12906 is widely referenced in SDI literature and the Dutch SDI has also been fundamental in Europe.

Table 2.1: SDI Origins by country or region with years. (Adapted from Masser, 1999, p. 68 - 73).

Place of Origins	Mandate and Instrument	Name of SDI and Coordinating Organ	Year Range (Inception year)
United States of America	Government based on Presidential Executive Order 12906	National Spatial Data Infrastructure (NSDI) by Federal Geographic Data Committee (FGDC)	1993-1994 (1994)
Canada	Independent and then later facilitated by way of National Funding Partnership through Geoconnections	Canadian Geospatial Data Infrastructures by GeoConnections	1997 – 1999 (1997)
Australia	Independent resulting from agreement from the Australian Prime Minister and the Heads of the State Governments	Australian Spatial Data Infrastructure (ASDI) and The Australia New Zealand Land Information Council (ANZLIC)	1996 – 1999 (1997)
Japan	Started through Independent Association then Liaison Committee of Ministries and Agencies set in response to earthquake (Masser 1999)	National Spatial Data Infrastructure (NSDI) by Liaison Committee supervised by Cabinet. NSDI promoting Association also set up to support SDI activities (Masser 1999)	1995 – 1999 (1997)
Great Britain	Independent but can be traced to report by Chorley Committee on handling geographical information (Masser 1999)	National Geospatial Data Framework (NGSF) overseen by Director General and Chief Executive of Ordnance Survey Great Britain. Coordination is by a tripartite responsibility of NGSF Board, Advisory Council and Government.	1987 - 1999 1996
Netherlands	Independent based on 1992 Dutch Council for Real Estate Information (RAVI) structure plan for land information	National Spatial Information Infrastructure by RAVI and NCGI	1992-1997 (1995)
European Union	Union government based on INSPIRE Directive 2007	EUROGI	2001 – 2010 (2007)

The regions and countries listed in table 2.1, are going to form a very important sample in the review of literature in this chapter. The governments of the various countries and regions have visible participation in the SDIs which have been listed in table 2.1 and this is considered to be highly important in SDI approaches. Table 2.1 has been used to generally reflect on SDI origins, together with how and when they came into existence in their place of origins as nicely summarised by Masser (1999, p. 73) by saying that "…. *these initiatives are confined largely to the public sector whereas others have a strong private sector and user involvement."*.

Rajabifard was among the early proponents of "product and process based" SDI as discussed above, by 2006 he had shifted towards what he termed "*third generation SDI concept*". The third generation advance a concept of largely decentralised and uncoordinated SDI with the view to bridge critical challenges which go beyond just access and sharing on spatial data (Williamson, Rajabifard, and Binns, 2006; Rajabifard et al, 2006; Rajabifard, 2007; 2008). The emphasis had shifted to spatial enablement at a larger scale taking into considerations government and society interaction to deliver economic empowerment and respond to global agendas like the millennium development goals (Rajabifard, 2010).

2.2.2 The SDI Definitions

In order to dwell into SDI definition, the three words that make its acronym are defined. **Spatial** is defined in terms of interactions of constructs that organise space determination such as distance, area, shape, dimensional perspectives of coordinates (one, two and three and four dimensional), angle, direction, size etc. Through these constructs spatial transcend into data regularly referred to as 'spatial data'. **Data** as defined by Ackoff (1999, p. 1) "are symbols that represent the properties of objects and events", while Chen *et al* (2009, p. 13) defined it as "computerized representations of models and attributes of real or simulated entities". For data to be there, the processes involve its collection, processing and presentation in textual, statistical and graphical format. In superior states of its handling and processing, data becomes information and then knowledge. Once converted to information and knowledge it plays important roles in reasoning and discussion to support operational, tactical and strategic decision-making processes by organisations and governments. **Infrastructure**, defined in the context of Hanseth and Monteiro (1998), are pervasive but enabling, shared and open socio-technical networks which are interconnected and related, with their development being done in continuum as an improvement of its installed base. This definition is further reinforced by Bowker *et al* (2010, p. 98) by defining infrastructure "as a broad category referring to pervasive enabling resources in network form".

From the above definitions it is discernible that spatial, relates to a particular phenomenon occupying a space where it is, e.g. a country, region, river, city etc. This particular term is often used interchangeably with geospatial (Davies, 2003). The data definition shows that factual information can be associated and determined for a particular phenomenon occupying space, e.g. a river position, river depth, country extent etc. Importance of data has been demonstrated in Davies (2003) whereby it is portrayed as the base to other useful precepts being information, knowledge and wisdom. The demonstration in Davies (2003) came through a comparative example derived from Bellinger Castro and Bells (2003) and Steyn (2001) and these are shown in Figure 2.1. In figure 2.1, a hierarchical dispensation is portrayed to reveal that data is required as a primary asset in order to derive information which in turn leads to knowledge and ultimately wisdom. Wisdom in this case is be promptly juxtaposed with effectiveness and efficiency in decision-making processes.

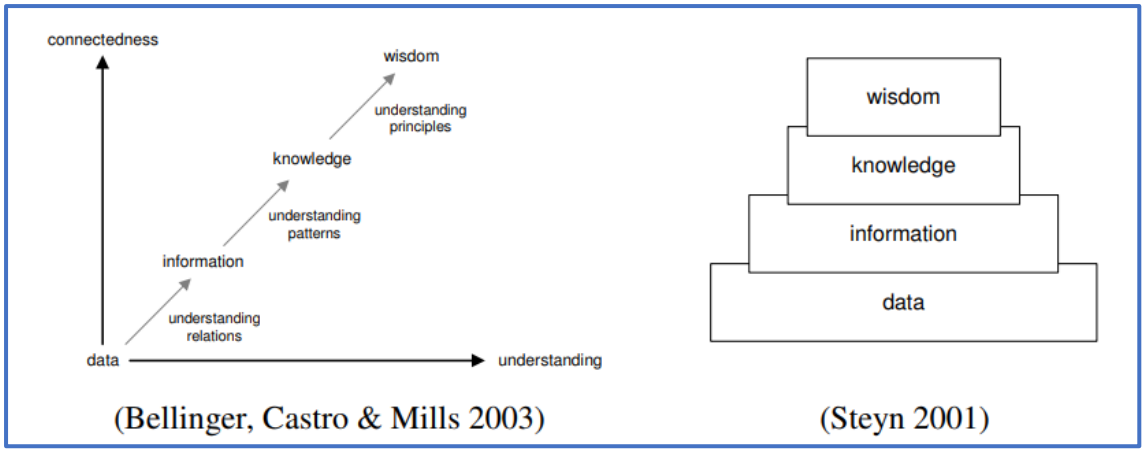

Figure 2.1: Two representations of data-information continuum (Source: Davies, 2003, p. 53).

In order to benefit more from spatial and data, the two abstract concepts are developed into systems that serves public good, primarily as geographical and/or land information systems, which are then escalated with the help of telecommunications infrastructures (Internet and World Wide Web) into some form of information infrastructure (Hanseth and Monteiro, 1998), hence Spatial Data Infrastructure (SDI). SDI as shown by its emergence in 2.2.1, is an infrastructure that bears the hallmarks of public good and national service. Following its emergence, SDI has been defined in line with aspirations and information needs of societies they serve at local, national, regional and global platforms. Depending on the platform at which SDI is occurring, it has been defined by practitioners and scholars across the globe and a number of its definitions are given here as tabulated by Chan *et al* (2001) and adopted by Rajabifard (2002) in Table 2.2.

Table 2.2: A sample SDI Definitions, (Source: Rajabifard, 2002 citing Chan et al, 2001, p. 23 - 24)

Source (reference)	Definition of SDI
Australia New Zealand Land Information Council (ANZLIC 1996)	A national spatial data infrastructure comprises four core components - institutional framework, technical standards, fundamental datasets, and clearing house networks
Global Spatial Data Infrastructure Conference 1997 (GSDI 1997)	Global Spatial Data Infrastructure (GSDI) should generally encompass the policies, organizational remits, data, technologies, standards, delivery mechanisms, and financial and human resources necessary to ensure that those working at the global and regional scale are not impeded in meeting their objectives
Thompson (1995)	An NSDI is one which makes effective use of computer and communications technologies for the efficient acquisition, management, and dissemination of spatial data and information on a national basis.
Dutch Council for Real Estate Information (RAVI) (Masser, 1998b)	The National Geographic Information Infrastructure is a collection of policy, datasets, standards, technology (hardware, software and electronic communications) and knowledge providing a user with the geographic information needed to carry out a task.
European Commission (European Commission, 1995)	The European Geographic Information Infrastructure (EGII) is the European policy framework creating the necessary conditions for achieving the objectives. It thus encompasses all policies, regulations, incentives and structures set up by the EU Institutions and the Member States.

Executive Order of US President (Clinton, 1994)	National Spatial Data Infrastructure (NSDI) means the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data
Federal Geographic Data Committee (FGDC, 1997)	National SDI is an umbrella of policies, standards, and procedures under which organisations and technologies interact to foster more efficient use, management, and production of geospatial data.
McLaughlin and Nichols (1992)	The components of a spatial data infrastructure should include sources of spatial data, databases and metadata, data networks, technology (dealing with data collection, management and representation), institutional arrangements, policies and standards and end-users
Hoffmann (1999)	A "Spatial (data/information/knowledge/expertise) infrastructure" should be more than a geographic information infrastructure. It is the spatial integration component for an information society system, which is the important interoperability element of a future information society.
Queensland Spatial Information Infrastructure Council (Department of Natural Resources, 1999)	The Queensland Spatial Information Infrastructure comprises the datasets, institutional arrangements, technical standards, products and services required to meet the needs of government, industry and the community
Victoria's Geospatial Information Strategic Plan of the State Government of Victoria, Australia (Land Victoria, 1999)	The concept of a spatial data infrastructure is extended to include more than just the data itself – it now encompasses all organisations and customers involved in the entire process, from data capture to data access, including the geodetic framework
Victorian Geospatial Information Strategy 2000-2003 of the State Government of Victoria, Australia (Land Victoria, 1999)	A spatial data infrastructure is conceptualised as a comprehensive geospatial information resource—the infrastructure, the value and capability of which are driven into Victoria's information systems and processes—the benefit, through the strategic elements of custody, metadata, access infrastructure, pricing, spatial accuracy and awareness

The definitions collated in table 2.2 span a period of around ten years. They were coined from different countries and regions, as such, they talk to the context of their origins and the general perceptions of the places and times. What is evident is that SDI was a new concept requiring a definition that can help it to prosper and give it direction over time. The above definitions have not deterred new ones from surfacing, as scholars and practitioners went about trying to understand SDI. For instance, the following;

- Béjar *et al* (2004, p. 2) defined SDI in this manner by saying "*we can describe an SDI as a composition of SDI-nodes that are SDI themselves*".
- (Crompvoets *et al*. 2004, p. 665): "*Spatial Data Infrastructure (SDI) is about the facilitation and coordination of the exchange and sharing of spatial data between stakeholders in the spatial data community*"
- Grus, Crompvoets and Bregt (2006, p. 20) has defined it this way; "*National Spatial Data Infrastructure is a complex adaptive system for facilitating the access and sharing of spatial datasets and services in the jurisdiction of one country needed to support spatially related issues*".
- European Union (2007, p. 4-5), through a Directive defined it thus; "'*infrastructure for spatial information' means metadata, spatial data sets and spatial data services; network services and technologies; agreements on sharing, access and use; and*

coordination and monitoring mechanisms, processes and procedures, established, operated or made available in accordance with this Directive".

- Rajabifard (2010, p. 3) defined SDI as "*an integrated, multi-levelled hierarchy of interconnected SDIs based on partnerships at corporate, local, state/provincial, national, regional (multi-national) and global levels*"
- Cooper et al (2011, p. 1) defined SDI as "*an evolving concept for facilitating, coordinating and monitoring the exchange and sharing of geospatial data and services, and the metadata about both."*

These definitions reveal SDI as an evolving concept, which is given meaning in several ways by practitioners and scholars. Therefore, it is important to look at these definitions to understand the picture that they are portraying as summarised in table 2.3 (Hendriks, Dessers and van Hootegem, 2012). In their work, Hendriks *et al* (2012) made some important conclusions about these definitions, that some of them tend to anchor on SDI components, while others are deliberately objective oriented and yet others just address the general picture by using more inclusive terminologies such as "framework". In their work they came up with what they termed 'Sorting Scheme for SDI definitions' which is a tabled structure having 3 rows and 3 columns as shown in table 2.3.

Table 2.3: Sorting scheme for SDI definitions. (Source: Hendriks, Dessers and van Hootegem, 2012, p. 1483)

Components \ Objectives	B0: No objectives	B1: Only data-related objectives	B2: Also user-related or broader objectives
A0: No components	–	(3) For example, Spatial Data Infrastructure (SDI) is about the facilitation and coordination of the exchange and sharing of spatial data between stakeholders in the spatial data community (Crompvoets *et al*. 2004)	(6) For example, An infrastructure for accessing and sharing spatial data to reduce the duplication of spatial data collection by both users and producers and enable better utilization of spatial data and associated services (Grus *et al*. 2010)
A1: General typification of components	(1) For example, Spatial Data Infrastructures are foremost social networks of people and organisations, in which technology and data play a supportive role. The technology is cheap, data is expensive, but social relations are invaluable (Craglia and Campagna 2009)	(4) Of this class, no examples were found.	(7) For example, An SDI is a set of technological and non-technological set-ups [components] within and between organisations [network] to facilitate access, exchange and use of spatial data [narrow objectives], thereby contributing to the performance of the business processes [broader objectives] (Vandenbroucke *et al*. 2009)
A2: List of components	(2) For example, The components of a spatial data infrastructure should include sources of spatial data, databases and metadata, data networks, technology (dealing with data collection, management and representation), institutional arrangements, policies and standards and end-users (McLaughlin and Nichols 1994)	(5) For example, National Spatial Data Infrastructure (NSDI) means the technology, policies, standards and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data (Executive Office of the President 1994)	(8) For example, infrastructure for spatial information means: metadata, spatial data sets and spatial data services; network services and technologies; agreements on sharing, access and use; and coordination and monitoring mechanisms, processes and procedures, established, operated or made available in accordance with this Directive. (. . .) INSPIRE should assist policy-making in relation to policies and activities that may have a direct or indirect impact on the environment (European Commission 2007)

The rows, are said to represent components represented by AO (No Components), A1 (General typification of components) and A2 (List of components). These rows are intersected with columns depicting SDI definitions on the basis of objectives ranging from B0 (No Objectives), B1 (Only-data related objectives) and B2 (Also user-related or broader objectives). In this scheme a definition of SDI bearing AO and B1 can be deduced by cell intersection of these two, e.g. definition by Crompvoets *et al* (2004).

In overall the components and objectives that are associated with SDI definitions are almost certain in addressing the aspirations of a given jurisdiction. Therefore, from the definitions, a political influence is witness-able and these range from institutions through local, national, regional all the way up to global levels of SDIs. A political influence in relation to these definitions can be summed up in the words of Craglia and Johnston (2004, p. 18) when they say "*Regardless of these different interpretations of what an SDI is, and the approach adopted for its development, an SDI has significant potential to underpin wider government strategies and initiatives such as e-government*." SDI has been shown to be an evolving phenomenon and offering opportunities to enablement to various communities it is meant to serve (Rajabifard, 2010; Scott and Rajabifard, 2017; Crompvoets *et al*, 2018).

2.2.3 Political Influence

It has been demonstrated in 2.2.1 that SDI origins are deeply entrenched in a strong political will. The Executive Order 12906 of 1994 and the INSPIRE Directive of 2007, can be used here as examples of how strong political will is instructive in facilitating SDI and its processes. In Executive Order 12906, Clinton (1994, p. 1), the President of the United states of America then, made a very bold political statement regarding the authority at his disposal to; "*implement the recommendations of the National Performance Review; to advance the goals of the National Information Infrastructure; and to avoid wasteful duplication of effort and promote effective and economical management of resources by Federal, State, local, and tribal governments*". From this powerful statement the popularly accepted definition of SDI was coined as enacted among the list in table 2.2. Another strong acceptance of political influence can be captured from the words of Craglia & Annoni (2006, p. 100) referring to the INSPIRE initiative when they say; "*SDIs are strongly embedded into a political process which touches upon the different ways in which public sector organizations in general, and data producing ones in particular, are funded in the member states*." Considering the USA-NSDI along those

of 10 other countries, Masser (1999) alluded that SDI generally portray the national contexts of their country of origins. These contexts were often reflected in naming of the SDIs and the major policy perceptions in building geospatial information into some sought of infrastructure or framework.

An example of country context can be seen from the USA Executive Order which elaborated the responsibilities of the Federal Geographic Data Committee (FGDC) and how other stakeholders were going to fit in with its activities in building SDI. The Executive Order 12906 further pointed to very significant directions on the following;

- ***Development of National Geospatial Data Clearing House***: These objective spells out a number of important things which needs to be done at the level of Secretary such as documentation processes, access and utilization of NSDI and the aspects of standardizing data documentation and funding.
- ***Data Standards***: This articulates and give direction to FGDC on the responsibility of establishing requisite standards to allow for SDI commencement.
- ***National Digital Geospatial Data Framework***: This objective put forward a broad requirement on the kind of digital data to be developed and this included boundaries, hydrology and transportation.
- ***Partnerships:*** this being a compelling statement addressing relationships which need to be established to allow SDI to develop.
- ***Scope:*** This spells out government agencies which are mandated to be involved with the NSDI development and those who status are optional especially certain military dispensations.

Another political influence that is well documented in the SDI literature is by European Union Parliament through a directive which was aimed at establishing what could be termed a 'Regional SDI' and its main goals were to allow for seamless dealing with environmental issues across the Union, (European Union, 2007). The European Union SDI popularly known as INSPIRE was constructed by sourcing all the required information from the SDIs of the member states. The European Union (2007), in formulating INSPIRE does give well-articulated positions on issues such as (a) metadata (b) spatial data interoperability (c) network services (d) data sharing (e) coordination (f) monitoring (g) spatial reference systems and (h) data themes. Though a number of European Union countries had started building national SDIs before the 2007, there is evidence pointing towards its influence in them as many reconfigured

and adapted to the expositions promulgated in what is commonly known as INSPIRE Directive 2007 (Bartha and Kocsis, 2011).

2.2.5 Representation and Presentation influence on SDI

Representation and presentation of geospatial data have remained fundamental pursuits by human race in an attempt to make sense of their environs (Dykes, 1997; Goodchild, Yuan and Cova, 2007; Fairbairn *et al*, 2008). Media, standardisation, integrating and cataloguing are thus very important influences in spatial data representation and presentation (Fairbairn *et al*, 2008). Spatial data needs to be represented and presented in most intelligible of ways in order to improve our understanding of the environment as we perform various functions for human interest. Representation in itself is a fundamental scientific undertaking as it helps humanity to close the theoretical postulations they have coined with reality (Couclelis, 1992). The represented data must be collated into powerful information that, must be presented with maximum visual impact to the users (Fairbairn *et al*, 2008). Feature representation has for long time used special primitives such as points, lines and shapes/areas as a way of modelling spatial data (Burrough and Frank, 1996). The primitives' way of representation has been followed by tessellations methods which indicates two leading modelling scenarios named vector and raster. The primitives gave rise to vector data and tessellations raster data types. These modelling methods usually appear in various contrasts and visual hierarchies to depict their presentation character of the features being represented and some scholars have called for their unification to improve topology (Goodchild 1989; Winter and Frank, 2000).

Spatial data representation and presentation spans a long history and the media on which it is communicated has transcended through the various stages of history (Fairbairn et al, 2008; Dykes, 1997; Goodchild, Yuan and Cova 2007; Cartwright, 2010). The most important media in the long history of spatial data representation and presentation is paper (Vitek, Giardino and Fitzgerald, 1996; Hurst and Clough, 2013). Paper has for a long time been used as media of presentation for spatial information, where measured data using methods such as theodolites, tapes, electronic distance measurements, photogrammetry have been cartographically processed to portray reality (Fairbairn *et al*, 2008). With the use of Paper as a presentation medium, a product commonly referred to as a map was always produced. In the case of Vitek *et al* (1996) the products of interest were "geomorphological maps". Maps are representations of reality, they are produced at various level of scales and even classified according to their

scales into categories such as Plans (large-scale), medium-scale and small-scale maps for better visualisation of geographic features (Fairbairn *et al*, 2008). These maps have ranged from very small localities such as settlement development areas all the way up to global maps. Maps have been presented and classified in different forms based on their utility such as topographic maps, thematic maps, engineering maps and cadastral plans (Vitek *et al*, 1996).

As maps were drawn, the strife has always been to standardize and integrate the features that are represented (Vitek *et a*l, 1996). What must be understood is that, maps are generalisation of reality and by using standard symbols and codes for representation help many people to read and comprehend the drawn features. It has to be recognised that, to derive extensive meaning from maps, feature representations are standardised through symbols and coding. The different data sets are further integrated into information under a map so as to build a picture that exposes relationships and character of natural landforms, man-related creations and countries' social, political and economic endeavours. To give examples we can produce engineering maps, tourist maps, agricultural maps, wildlife management maps, electoral maps, security maps, climate variations maps etc. Suppose that the area of influence is one, we can integrate these maps so as to come up with a multi-purpose representation and presentation on one map sheet. Integration brings about the benefit of the economies of scale in that one map sheet represent many features and can be used by many users. Also, a one stop acquisition of the various information will have been achieved and this leverage several processes. Maps are also produced and stored for acquisition by interest groups which means that multi-feature representation and presentation of maps does allow for better storage or cataloguing of maps as products (Fairbairn *et al*, 2008).

The above illustrate that representation and presentation does have a lot of influence on the discourses of spatial data. It follows therefore that as human activity evolved to the technological era of today, it had to impact on humanity chatting new ways of representing and presenting geospatial data (Hurst and Clough, 2013). Chatting new ways is necessary because technology brings along better opportunities for standardising and integrating spatial data. The technological progression has seen innovations such as computer and graphic card development which have led to representation and presentation of geographical information in computers and its associated systems (Vitek *et al*, 1996; Dykes, 1997; Goodchild, Yuan and Cova, 2007; Cartwright, 2010). The computer by being able to handle graphics has led to development of software such as Computer Aided Design (e.g. AutoCAD, Mirostation etc),

photogrammetric processing software, geographical information Systems (GIS) software and virtual reality, which are all vital in representation and presentation (Vitek *et al*, 1996; Fairbairn *et al*, 2008). The computer coupled with the internet and mobile technologies effectively transformed the whole geospatial representation and presentation to everyone hence the need for systems which can address the changes (Hurst and Clough, 2013). Representation and presentation have been taken to new heights through the Internet and web-enabled mobile devices. These new technologies have become the trend setters and the real game changers by influencing mass demand for spatial data (e.g. location-based services).

2.2.5 Technological Influence on SDI

Modern technologies have had a sweeping influence on many fields as we know them. The influence on geospatial data collection, processing and consumption have been driven by Global Positioning Systems (GPS), spatial sensors (Remote Sensing (RS), Photogrammetry, Unmanned Aerial Vehicles (UAVs) and Information Communication Technologies (ICT). GPS, RS, GIS, UAVs and ICT, collectively referred to as geospatial technologies have seen a lot of transformation in GI and their influence took a tremendous speed in the 1980s, (Waldoi, 2002; Gaudet, Annulis and Carr, 2003). Geospatial technology has been defined by Gaudet *et al* (2003, p. 24) as;

> "*an information technology field of practice that acquires, manages, interprets, integrates, displays, analyses, or otherwise uses data focusing on the geographic, temporal, and spatial context. It also includes development and life-cycle management of information technology tools to support the above*."

This definition reveals many fields and processes that need to be streamlined into a system with integrative and interoperable capabilities to allow for data access and information sharing by all stakeholders. These technologies change rapidly and affect a lot of geospatial information societal activities, for example; data collection, processing, products and use, as such they influence real transformation on various fronts, (Jackson, Schell and Taylor, 2009). Geospatial technologies and how they change affect countries, regions, continents and the whole globe, therefore their studies can be carried out on any of these scales. That means studies can focus on the activities of individual nations or we can select a number of countries for investigations (Hjelmager *et al*, 2008).

Focussing on GPS, evidence is abundant that it has given a true geodetic coverage of the earth and led to improvement in spatial referencing systems (Seeber, 2003). The origins of GPS were led by USA through its Department of Defence (DoD) which developed and maintained the NAVSTAR-Global Positioning System. In Russia another GPS system named GLONNASS has been developed and the Europeans developed the GALILEO constellation. These technologies have been and continue to be harnessed by large industrial corporations such as Leica Geosystems and Trimble Geomatics by developing a variety of receivers which can track these satellites and obtain geospatial data of varying degree of graphical accuracies and ability to use feature data dictionaries for attribute data collection. GPS and its measurements have now become routinely integrable with spatial sensors of sorts and geo-databases.

A combination of GPS and spatial sensors have led to obtaining good geodetic coordinates and processing of related images to support several endeavours of the natural phenomenon including man-made things and activities. The sensing technology focuses mainly on the use of special satellites capable of taking images of the surface of the earth for example Spot and QuickBird Imageries etc. Remote sensing is useful to capturing geometric, land use and biophysical data which is then linked to calibrated data from GPS to produce maps and other geospatial information products. Further related to RS, though more earthbound are techniques such as photogrammetry and Unmanned Aerial Vehicles (UAV) and other scanning technologies e.g. total station surface scanners and Ground Penetrating Radars (GPR).

ICT adds to GPS and spatial sensors by allowing for sharing and widened consumption of spatial resources by all communities in pursuit of their interests across the world. The human interest e.g. environmental, farming, mining, tourism, land ownership etc, drives us to exploit how best to harness the capability of technologies. The realisation of the foregoing has influenced the emergence of the concept of SDIs as articulated in 2.2.1. Recognising the influence of ICTs, Bernard and Craglia (2005) acknowledged the World Wide Web (WWW) and its underlying functionality in building interoperable geographic interfaces such as; (a) *Web Catalogue Services* (b) *Web Feature Service* (c) *Web Coverage Service* (d) *Web Gazetteer Service* (e) *Geographic Markup Language* (f) *Web Map Service* (g) *Web Coordinate Transformation Service*. A lot of these services have now been developed into real platforms to support activities in geospatial information through the efforts of Open Geospatial Consortium, (Bernard and Craglia 2005). Bernard and Craglia (2005, p. 2) emphasized their influence on SDI by stating that "*the existing specifications and standards have been proven*

to help in setting up SDIs of interoperating GI services that allow efficient access to spatially distributed geodata".

2.2.6 The SDI Momentum

SDI push and momentum occurred largely at the turn of the twenty first century and was evidenced by various names ranging from organisational, local, national, regional and all the way to global, (Rajabifard and Williamson 1999; Coleman and McLaughlin 1998). In moving SDIs forward through its various levels, a number of scholars used the theory of diffusion of innovation by Rogers (1995) as a vehicle. Such researchers have been elaborately mentioned in Grus, Crompvoets, and Bregt (2007) with specific approaches they followed. To validate this use of diffusion of innovation theory in SDI, an example can be followed in the work of Rajabifard (2002), used in studies focussing on a regional SDI in Asia and Pacific. The work by Rajabifard (2002) also came up with the ideas of product-based and process-based SDIs.

Since 1990, SDI momentum was progressing well and by the end of twentieth century Coleman and McLaughlin (1998) ventured into the concept of Global SDI (GSDI) defining its components, stakeholders and interfaces while Rajabifard and Williamson (1999) later pursued the concept of SDI hierarchy touching on its nature. Taking cue from these works, Nebert (2004) developed a comprehensive resourceful material commonly known as "*SDI Cookbook*". SDI Cookbook played a role in SDI development and growth but as that happened, signs of complexity emerged as witnessed through investigations by Grus, Crompvoets, and Bregt (2006) following the theory of Complex Adaptive Systems (CAS). The complexity in SDI was exposed by the time when, they were put under spot light through assessment processes. SDI assessment was started with very intuitive approaches. The SDI assessment methods such as SDI Readiness Index (Delgado Fernández, 2005), INSPIRE State of Play (2005), the Performance Indicators (Giff, 2006) and many others have led to a more comprehensive assessment method and resource called Multi-View SDI Assessment Framework by Grus, Crompvoets, and Bregt (2007). The intention of assessment was to generate knowledge in order to inspire reviews and future actions on SDI.

Some literature reviews, for instance, Masser (1999) show that, research in the early days have often focussed in the technical aspects of SDI, though in its development it has emerged that the organisational aspects are fundamental, Kok and van Loenen (2005). In addition to

organisational aspects it has also emerged that users are fundamental in SDI advancement, (Budhathoki., (Chip) Bruce, Nedovic-Budic, 2008). The point of view of the users was earlier articulated in GeoConnections (2005, p. 5) by stating that "*momentum from the community of users will propel the development of the CGDI down the maturity curve*". This statement referred to Canada Geospatial Data Infrastructure (CGDI) but in reality, it looks and sounds reasonably true for all sorts of jurisdictions where SDI development is a primary concern.

2.2.7 SDI Perspectives

The concept of perspectives has been widely used in the SDI literature. The perspective concept was used by Coleman and McLoughlin (1998) to demonstrate the diversity in the stakeholders who have interest in SDI development. By so doing Coleman and McLoughlin came up with five fundamental perspectives of SDI Development being; (a)Data driven perspectives (b) Technology driven perspective (c) An institutional perspective (d) A market driven perspective and (e) An application driven perspective.

These perspectives speak to the early efforts which played a part in development of SDIs. The data centric and technology driven perspectives are highly characterised by creation, dissemination, maintenance, integration, interoperability, sharing and exchange in order to better make decisions and improve business performance, (Coleman and McLoughlin 1998). The institutional perspective on the other hand has been nicely summed up by Coleman and McLoughlin (1998, p. 15) by referring to what they call *"inherent mandates, responsibilities, limitations, conflicts and financial constraints of the respective organizations and constituencies involved."* The word constraints as used in this reference is an interesting one because, when deeply viewed it certainly permeates across all the perspectives mentioned here. To elaborate this point, we can look at the market driven perspective which is generally described as short-term endeavour operated by private businesses as opposed to jurisdiction-wide and long term as SDIs are viewed by governments entities. The different lineage as to the kind of information to produce has often created constraints for the stakeholders to collaborate and pursue similar outcomes. These constraints have also been reported as visible in applications whereby Coleman and McLaughlin (1998, p. 16) summarises the scenario by saying that; *"they form many different groups whose perspectives are sometimes at odds with one another"*.

The perspective concept was once more utilised by Chan, Feeney, Rajabifard and Williamson (2001) in their attempt in defining SDIs' dynamic nature. Chan et al (2001), basing their justification on the previous work focussing on geographical information systems (GIS), pushed forward four perspectives which were believed to be showing characteristics of dynamism, (Levisohn 1997; Chan and Williamson 1999a; Chan and Williamson 1999b). The justification in Chan et al (2001, p. 7) is captured when they stated that "*the definition classification system groups the definitions of GIS into four perspectives: identificational, technological, organisational and productional".* From this statement they went on to articulate that, the same perspectives can be extended to describing discourses associated with SDI. In this scheme of perspectives, identificational defines uniqueness in the system while technological addresses the form and functionality of the system. Further, the organisational articulates SDI in terms of organisational settings while the productional perspective is more interested in the context or place where the SDI is being developed.

The perspectives enacted from the two scenarios does bear some level of similarities and can support SDI advancement in a similar manner. These perspectives are still as relevant as they were pronounced in the 1990s and 2001. Many years have passed since, some countries have well developed SDIs and some don't. Therefore, in trying to understand why other countries have not manged a holistic SDI advancement, inherent constraints that exist within these perspectives need to be adequately understood.

2.3 SDI Components

The term component is widely used in science and it helps the user to discern between constituent parts that are forming a whole. In the case of SDI, McLaughlin and Nichols (1992) suggested a number of things which can be considered as ingredients of SDI. These ingredients or components were summarised by Coleman and McLaughlin (1998, p. 8) to be; "*sources of spatial data, databases and metadata, data networks, technology (dealing with data collection, management and representation), institutional arrangements, policies and standards, and end-users*". The challenges that can be associated with these components differ according to jurisdiction and level at which SDI is considered for development, (Coleman and McLaughlin 1998). But then Rajabifard (2002, p. 26) made emphasis related to SDI development by alluding that; "*the design of any SDI requires an understanding of the nature of the concept, the contributing components and the impact of global drivers*". Rajabifard (2002) then went

on to propose an interactive model which depicts the nature of SDI caped by its dynamism. This model is referenced here as figure 2.2. In the views of Rajabifard (2002, p. 29) *"... an integrated SDI cannot be composed of spatial data, value-added services and end-users alone, but instead involves other important issues regarding interoperability, policies and networks*." This quote does suggest that when we look at the components of SDI in the context of every country as alluded to by Masser (1999), we have to delve deeply into these issues for instance evaluating impacts, successes, quality and constraints on the very processes.

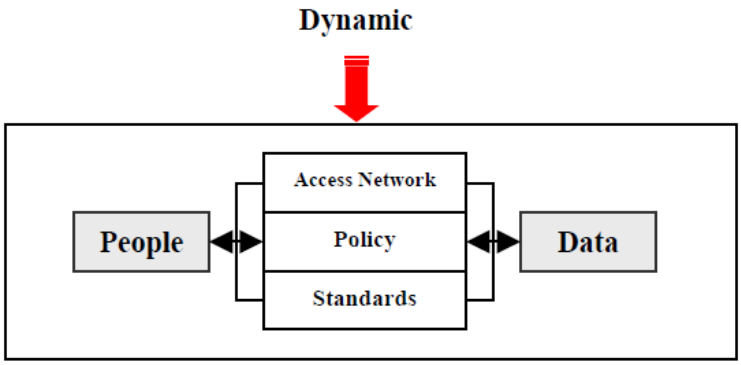

Figure 2.2. Nature and relations between SDI components (Source, Rajabifard 2002, p. 29)

A snap view of the dynamic model as provided by Rajabifard (2002), clearly reveals a symmetry between Data and People with Access Network, Policy and Standards as the mirror block of the two components. Since Rajabifard (2002) model of SDI nature and components, a number of years passed and temporal changes have taken place and we find the same components of SDI structured slightly different by Jakobsson (2006) as depicted in figure 2.3. Jakobsson (2006) based the components on organisations with reference datasets and access network at the far ends of a quadrant structure addressing people, technical standards, policy and administration.

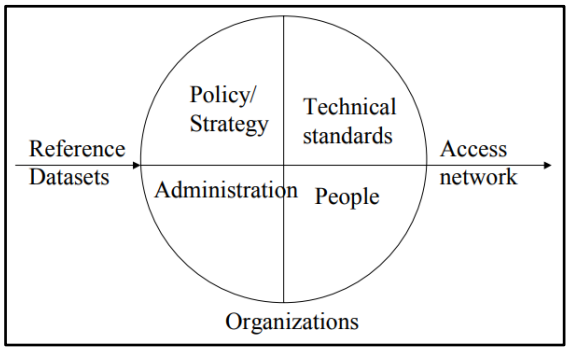

Figure 2.3: Components of SDI, (Source: Jakobson, 2006, p. 49)

Despite their structural configuration, figure 2.2 and 2.3 reveals five main components that are universally accepted to make SDI and they are; (1) Data (2) People (3) Policy (4) Standards and (5) Access networks. These components exist and respond in a dynamic way to a social system in a jurisdictional set-up (Rajabifard and Williamson, 2001). Examples of social system objectives could be SDI championing and political will, usually following the guidance of national spatial data needs and strategies in production of product-based and/or process-based SDI (Rajabifard and Williamson, 2001; Rajabifard, 2002). Rajabifard and Williamson (2001, p. 8) insists that it is necessary to understand the social system that the SDIs operate in because; "*The characteristics of the social system strongly influence the approach taken to the development of an SDI initiative*." That being case the SDI components together with the two models are reviewed in the next subsections in order to give a deeper perspective to this section.

2.3.1 Data

Geospatial data has gone through the ages as key in decision-making, going far back as the days of the Pharaohs and the Pyramids in Egypt to the world of today associated with highly sophisticated equipment. Since the 1990s, geospatial data has begun to be viewed as ubiquitous, (Coleman and McLaughlin 1998). The ubiquity in geospatial data has played a fundamental role in the development of SDIs as we know them today. Geospatial data is elaborately discussed in the SDI Cookbook by Nebert (2004) focusing on issues of development, metadata, cataloguing, visualisation and access.

The threshold in geospatial data development, is its collection which has been succinctly elaborated in Nebert (2004) by acknowledging that government has always played a leading role in this responsibility. The spatial data collection methods of land surveying, photogrammetry, GPS surveys and remoting sensing yields a lot of numerical and graphical data which are cartographically processed to produce useful information to aid decision-making e.g. Cadastral maps, topographic maps, geological maps, conservation maps, tourist maps, weather maps, engineering plans etc. Before the explosion of high technological equipment, the information collection and processing used to be extremely labour intensive with limited opportunities to multi-layering. Therefore, supply-oriented maps were often produced at a given scale as per set standards by the government mapping agencies, (Nebert 2004). The government standardised maps were then used as a base upon which theme data can be overlaid, ensuring some level of data integration. Most of the olden methods which

were used in spatial data collection and processing have now been improved by technologies such as Global Positioning Systems (GPS), Multi-stations (theodolite, electronic distance measurement and scanning all in one), Remoting Sensing Satellites, Unmanned Aerial Vehicles, and Information Communication technologies (ICT). The emergence of these technologies has made it possible for spatial data to be collected into a seamless workflow process that often end with multi-layers in Computer Aided designs (CAD) and Geographical Information System (GIS) software. The technologies have also led to ease of integration and interoperability in spatial data but a number of data sets do experience duplication and in some instances lack of requisite accuracy requirements.

In the earlier days, work on most cases involving spatial data operations was performed by geographical information experts e.g. land surveyors, cartographers, geographers, geologists, environmentalists, planners etc, but in the current times the technology has revolutionised all these and virtually everyone is now a player. Describing these changing scenario Nebert (2004, p. 13) has stated that; "*Nearly anyone can create their own maps, thanks to the use of desktop mapping, GIS, GPS surveying, satellite imagery, scanning and intelligent software*". To avoid confusion in collection, processing, storage and distribution of geospatial data, it is important to associate it with its comprehensive explanations named Metadata. Metadata are very important especially in the realisation of many players in geospatial data activities. According Nebert (2004), metadata is very useful in that it can help in harvesting spatial data for use, while maintaining data qualities and integrity of its origins. Metadata are important because they can be used for data discovery, exploration and exploitation, (Nebert 2004). Despite all the good things said about Metadata, many countries across the world continue to have problems in constructing them, hence struggle with the building of functional SDIs. The Metadata problems pose a real hindrance to geospatial data usage and development of SDIs across the various hierarchies.

Spatial data needs to be managed through cataloguing processes so as to store for sharing, use, and discovery. The technological explosions have almost made this scenario mandatory across the globe and a number of developed countries such as USA, European Union, Australia and a number of middle-income countries have implemented cataloguing of data through clearing houses and such other related frameworks, (Nebert, 2004). The development in these countries have been driven by World Wide Web (WWW) which has allowed for visualisation, sharing and exchange of spatial data over a network of inter-connected computers globally. This has

changed the playing field in geospatial data workflow process to shift from being supply driven to be demand driven, with the user's role having become central to its activities. As such spatial data access is no longer a privilege but a need that requires solution for users of all sorts across world.

In developing SDI today, the picture summarised above need to be taken into cognisance. For countries with developed SDIs this could be the case of making evaluation and coming up with methods of improving. For countries who are still struggling with the establishment of SDI, this could also be time to reflect and study the constraints that are associated with this component so as to come up with effective progression plans.

2.3.2 People

Geospatial data and many human activities interact to give a picture of completion. This has been well realised during the information communication technologies era, so much that almost everyone has a role to play in the geospatial data collection, processing, use, sharing and distribution. People have become important in all aspects of geospatial data, which has in the process narrowed down the gap between people traditionally viewed as data providers and data users (Davies, 2003; Budhathoki, (Chip) Bruce and Nedovic-Budic, 2008). Davies (2003) has made account of this scenario and even indicated that between the data providers and the data users a new group called integrators have evolved. The integrators have been largely responsible for developing platforms and applications to handle various geospatial data sets. Basing reasoning on the concept of Location Based Systems (LBS) Davies (2003) came up with a recategorization that can be viewed as fit for SDI as shown in figure 2.4.

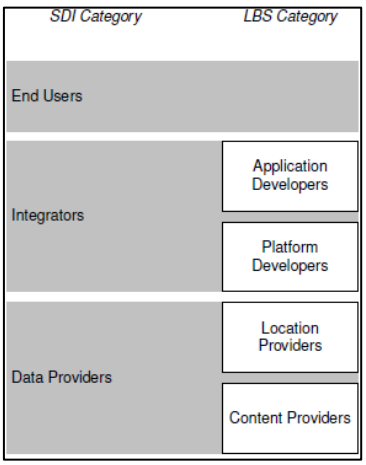

Figure 2.4: SDI people categories formed from LBS categories, (Source: Davies, 2003, p. 67).

The involvement of people with spatial data today is extremely wide and this calls for action in exploiting the various viewpoints proposed in Hjelmager et al. (2008) namely; enterprise, information, computation, engineering and technology. These viewpoints are very important and they affect several people across varied platforms at corporate, local, national, regional and global scales (Hendriks, Dessers and van Hootegem, 2012). The fundamentality of these component has been captured by Hendriks, Dessers and van Hootegem (2012, p. 1480) by stating that; "*many disciplines are interested in SDI, including geography, sociology, informatics, organization studies, public administration, economics and environmental studies*." The many interested people and various discipline spells a complex scenario which can prove very difficult to coordinate in order to achieve desired results.

From the onset, geospatial professionals and the organisations they are associated with were viewed as the main players of SDIs and as such it is not surprising to find that so many Surveys and Mapping Agencies are credited with its initiatives. This situation has seen their dominance over it for some time, but technology has changed the dynamics so much that unskilled users started contributing spatial data through their acquired sensors. These developments have instigated researchers such as Budhathoki, (Chip) Bruce and Nedovic-Budic (2008) to follow a line of inquiry which relooked into the user as an active participant in the SDI. The advancement in technologies and proliferation of sensors has led to the emergence of what is referred to as Volunteered Geographical Information (VGI) through the advent of tools such as Google Maps, Google Earth, OpenStreetMap, Common Consensus, (Budhathoki, (Chip) Bruce and Nedovic-Budic, 2008). Already by the year 2008, these tools were said to be attracting a lot of users going into millions of people around the world, (Budhathoki, (Chip) Bruce and Nedovic-Budic, 2008). Budhathoki, (Chip) Bruce and Nedovic-Budic (2008) had sort to relate this component in the matrix proposed by Eglash (2004) which is presented here as Figure 2.5. Figure 2.5 is a four-cell matrix with fundamental cardinal points depicting people as they interact with a technological dispensation such as SDI. This diagram clearly exposes the Producer and their associated organisations as key, while others within the component are just recipients. This structure and its reconceptualization are vital to the spatial data in the current and future times, especially in view of establishing an all-inclusive platform known as SDI.

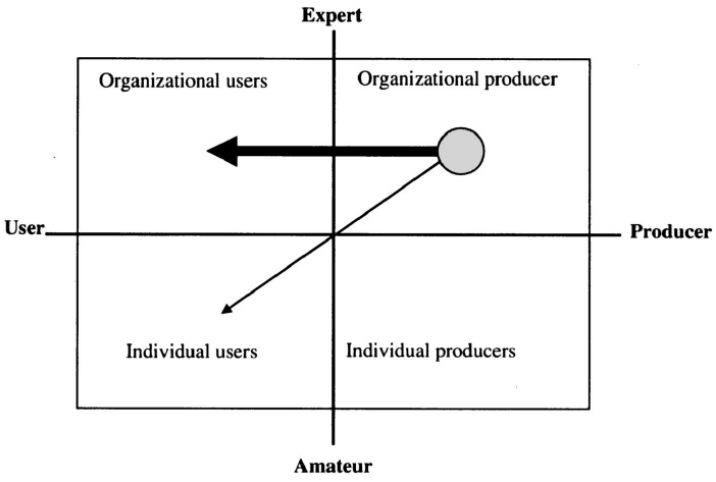

Figure 2.5: GI Production and conception of the user in contemporary SDIs (Source: (Source: Budhathoki, (Chip) Bruce and Nedovic-Budic, 2008 adapted from (Eglash 2004), p. 151)

According to Budhathoki, (Chip) Bruce and Nedovic-Budic (2008) this has influenced what they described as a 'legacy view' that has been inherited in relation to the user of SDI. This poses us with challenges and constraints that can delay the start or advancement of an SDI in a jurisdiction.

2.3.3 Policy

Going by the definitions which were tabulated in subsection 2.2.2, development of SDIs does affect economies locally, nationally, regionally and globally. It is therefore important to realise this so as to develop policies that are progressive in addressing a broader spectrum of SDI issues. The world of today is very much interconnected and policies that are developed to support SDIs must take cognisance of this fact. Policies of comprehensive nature are driven by governments and they must be purposefully designed to achieve envisioned requirements. A policy meant to advance SDI, when issued by government must be adequately formulated to make it possible for the aspirations of the users to be fulfilled. Policy has to activate and spur various users into action and lead to positive results from inputs.

Policy by its nature is a very broad endeavour, as it is meant to guide development and keep checks and balances within a jurisdiction. Policy can take dimensions such as social, economic, political and technological outlooks. These four main realisable domains are often intertwined to give the area of policy application a very effective leverage. Therefore, it is not surprising that when we refer to Policy here; we are referring to Policy, Acts and guidelines that are

necessary in supporting SDI development and review. Davies (2003) gave examples of SDI Policies as; (a) spatial data access and sharing (b) spatial data transfer (c) custodianship (d) meta data and (e) standards. These Policies can be fragmented across a jurisdiction and can be very useful but for them to be highly effective an overarching Policy on SDI has to be considered as a better way to proceed. Such an overarching Policy should come in the form of what Moulton and Sandfort (2017) termed "*public service intervention*". Public service intervention has been defined by Moulton and Sandfort (2017, p. 149) as "*interventions that are intended to benefit the public that are authorized at least in part by political authority*". This definition bears the hallmarks of the various definitions of SDI found in section 2.2.2 and the political influences as addressed in section 2.2.3. Policy should be able to inspire change in attitudes of individuals towards impending public interventions. The attitude aspect can be objectively stated in the words of Oxley, Vedlitz, and Wood (2014, p. 254) when they Said that "*this attitude change involves a change in state from the individual viewing the issue as a non-problem to the individual viewing the issue as a problem*."

SDI Policies can be subscribed to the theory of '*policy problem recognition*' as discussed in Oxley, Vedlitz, and Wood (2014). The theory of policy problem recognition itself is anchored on three major tenets of attitudinal response by individuals to instruments of public service interventions and these are (a) *remaining in the status quo* (b) *receiving a persuasive message about the need for a policy* and (c) *evaluation of the first two tenets*. The first tenet takes the view that there is nothing pressurising towards changing the way things are being done while the second tenet is based on persuasion by those who recognises the pressing changes in the status quo. The third tenet is an evaluative one where for instance, in the case of SDI, user institutions make assessments of their needs to partake in its building by constructing attitudes through (a) and (b).

2.3.4 Standards

Geospatial data collection, processing, representation and collation has been underpinned by various standards. Standards are fundamental in geospatial data because they allow for ease of readability, integration and interoperability especially with the current available technologies. The International Standards Organisation (ISO) has taken a lead in developing geospatial data related standards through its Technical Committee 211 (ISO-TC211). In addition to ISO, Open

Geospatial Committee (OGC) have also been very active in development of some very useful standards. This has led to an abundance in geospatial data related standards when coupled with the effect of several disciplines which uses it. Davies (2003, p. 72) had identified standards relevant to SDI to be the following (a) "*Data format, exchange and access – for both spatial and a-spatial data sets*;" (b) "*User design – database schema, data coding and classification, metadata*;" (c) "*Map compilation and accuracy; and*" (d) "*Map presentation*". These standards are very useful when it comes to designing databases and exchanging data, (Davies, 2003).

Jurisdictions tend to come up with their own standards on geospatial data processes, (Davies, 2003). According to Davies (2003), the practice seems to have taken much push with the development of NSDIs. These standards are on their own, complex, but the complexity in their development is further compounded by the Information Communication Technologies (ICT), which are currently playing a very big role in geospatial data processes. This means that standards do pose serious challenges because as Crompvoets, Bregt, Rajabifard & Williamson (2004, p. 683) puts it "*Standards can be applied at many different levels within an SDI*." The challenges become more pronounced in developing nations which may lead to difficulty in a meaningful inception and steady progression in development of SDI.

Five fundamental viewpoints have been put forward in an attempt to come up with tactics of dealing with standardised ways of doing things in SDI. These viewpoints are named; the enterprise viewpoint which is meant to address the general requirements of establishing SDI; the information viewpoint which focuses on semantics and processing information that is to be built into an SDI; the computational viewpoint which seeks to enable an SDI system set of objects to interact at interfaces; the engineering viewpoint which is meant to enable distributed objects within the system to interact; and the technology viewpoint which addresses technology specifications that can help in the implementation of SDI and its related systems, (Hjelmager *et al*, 2008). A succinct representation of these Viewpoints is displayed on figure 2.6. Two viewpoints, being the Enterprise and Information were considered and discussed by Hjelmager *et al* (2008) as shown in figure 2.6(a) while the computation viewpoints as highlighted in figure 2.6 (b) has been widely considered and discussed in Cooper *et al* (2013).

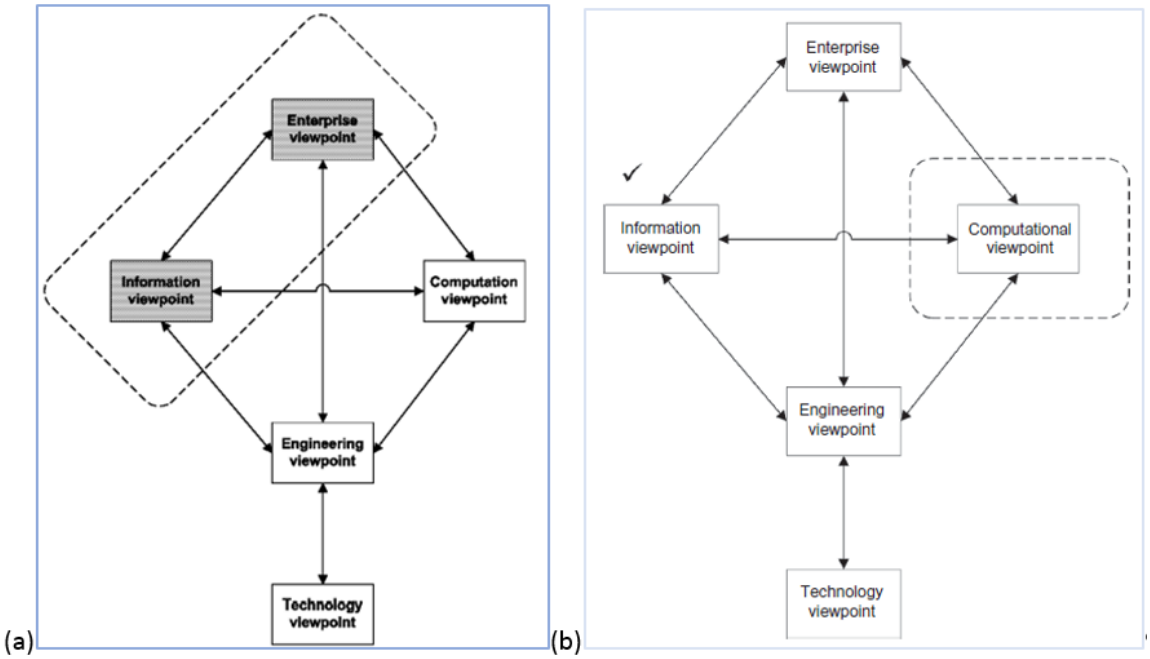

Figure 2.6: The RM-ODP Model highlighting discussions of (a) Enterprise and Information viewpoints (Source Hjelmager et al 2008, p. 1300) and (b) Computational viewpoint (Source: Cooper et al 2013, p. 1140).

These viewpoints are defined in the ISO-TC211 Reference Model-Open Distributed Processing (RM-ODP) (Cooper *et al*, 2013). The works by Hjelmager et al (2008) and Cooper *et al* (2013) were sanctioned by International Cartographic Association (ICA), through a Commission specific to Spatial Data Infrastructures. In consideration of the two viewpoints they discussed, Hjelmager *et al* 2008 used Universal Modelling Language to build fundamental relations that exist when SDI is being built. In so doing they identified SDI stakeholders to include Providers, Users, Producers, Brokers, Policymakers and Value-Added Reseller. They produced quite a number of diagrams in their discussion but for the purpose of this study Figure 2.7 was found more relevant and adopted. What is interesting about figure 2.7 is the aspect of constraints that, are associated with a number of components such as legal and business agreements. This begs a number of questions; e.g. (a) what are the impacts of constraints on SDI development? (b) How can they be dealt with so as to support SDI progress? (c) What about constraints associated with other components such as standards? These questions can be extended to Cooper et al (2013) where the Computational Viewpoint was considered and a number of objects were suggested being: "SDI Registry, SDI Data, SDI Processing, SDI Application, SDI Portrayal and SDI Management".

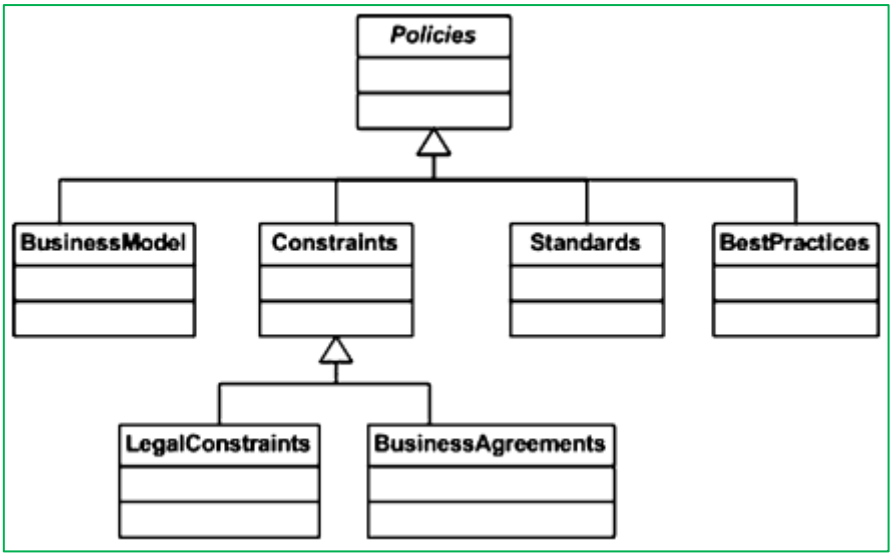

Figure 2.7: The various types of policies in SDI and their relationships (Source: Hjelmager et al 2008, p. 1304)

The whole field of questions relating to constraints can further be asked in respect of what Cooper *et al* (2013) has referred to as "*eight SDI processes*" as structured in figure 2.8. SDI by its nature requires to be started and transited through the various stages of the processes found in figure 2.8. Through the processes, there are most certainly a bundle of constraints that can cause the proceedings to be slow or remain just a good idea of the meetings that recommended SDI development. SDI slowness or remaining just a good idea emanating from meetings has been largely associated with developing countries, (Makanga and Smit 2010; Mwange *et al*, 2016).

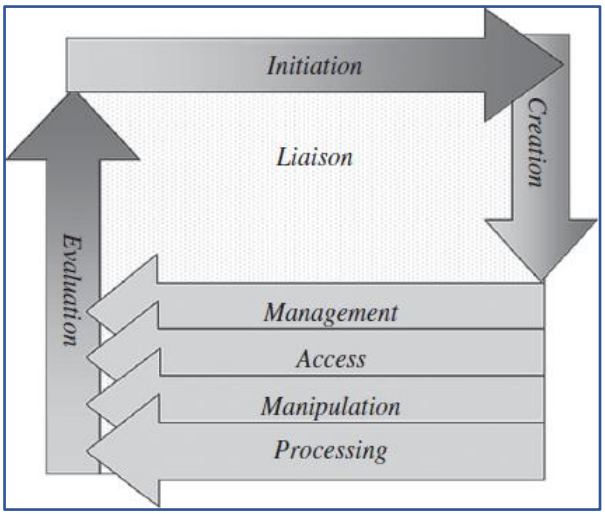

Figure 2.8: The eight SDI Processes. (Source: Cooper et al, 2013, p. 1146)

In overall, standards in SDI are important in facilitating data integration and interoperability. That is why the Australian Land Information group had in 2001 identified reference systems, data models, data dictionaries, data quality, data transfer and metadata to be the major areas of development, (Davies, 2003). While United States of America and European Union had since the 1990s developed metadata standards for instance the highly utilised Content Standard for Digital Geospatial Metadata, Version 2.0, 1998 by FGDC, (Crompvoets *et al,* 2003). The aspect of data transfer by its nature requires that there be appropriate communication networks to allow for data sharing and exchange to happen fast and with ease. The ICTs have in that sense greatly filled the void of access networks and availed a positive influence on the advancement of the SDI concept.

2.3.5 Access Networks

The need to access and share geospatial data has been recognised by the development of early global maps and atlases (Davies, 2003). In order to facilitate the data getting to those in need of it, ways had to be developed to cater for that and this has been well articulated by Davies (2003, p. 67) by saying "*the avenue by which data within an SDI is made available to the community, can be described as the access network.*" These access networks are now highly facilitated and supported by Information Communication Technology (ICT) and sensors which have become ubiquitous across the globe. In the words of GeoConnections (2005, p, 1); "*Networked access makes data more readily and freely available. This premise is the driving force for building an Internet-based, distributed geospatial data infrastructure*." The quotations from Davies (2003) and GeoConnections (2005) describe well the realities of today, which should encourage all nations to realise that having SDI will leverage a number of social and economic activities.

Over the years, nations which managed it, have developed Geoportals as the main points for access in SDI structured environment. Sometimes these portals have been referred to as Clearinghouses by other nations (Coleman and McLaughlin, 1998; Crompvoets 2002; Crompvoets and Bregt, 2003; Crompvoets, Bregt, Rajabifard and Williamson, 2004). In that respect Crompvoets *et al* (2004, p. 666) defined a Clearinghouse as "*the access network of an NSDI that facilitates access to the spatial data. It provides complementary services and improves the exchange and sharing of spatial data between suppliers and users*."

Access networks were traditionally dependent on wired interconnections (broadband connections) but today mobile services have made very serious inroads into this domain with their Third Generations (3Gs), Fourth Generations (4Gs) and the Fifth Generations (5Gs) products of Long-Term Evolution (Bangerter, Talwar, Arefi and Stewart, 2014). Long Term Evolution (LTE) products are mentioned here to appreciate the role of mobile technologies in access networks. According to Bangerter et al (2014) the 5G is a work in progress and its impacts are going to be realised within a period of 10 years, figure 2.9 reveals this within the context of an evolutionary network progression.

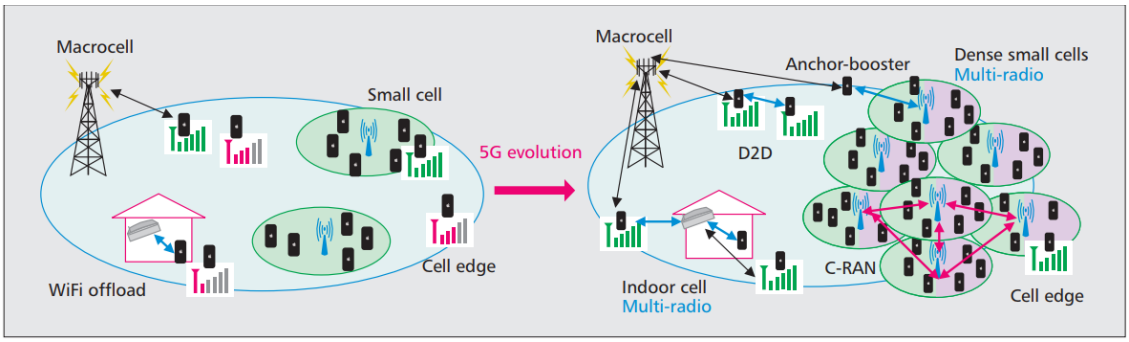

Figure 2.9: The Evolution of the HetNet (Source: Bangerter, Talwar, Arefi and Stewart 2014, p. 92)

What is at play in figure 2.9 is that, more devices are now working together, which improves the inter-communication and efficiencies on data transitions. These devices continue to work wonders on geospatial information delivery. Movements have already been made to integrate the internet (World Wide Web) and mobile technologies which are primary enablers of access networks concept with Global Navigation Satellite System (GNSS) as depicted in figure 2.10. This offers unparalleled opportunities for accessing geospatial data as emphasised in Bangerter *et al* (2014, p. 94) by saying that:

> "*5G Era devices will increasingly support a rich array of device location capabilities. These capabilities will range from processing, with ephemeris assistance data, an ever-maturing set of GPS and GLONASS satellites to include the Beidou, Galileo, and even IRNSS constellations*."

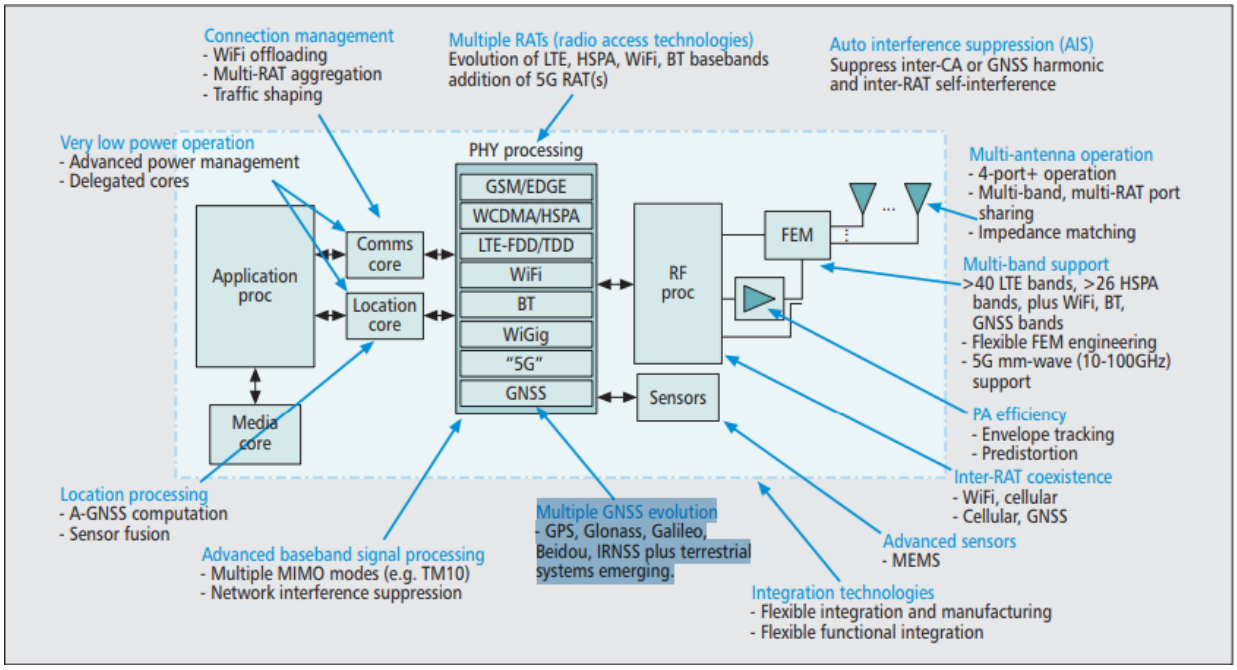

Figure 2.10: Device technologies for 5G era (Source: Bangerter, Talwar, Arefi and Stewart 2014, p. 94)

Bangerter *et al* (2014) go on to opine that the level of integration will lead to obtainable accuracies of less than 1 metre indoor mapping where techniques such as geo-fencing and crowdsourcing will be embedded into the system which they dubbed "a holistic location engine". This technological integration will spur interoperability and those with robust SDI programs will stand to benefit because, the wired interconnections and mobile services will facilitate browsing, uploading and downloading insurmountable sizes of geospatial data through the integrated devices as access networks.

2.3.6 The SDI Models

Through its various discourses, in the late 1990s and early 2000, SDI was found to follow two main generic types. These generic types were identified in Rajabifard and Williamson (2001, p. 7) to be "*product-based and process-based*". The product-based SDIs as shown in figure 2.11 are said to be more technical in approach led by data integration through database structures, to create various layers of information through a geographical information system software (GIS). According to Rajabifard *et al* (2006) the product-based type of SDIs were generally led by national governments with the National Mapping Agencies (NMAs) leading the efforts. On the other hand, process-based SDIs as shown in figure 2.12, go further by subscribing more to openness in facilitating geospatial data sharing, exchange and access,

(Rajabifard and Williamson, 2001). The process-based SDI model was heavily influenced by the advent of the Internet and the World Wide Web with their distributed but interconnected networks and sharing capabilities (Rajabifard *et al*, 2006).

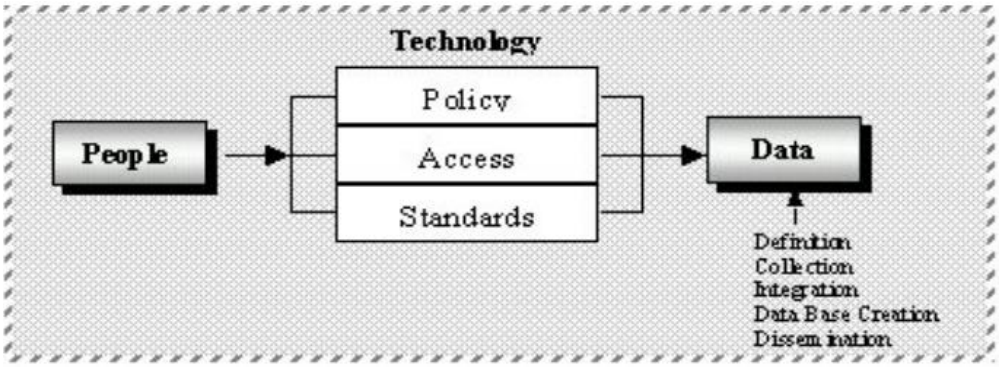

Figure 2.11: Product-based SDI. (Source: Rajabifard and Williamson, 2001, p. 7)

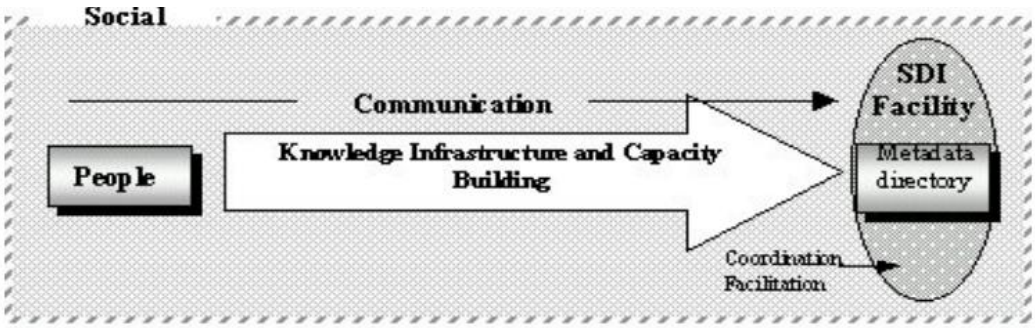

Figure 2.12: Process-based SDI. (Rajabifard and Williamson, 2001, p. 7)

Rajabifard and Williamson (2001), comparing these two models raised adequate reasons that speaks for SDI in the realm of the process-based approach. They argued convincingly that this approach address itself to a number of considerations which are often pronounced in defining an SDI. They further opine that the process-based approach was more consistent with the theoretical propositions of the diffusion by Rogers (1995), which anchors on a social system and its influencers such as decision makers, diffusion channels, complexity, the change agents in innovation adoption.

As time went on, a third generation of SDI which bears characteristics of decentralisation and incoordination were identified to be taking centre stage in discourses (Rajabifard *et al*, 2006). This third generation SDI saw the multi-user of geospatial data as important, hence requiring a platform that can allow for functional interaction of heterogenous entities in a social system

(Rajabifard, 2007). This type of SDI has been defined by Rajabifard (2007, p. 3) as; "*an integrated, multi-levelled hierarchy of interconnected SDIs based on partnerships at corporate, local, state/provincial, national, regional (multi-national) and global levels*". Partnerships across many users in the economy underpins this third generation SDI and participation in it is ubiquitous compared to the earlier two SDI types. According to Rajabifard (2007) it has to provide "*models of governance*", "*promotion of data sharing*", "*establishment of enabling platform*" and "*creation of a fully spatially enabled society*" as key variables in its implementation and development. The evolving nature of SDI and its typologies is shown in figure 2.13.

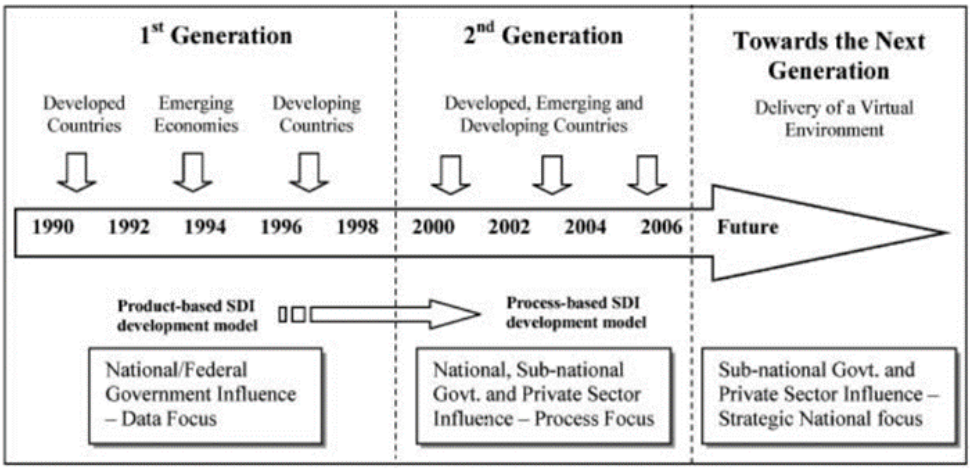

Figure 2.13: Continuum of SDI Development based on the first and second generations of SDI (Rajabifard et al, 2006, p. 730).

This calls for introspection, especially jurisdictions struggling with SDI implementation. There is need to understand these SDI models so that if a product-based model was used in kick-starting SDI, its limitations should be tamed as the SDI evolve into a process-based phenomenon and further. It has to be realised that constraints are inherent in various stages of SDI and they aggregate, therefore inhibiting SDI development. Country contexts are very important as seen by various articles which focus on USA, Australia, The European Union SDI efforts (Rajabifard *et al*, 2006).

2.4 SDI Developments

As stated in the introduction SDIs sprouted during the 1990s largely pioneered by the United States of America. Therefore, in an attempt to study SDIs, researchers are always tempted to refer back to those which started during those time periods. The practitioners across the world in an attempt not to reinvent a wheel, tend to relate to the early SDIs. Some late adaptors, like most African countries, have not all been successful going by the work of Makanga and Smit (2010) read with Mwange *et al* (2016). Despite the difficulties, their need to develop SDIs have remained high to date. SDI development tend to occur at a number of hierarchies which's data need to be interdependent. The hierarchies of SDI development are found to start from corporates, local, national, regional and all the way up to global (Rajabifard and Williamson, 2001; Rajabifard, 2002). In order to put this study into perspective the hierarchies are discussed and then a number of examples are drawn across the globe to give a picture of SDI development.

2.4.1 SDI Development Hierarchies

Human endeavours are replete with hierarchies. For geographies, humans have commonly named and accepted structures made of populated settlements (villages, towns and cities), other land uses (fields, cattle posts, game reserves etc), municipalities, districts, provinces, countries, regional groupings of countries, continents and the whole world. Coupled with these geographies are human activity structures in the form of how they execute their workflows to harness the resources associated with the various levels of place. The commonly accepted human workflow structure is institution which is replicated through various tasks and geographic levels. Examples of institutions include those traditionally involved with land management activities (survey, mapping, planning, environmental), agriculture (ploughing and livestock rearing), security (police and soldiers), infrastructural development (water, power, technological communication, roads) just to name a few. These institutions and many others not mentioned are usually arranged to permeate through all the levels of the geographies stated above (e.g. Village Housing Unit, Municipal Planning Authority, National Ministry of Lands, Regional Economic Union, United Nations Food and Agricultural Organisation). To be able to maximise decisions about the activities of these institutions and their associated geographies, information is required. In the case of SDIs development, geographical information is required and it needs to be structured in a manner that is intelligible at the various geographical and governance levels. Explaining these scenario Rajabifard and Williamson (2001, p. 3) stated

thus "*with the rapid improvement in spatial data collection and communications technologies, SDIs have become very important in the way the spatial data are used throughout a company, a governmental agency, a nation, throughout regions and even the world*."

What is evident in the quote from Rajabifard and Williamson (2001) is the aspect of hierarchies based on governance and geographical spread that is associated with SDIs. Using this reasoning Rajabifard and Williamson (2001) have suggested a strongly interdependent model for these relationships and referred to it as "Hierarchy for SDIs", figure 2.14.

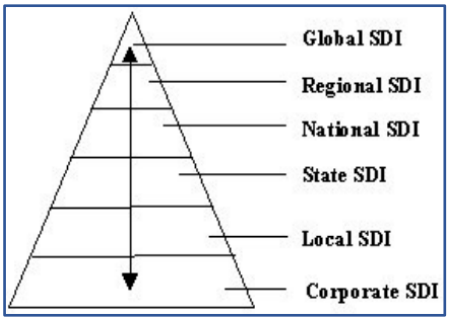

Figure 2.14: A Hierarchy of SDIs at different levels of jurisdiction. (Source: Rajabifard and Williamson, 2001, p. 6)

Consistent with this SDI Hierarchy model, a number of examples were mentioned in Rajabifard and Williamson (2001). According Rajabifard and Williamson (2001, p. 5), SDIs initiatives were found in countries such as "*Australia, Canada, China, Colombia, Denmark, Finland, France, Germany, Hungary, Italy, Indonesia, Japan, Malaysia, Netherlands, Portugal, Spain, Switzerland, UK, and USA*" which indicated national SDI levels. Further to that they also state that "*Asia-Pacific SDI (APSDI) and the European Geographic Information Infrastructure (EGII)*" were the only visible regional level SDIs. These SDIs are very important in the discussions of SDI developments as perceived in this section; therefore, a few will be purposefully selected for further discussion. Even though there were ongoing national and regional efforts in SDIs, the global seen was also set ablaze with the introduction of what was called the 'Global Spatial Data Infrastructure (GSDI)'. GSDI is that same concept which was initially defined in Coleman and McLaughlin (1998) as quoted in subsection 2.2.2 of this study.

In discussing SDIs across the world, it makes sense to appreciate these levels of SDIs. It is particularly important to take cognisance of the corporate SDI because it forms the foundations of the SDIs above it, especially if we are to talk of them in the context of process-based models.

The process-based typology talks to the interdependence of data across the various levels of SDIs so as to truly satisfy the Coleman and McLaughlin (1998) definitions which discourages impediments in geospatial data dealings to everyone involved. What is summarised here indicates that hierarchies are very important in the development of national and regional SDIs as in the context of the countries under study.

2.4.2 SDIs in North America

According to sub-section 2.2.2, North America is the pioneer of SDI especially the United States of America (USA) and Canada. These two countries have solid foundations of SDI such that, other countries across the globe have sought to adapt them. The USA in particular, is well known for its Content Standard for Digital Geospatial Metadata, Version 2.0, 1998 by Federal Geographic Data Committee, (Crompvoets *et al*, 2003). In the USA, the Federal Geographic Data Committee (FGDC) is well known to be responsible for the SDI activities (Clinton, 1994; FGDC 1998; Coleman and McLaughlin 1998; Rajabifard and Williamson 2001; Crompvoets 2002; Crompvoets and Bregt 2003; Crompvoets *et al* 2003; Maguire and Longley, 2005). To appreciate how SDI originated and evolved in the USA, Robinson (2008) acknowledges NSDI to have started in 1994 (Table 2.4) but then went on to delve into a rich history of spatial data coordination which dates back to the 1840s.

Table 2.4: Evolution of OBM Circular A-16. (Source: Robinson 2008)

Source	Year	Description
Executive Order	1906	Created U. S. Geographic Board.
Executive Order 3206	1919	Created a new Board of Surveys and Maps that took over the responsibilities of U.S. Geographic Board.
Executive Order 9094	1942	Abolished Board of Surveys and Maps and authorized Director of OMB to perform the functions of the Board.
OMB Circular A-16	1953	Described responsibilities of Federal agencies with regard to the coordination of surveying and mapping activities.
A-16 Exhibits A,B,C, & D	1953-1964	Attachments to A-16 that outlined programming and operations for specific activities (Topographic Mapping, National Atlas, Geodetic Control, International Boundaries). Some Exhibits were revised
A-16 Revised	1967	Better described responsibilities of Federal Agencies to provide leadership and coordination.
OMB Memo 83-12	1983	Established coordination of Federal digital cartographic data programs.
A-16 Revised	1990	Established Federal Geographic Data Committee and expanded Circular to include more programs
Executive Order 12906	1994	Established the National Spatial Data Infrastructure (NSDI).
A-16 Revised	2002	Strengthened coordination responsibilities of Federal agencies and incorporated NSDI into the Circular.
OMB Memo M-06-07	2006	Required agencies to designate Senior Agency Official for Geospatial Information (SAOGI) at Assistant Secretary-level.

The USA has since then and in the early 1900 developed a robust system of data coordination through the Office of Management and Budget (OMB). According to Robinson (2008) spatial data coordination was enhanced through Executive Orders since 1906 when the institution of a geographic board was established. The 1906 Executive Order was to be reformed and reviewed over the years leading to the emergence of what has been popularly known as Circular A-16. This circular has since its inception in 1953 been subjected to several revisions culminating to its edition of 2002 which was adopted by the FGDC.

Table 2.4 shows a long history of coordination of spatial information in the USA and how it is all connected with the emergence and development of National Spatial Data Infrastructure (NSDI). This table succinctly depicts the policy direction that was adopted since the early 1900 and how it has consistently transited the USA through various stages of geospatial information handling into the arena of SDIs. The USA SDI was summed up to be the most comprehensive and mature by Maguire and Longley (2005, p.5) by acknowledging a set of its achievements in saying that it was;

> "*developed along three parallel fronts: a set of standards for describing, accessing and exchanging digital data; a clearinghouse network offering on-line access to metadata; and a set of framework data sets (e.g. administrative boundaries, orthophotography, and rivers) that cover the whole country*."

To date the USA NSDI is well developed under FGDC website https://www.fgdc.gov/ which has links to metadata, standards, geoportals, data contribution and maps creations. Figure 2.15 is a typical entry map into the USA FGDC geospatial platform. Entry into this geospatial platform is through registration and it allows the user to interact with platform to perform a number of things. The main purpose and focus of this USA Geospatial Platform are revealed through its rich and comprehensive USA data sets. This platform has global data sets as well and large-scale maps of most countries can be viewed and downloaded, e.g. road and plot information of Gaborone City, Botswana.

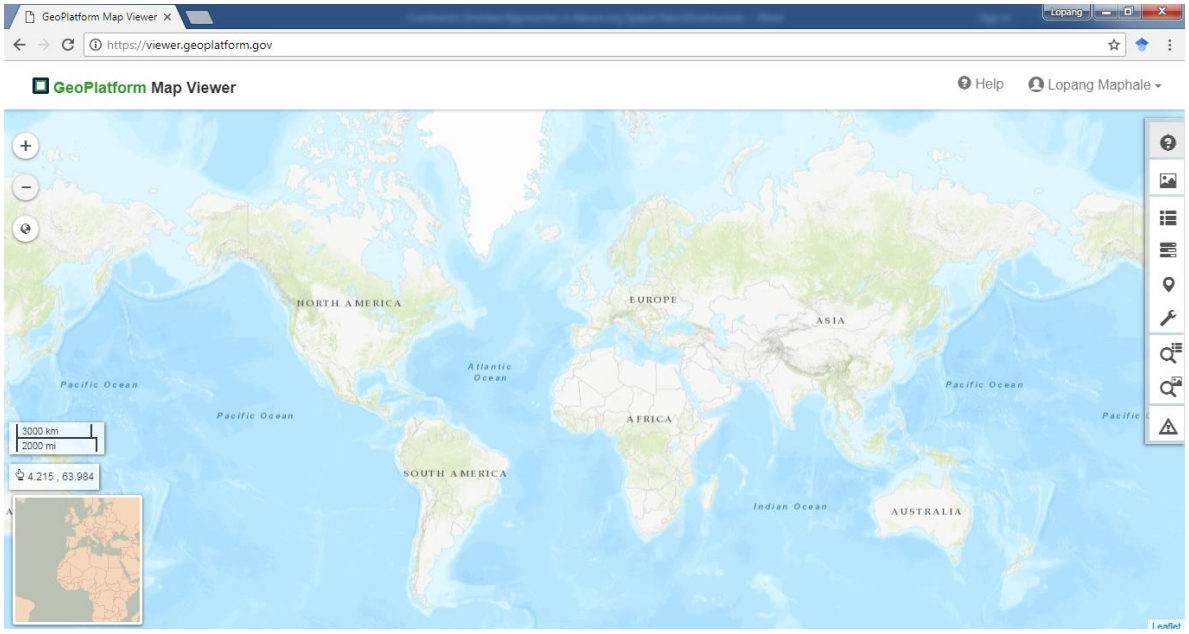

Figure 2.15: USA Geospatial Platform. (Source: https://www.fgdc.gov/).

Canada on another hand has also had a successful journey in the realm of SDI. The Canadian SDI development is accredited as independent when compared with that of USA which is driven within government. The Canada Geospatial Data Infrastructure (CGDI) is premised on an independent entity known as GeoConnections which was established in 1999 by Natural Resources Canada. Though viewed as independent, GeoConnections has from its inception been structured as a 'national funding and partnership' brand, (GeoConnections, 2008). The Canadians from inception viewed CGDI in the same amplitude as well-known infrastructures such as roads, utilities and even fundamental services like the police service (GeoConnections, 2001a; GeoConnections, 2001b). The objective seems to have been, not just to establish the SDI but to bring it to the understanding of all users. This can be understood from GeoConnections (2001b, p. 2) whereby they stated that "*It is anticipated that this infrastructure will, through its ease of use and demonstrable value, become a self-sustaining infrastructure like the Internet, and its many pieces will be supported by the commercial and government organizations that employ it*". The statement speaks volumes in relation to the idea of SDI awareness and ease of use by stakeholders. The statement is a clear agenda setting and can be assessed in a given passage of time.

The Canadian SDI was indeed reviewed in 2005, whereby its target document was reviewed and a number of considerations explored such as aligning its activities to the Federated

Architecture of government (GeoConnections, 2005). This consideration in itself contain a powerful political influence, which was interlaced with a strong technical component in that it recognised the ISO Reference Model for Open Distributed Processing (ISO RM-ODP) as a building template for Canadian SDI. GeoConnections mandate in CGDI was renewed in 2005, with great emphasis in developing applications in four main areas being; (a) *public health* (b) *public safety and security* (c) *environment and sustainable development* and (b) *matters of importance to Aboriginal people* (GeoConnections, 2008). Through their work GeoConnections have managed to cement a number of fundamentals to develop a comprehensive framework for CGDI as presented in figure 2.16.

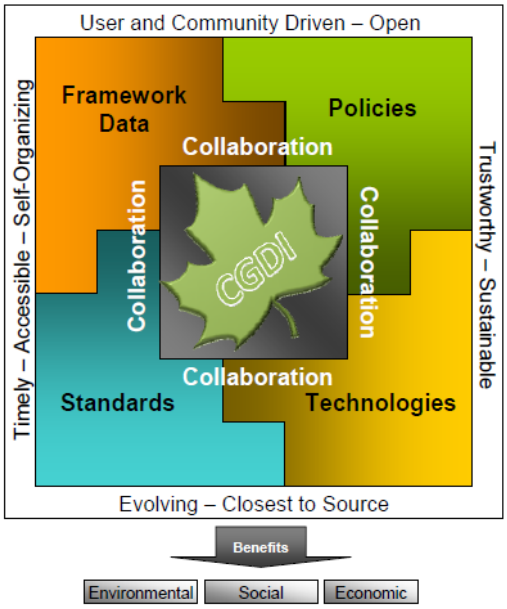

Figure 2.16: The Canadian Geospatial Data Infrastructure (CGDI) components and guiding principles: (Source: GeoConnections, 2012).

The framework on figure 2.16 recognises openness as key to CGDI driven by users and community (people component), which is reminiscent of third generation SDI. The other key components being; framework data, policies, technologies and standards are sworn together with SDI as core on top of the people. In this structure collaborations are nicely thrown right around the core to indicate the importance of partnerships in this SDI. The framework is then allowed to have a wing which is deliberately showing the benefits that are associated with CGDI.

The CGDI is among the most successful SDIs, but they have not stopped learning and seeking for new ideas of making it what was specified in the various roadmaps over the years since 1999. This statement is supported through the literature of the CGDI over the years summarised as; architecture description (GeoConnections, 2001a; GeoConnections, 2005a); target vision (GeoConnections, 2001b); knowledge and better decisions (GeoConnections, 2005b); achieving the vision (GeoConnections, 2005c); Building and sustaining (GeoConnections, 2008); vision, mission and roadmap (GeoConnections, 2012a); Overview (GeoConnections, 2012b); performance project (GeoConnections, 2013). The reviewed CGDI literature reveals how Canada has progressed through its various stages of SDI and this is a great lesson. The benefits of CGDI were shown through a number of case studies in GeoConnections and Kim Geomatics (2013) as it supported activities related to Park Spaces, Data Imagery, Environmental, Food and Aboriginal Communities Development.

In overall, SDI in North America reveals that the two countries discussed here, do have similar Federated governments. But their SDI implementations differ, in that the USA one is highly government driven with statutes and a central government committee being at the centre of the implementation process. Contrastingly, Canada has had what can best be referred to as a project approach running under the auspices of an established organ partly funded by the state but having participation of other important players in geospatial data infrastructure building. What is important about these successful SDIs is that lessons can be drawn from them by other countries and adapting to their local situations.

As countries draws lessons and learn from these SDIs, they have to equally be aware of the challenges associated with them. Regarding USA SDI, challenges have been reported alongside its progression since it was started in the early 1990s (Nedovic-Budic *et al*, 2001). The USA SDI was originated within a decentralised governing environment possessing entrenched data sharing, technological and political practice (Harvey et al, 2012). The USA governmental structure consist of central government, 50 states, over 3000 counties, above 35000 municipalities and townships (Nedovic-Budic *et al*, 2001), which implies a very complex administrative setup. According to Harvey *et al* (2012) the USA SDI architecture experienced challenges integrating geospatial wok for local and regional levels of government. The recognised challenges include; decision support, data sharing and re-use, coordination,

policy formulation and alignment, keeping with technological changes and standardisation (Harvey *et al*, 2012).

2.4.3 SDI Development in Europe

The SDI development in Europe occurred in several countries in response to improving technologies but what is singled out for review here is the European Union Commission SDI. In doing so, it has to be acknowledged that the early adopters of SDI concept in the European Union were countries like Netherlands, Great Britain, Portugal and Spain just to name a few. In most European countries, the National Mapping Agencies (NMAs) were leading institutions in SDI inception and ultimate development (Jakobsson and Vauglin, 2001). According to Jakobsson and Vauglin (2001) through an organisation named Eurogeographics, the activities of NMAs in Europe were brought under an umbrella theme of data quality. This umbrella of NMAs were later to play a leading role in Regional SDI; The Infrastructure for Spatial Information in the European Community (INSPIRE). INSPIRE is a culmination of what started in 2001 through integration of datasets found in NMAs of member states of the European Union (Jakobsson and Vauglin, 2001; Craglia and Johnston 2004; Craglia and Annoni, 2006). INSPIRE as currently known came about through adoption of a Directive of European Union in 2007 signalling to a Regional SDI with geospatial information capable of integrated environmental analysis (Crompvoets *et al*, 2018). Though the directive was at regional level, Crompvoets *et al* (2018) accede that INSPIRE directive has come to define SDI implementation within individual member states.

Despite the Directive of 2007, there are other efforts which are considered influential to coining of INSPIRE concept. In review of the literature, authors such as Craglia and Maser (2001) indicate that the INSPIRE initiative could be rooted in the policy which was developed by the European Commission (EC) Directorate for Information Society between the year 1995 and 1997. Another notable effort is Water Policy Framework (WPF) focussed on geospatial information of water basins in the European Union (Craglia and Masser, 2001). The WPF of 2000 was mandatory on member states regardless of size, it involved collection of spatial information of the water basins and representation in a GIS format (Craglia and Masser, 2001). Yet another effort was the European Commission funded project dubbed Geographic Information Network in Europe (GINIE). This project was funded through EC's Information Society Technologies Programme (Craglia and Johnston 2004). As captured by Craglia and

Johnston (2004), this work exposed a number of important social and economic benefits of geospatial information e.g. usefulness to policies in general, economic value, social value and trans-boundary and hierarchical value. In appreciation of these benefits they also compiled what they viewed to be a number of underlying challenges that can be associated with building geospatial data into an infrastructure and these are shown in Table 2.5.

Table 2.5: SDI progression obstacles. (Adapted from Craglia and Johnson, 2004, p. 19)

Obstacles	**Descriptions**
Gaps in spatial data	This is attributed to spatial data that is incomplete
Lacking documentation	Spatial data not completely described
Incompatible spatial data sets	Difficulty in integration of spatial data sets
Incompatible geographic information initiatives:	Geographic information existing as silos and lacking standards representation approach
Barriers to sharing and re-use:	cultural, institutional, financial and legal barriers prevent or delay the use of existing spatial data
interoperability	Reflects a total lack of inter operation across a jurisdiction
Coordination and leadership	This implies where they are insufficient to drive meaningful geospatial information transition
Isolation	This deals with geospatial information development devoid of e-government strategy and link to other important infrastructures
Cultural and organisational issues	Gross underestimation of the cultural and organisational issues
Benefits	Insufficient evidence of short and medium-term benefits of SDIs
Capacity Building	Insufficient consideration given to the crucial need for capacity building (education, training) and targeted research

These obstacles were clearly noticed in Europe about 20 years back despite its general status of being a developed world and Craglia and Johnston (2004) recommended strongly for them to be addressed in a coherent manner within the frameworks of the INSPIRE initiative. In pursuit of coherence the EC invested heavily in SDI research processes over extended periods e.g. years 2003 – 2005 saw the 32-country study where the Catholic University of Leuven was engaged (Maser 2005; Craglia and Annoni, 2006). In addition, the EC established a Spatial Data Infrastructure Research Unit, under the Joint Research Centre of the European Commission Institute for Environment and Sustainability (Craglia and Annoni, 2006). These experiences could be summed by the of words Crompvoets et al, (2018, p. 279) when saying "*before INSPIRE, the governance of national SDIs was about managing relationships and dependencies within countries, between different data producers, between producers and users and between different administrative levels"*.

INSPIRE initiative has made a lot of progress and achievements by far, which can be accessed through its website https://inspire.ec.europa.eu/. This website offers resources such as INSPIRE library, roadmap, geoportal, thematic clusters, registry, legislation, themes, practice and training. In addition, most European Union member countries have reciprocated the INSPIRE directive in their own countries, to ensure that a number of its SDI requirements and standards are complied with. It was important for member states to reciprocate this directive, because it was mandatory that they link their relevant SDI resources to INSPIRE European Union portal. A perspective view is presented in figure 2.17 to show countries and their implementation of the INSPIRE initiative. The INSPIRE initiative reveals a political regional influence on the development of SDI. Various regions of the globe can learn from this Regional SDI approach in their efforts to build their own. What is important to note about INSPIRE is that the several SDIs have been constructed across hierarchies such as corporate, local, national and regional with seamless interoperability as key to the proceedings. By clicking on the flag on the figure 2.17 the SDI opens more options to view about the actual SDI proceedings in the particular country selected. Specific information sets that come out are that of Website, SDI indicators for the specific country over the years, original language reporting, dashboard and the geoportal. This information-sets play a pivotal role as metadata that connects users with originators of the data that are found in INSPIRE. This goes a long way in satisfying what can be regarded as the spirit and mind of SDI.

From figure 2.17, a conclusion can be drawn that INSPIRE has had a good progression. That being the case, challenges have been there in particular the nature of multilingual representations and interoperability (Nowak, Nogueras-Iso and Peedell, 2005; Craglia and Annoni, 2007). Countries have experienced difficulties in embracing this initiative as witnessed by examples of Slovenia attempts to accommodating the benefits of private data producers and users (Lipej And Modrijan, 2010). The governmental organisations and private practitioners involved could not find common ground in terms of "*risks, benefits and rewards*". One other notable challenge reported by Patroumpasa *et al* (2015) was its lack of connection to Semantic Web technologies owing to its early crafted standards and the fact that its evolvement was slow.

Figure 2.17: INSPIRE implementation Country map (Source: https://inspire.ec.europa.eu/inspire-your-country-map/27543. Accessed 6/03/2018).

These challenges experienced by the European Union countries are very useful as a template for studying contexts (legislation, technology, organisational structure, funding models etc.) of countries under SDI implementation. It is important to realize the evolving nature of SDI and work to avoid certain pitfalls in its development. A more recent work focussed on INSPIRE, dealt with SDI governance and its associated challenges (Crompvoets *et al*, 2018). According Crompvoets *et al* (2018, p. 256) "*the governance of SDIs deals with the adoption of structures, procedures and instruments for managing the relationships and dependencies between all involved actors, units and organizations*". The quoted phrase takes stakeholders into full recognition by emphasising the alignment and reconciliation of their needs and interests as individuals and a collective. SDI development still poses challenges in the European Union INSPIRE despite several promising efforts by the member states.

2.4.4 SDI Development in Asia and Pacific

This region has been defined by Rajabifard & Williamson (2003, p. 1) this way;

> "*Asia and Pacific region is the largest region in the world with a vast geographic area of land and water, some 60 per cent of the world's population and includes 55 countries as defined by the United Nations. The countries span a wide part of the globe from Iran*

and Armenia in the west to French Polynesia in the east, from the Russian Federation and Japan in the north to New Zealand in the south."

Rajabifard & Williamson (2003) have further explained that this region was among SDI pioneers at a regional level. The origins of this Regional SDI seem to have been influenced by trade if one is to go by examples of various trans-corporations that are mentioned in Rajabifard & Williamson (2003). Trade dictated that a number of regional cooperation had to occur and governments took a lead in it, focussing on various efforts listed in Rajabifard & Williamson (2003) as the following: (a) *regional mapping* (b) *regional emergency management* (c) *regional security* (d) *regional access to health care resources* (d) *regional environmental monitoring and management* (e) *shared oceans surroundings* (f) *fishing, shipping and transport* (g) *agricultural and forestry management*. The cooperative nature of the involved nations started in 1995 with what they called "*Permanent Committee on GIS Infrastructure for Asia and the Pacific*" as elaborated in Rajabifard (2002) and Rajabifard & Williamson (2003)

The Asia and Pacific Regional SDI has been studied extensively and a related thesis produced by Rajabifard (2002). In the study by Rajabifard (2002), a hierarchical conceptual consideration meant to comprehensively address Regional SDI developments was proposed as depicted by figure 2.18. The model shows important elements in development of SDI from one level to the higher one in a governance structure. This hierarchical model was referred to by Bejar *et al* (2004) when they define SDI as a connection of nodes in their work pertaining to Spanish SDI architecture. The hierarchical model depicts a complex social system and by inference, it can be noticed that any weak nodes and connections, may lead to an overall weakness of the system in terms of its intended objectives. If a scenario of Regional SDI stated here is deeply considered, it emerges that, if one or a number of countries in Asia and the Pacific exhibits entrenched weaknesses or constraints in SDI, they will inhibit the comprehensive development and realisation of its intended outputs. Therefore, the effectiveness and efficiency of such SDI can be said to be directly related to the prevailing constraints of the various nodes participating in its development and sustenance. To develop and improve such SDI, we need to invoke a design and development system which keeps constant track of its prevailing constraints and related solutions on its life-cycle.

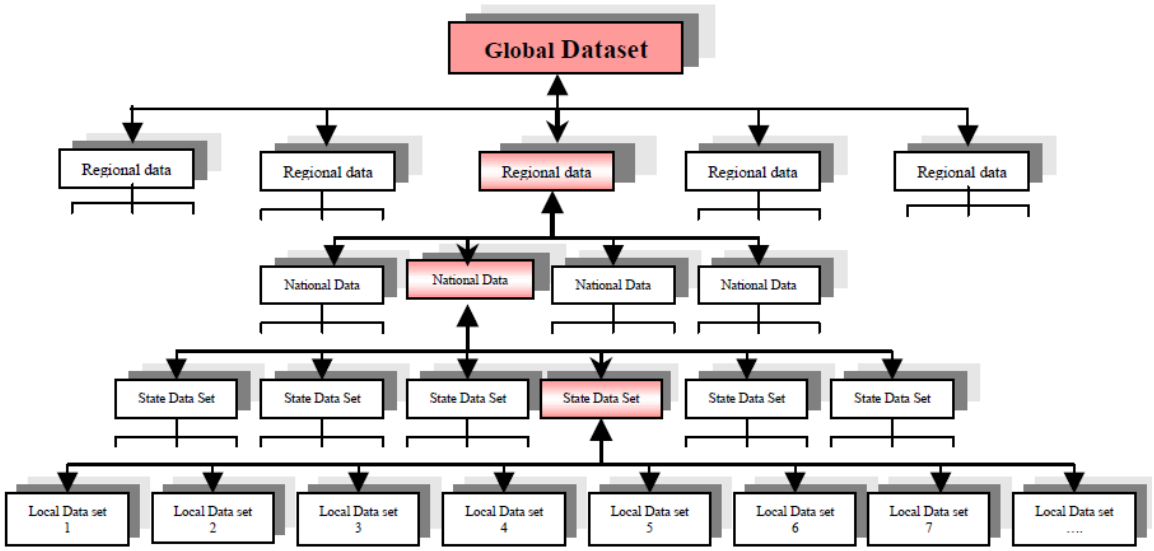

Figure 2.18: SDI Hierarchies, (Source: Rajabifard, 2002, p. 58)

In addition, Rajabifard (2002) indicated reasons that can hamper the SDI development progression. Therefore, it can be followed that despite the comprehensive study in Rajabifard (2002) read with Rajabifard and Williamson (2003) a regional SDI in the same mould of the one reviewed in case of INSPIRE is still not available. To buttress this point, Tumba and Ahmad (2014) acknowledges that some countries in Asia-Pacific do have potential but they are still facing immense challenges in SDI drive. Only a few countries seem to have manged a commendable progression being; Australia, New-Zealand, China, Japan and Singapore. Australia and New-Zealand have a common geoportal found at www.anzlic.gov.au. Lack of well-developed lower structures of SDIs as shown in figure 2.18 affects development of higher order ones such as those at the Regional level.

2.4.5 SDI Development in Africa

The development of SDIs in Africa and Southern Africa is firstly connected to the work of Food Agricultural Organisation (FAO) in 2001 through the resource workbook produced and titled "***Southern Africa SDI Workbook and Background Materials***". The wok produced by FAO and SEK (2001), premised SDI for Southern Africa on what they perceived to be a key-drivers defined within the frameworks of environmental and natural resource management in a long-term to support growth in economies. This objective or key driver bears connotations of strategic approach and it was no surprise when it was further linked with SDI by FAO and SEK (2001) to be able to help drive the following;

- *Need to be more responsive to key partners and clients*
- *Demand for greater accountability*
- *Opportunities provided by new technologies*
- *Electronic exchange of data and information.*

In the resource workbook by FAO and SEK (2001), a structure of ISO-TC 211 is also presented which reveals that through Republic of South Africa, Africa had from early on been represented in such high-level spatial data committees as seen in figure 2.19.

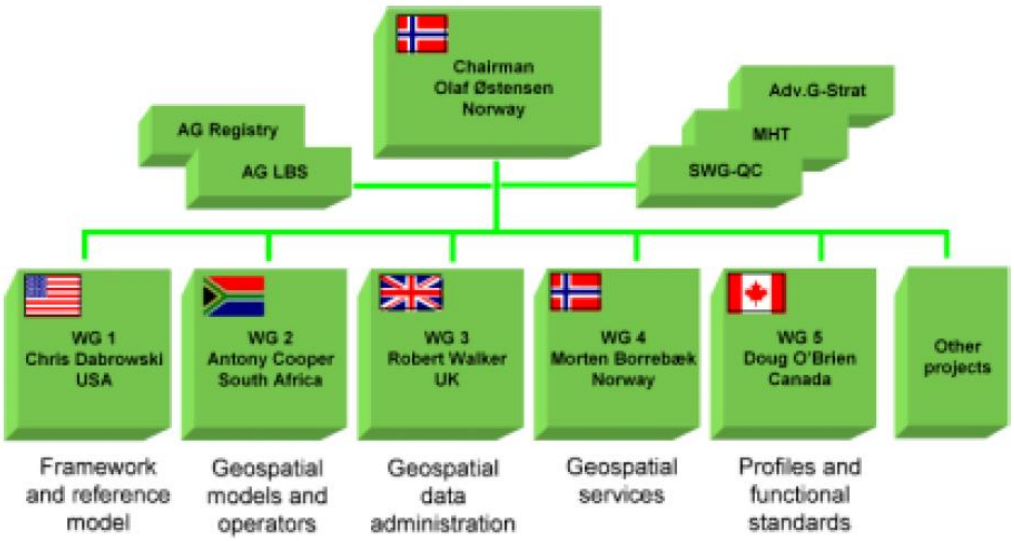

Figure 2.19: Structure of ISO TC 211, (Source: FAO and SEK, 2001).

The inception of SDI as characterised above implies a reasonable early start by most African countries. Three of the countries found in the Southern African Customs Union (SACU), being Botswana, Namibia and South Africa do appear in this SDI workbook by FAO and SEK (2001).

The second line of review regarding African SDI literature is derived from UN-GGIM indexed reports for countries which start in 2011 up to 2019 found at website http://ggim.un.org/country-reports/. These reports are written in English (Botswana, Swaziland, Egypt, Zambia, Zimbabwe, Sudan, Namibia, Nigeria and Rwanda) and French (a number of Francophone countries like Morocco, Ivory Coast, Mali and Senegal). Due to lack of skills in reading and understanding of French language, the reports from those countries

could not be summarised. The contents of country reports written in English are summarised below to decipher SDI content and progress.

- **Botswana (Country report 2011 and 2015)**: The 2011 report was done by National Mapping Agency (NMA) being Department of Surveys and Mapping focuses on general land administration, efforts towards technology adaptation, development of early computers systems and a master plan which was put together to facilitate establishment of National SDI (Botswana Department of Surveys and Mapping, 2011). The report goes further to indicate that National SDI (NSDI) was implemented under a Land Administration Procedures Capacity and Systems (LAPCAS) project. The 2015 report further refers to the continued efforts in digitalisation within the Department of Surveys and Mapping. It also touches on issues of policy, e-government strategy and international collaborations in international-boundaries surveys and alignment (Oitsile, 2015).
- **Egypt (Country Report 2011 and 2016):** The 2011 report introduces the Geographical Systems Department as central to geographic information, its Geographical Information Systems (GIS) software acquisition track record and the use of GIS in census, health sector, education, slums mapping (Mohammed, 2011). In addition, movement towards NSDI efforts consistent with product-based typology is also mentioned in the report. The 2016 report revealed a country actively pursuing geographical information portals and NSDI. In case of NSDI coordination, legal framework and unique spatial identifier are discussed. In addition, the 2016 Egyptian report elaborates statistics and efforts to establishing a statistical geospatial framework of Egypt (Mohammed, 2016).
- **Namibia (Country Report, 2011)**: Report focussed on the core activities of Department of Surveys and Mapping such as: Cadastral Management System (CSM), Land Information System (LIS), Cartographic Databases, Geodetic Network and functionality and general geospatial information management (Okafor, 2011). It was in 2011, that movements towards SDI were fast-tracked with the establishment of a legal framework under the Statistics Act. In appreciation of the Act, Sinvula et al (2013) undertook stakeholder identification for this SDI based on the ICA Reference Model for Open Distributed Processing (RM-ODP).
- **Nigeria (Country Report, 2011):** The Nigeria country report is styled as National Geospatial Data Infrastructure (NGDI) and the sector responsible for it is the National

Space Research and Development Agency (NASRDA). In this report, huddles associated with SDI are acknowledged and ways around them pin-pointed as solutions to implementation (Agbaje, 2011). NGDI, though started in 1999, seems to have had a purposeful focus with the geoinformation policy proposition in 2002 which saw establishment of its Committee and six Sub-Committees, coining of a vision statement, workshops, collection of fundamental data sets and efforts geared at capacity building. According to this report, Spatial Data Clearinghouse was to be established and based at NASRDA. Progress in this NGDI can be deduced from the purposeful construction of a four-storey building, approval of the policy in 2006, user requirement analysis and policy revision. The report concludes by alluding to problems and/or challenges faced by NGDI chief among them: "*funding, capacity building, awareness and technological*".

- **Rwanda (Country Report, 2015):** The Rwanda report focuses on a land reform exercise spear-headed by a revamped digital land administration system which had led to a lot of properties being titled and connected directly with the country's banking systems. The Rwanda report does not specifically mention the National SDI establishment but refers to major technical progression in geoportals (planning) and metadata being done.
- **South Africa (Country Report, 2015):** This is a SACU member and the report was prepared by the National Geo Information Directorate under the Department of Rural Development and Land Reform (DRDLR). This report makes a short brief on the history of South Africa and its associated land statutes. It then goes onto show case more recent legislation such as the Geomatics Practitioners Act of 2013, Spatial Data Infrastructure Act of 2003, Deeds Registry Amendment Act of 2013, Sectional Titles Act of 2013 and Restitution of Land Rights Act of 2014. Among these acts South African Spatial Data infrastructure (SASDI) Act is very important in this study. SASDI according to this report appears as a pro-government legislation aimed at inter-governmental geoinformation sharing. SASDI has already been put under review with the aim of improving its related administrative functions, supporting continued policy reviews and strategic advancement. Progression of SASDI have been reported by several commentators such as Clarke (2011), Harvey et al (2012), Cooper et al (2013). Clarke (2011) for instance had identified a number of challenges associated with SASDI to be the following: need for Act amendment, promulgation of regulations,

development of key policies, development of key standards, metadata recording processes, functional geoportal development, awareness, capacity building, common understanding and Act compliance issues.

- **Kingdom of eSwatini (Country Report, 2015):** This country is also a member of SACU and its report was prepared by the Surveyor General. In its reports, shortage of personnel with requisite geoinformation skills is acknowledged (Kingdom of eSwatini Survey General, 2015). In regard to SDI, movements towards it were facilitated through interviews with stakeholder and a workshop with the help of Regional Centre for Resource Mapping for Development (RCRMD).
- Zambia (Country Report, 2015): The Zambian report is prepared by the Ministry of Lands, Natural Resources and Environmental Protection. This report emphasises fundamental land survey activities such as geodetic network, aerial photography, and associated geoinformation extraction process. SDI is mentioned only as a subset of other activities such as national land audit and titling.
- Zimbabwe (Country Report, 2015): This report is prepared by the Surveyor General within Ministry of Lands and Resettlement. The report articulates in detail the functions of the Surveyor General for examples, densification of geodetic control network, cadastral surveys reforms, mapping and international boundary alignments with Mozambique, Zambia, Botswana, Namibia and South Africa. This report talks of land reform without specific reference to building of SDI.

For all the countries discussed here, those which mentioned SDI are on average associated with a lands ministry and are mostly from the surveying and mapping environment. SDI development efforts are not so well elaborated for most countries safe for Nigeria, Egypt and South Africa. These three countries have seen it necessary to infuse policies and acts on their SDI efforts. In summary, the above summaries are considered useful in aiding studies, understanding and inferences to the various results associated with SDI implementation in Africa.

In view of the above discussed SDI discourses, a third dimension in reviewing of African SDI literature is considered within the frameworks of SDI Assessment. SDI reviews carried out in Africa have pointed to a status of it being undeveloped for instance Makanga & Smit (2010) focussing on continental; Maphale & Phalaagae (2012) on national effort of Botswana;

Mwange *et al* (2016) addressing the aspect of readiness. The undeveloped status of the SDI in Africa was in some instances spread across given quantitative scales and this had been done in case of Makanga & Smit (2010) and Mwange et al (2016) reviews. The results coming from these two reviews are quite useful to this study as they establish clear scalable gaps showing that, since the inception of the concept of SDI, Africa as a whole has struggled with the concept. On the other hand, the same studies emphasize that having a well-functioning SDI is a way to go in the midst of the ever-advancing geospatial technologies and increasing stakeholder communities. These gaps challenge African scholars and practitioners to come up with ways of ensuring that they put their nations in appropriate courses towards establishment of SDIs. To put these arguments in perspective the results from Makanga and Smit (2010) and that of Mwange et al (2016) are presented in the tables 2.6 – 2.7 for appreciation, interrogation and alignment with this work.

Makanga and Smit (2010) administered a questionnaire across 29 countries and obtained results of each indicator as presented in table 2.6. These indicators were based on a Likert-type scale with answers ranging from 0 to 4. Where, 0 = not sure, 1 = absolutely false, 2 = False, 3 = Slightly true and 4 = Absolutely true (Makanga and Smit, 2010). These values were given as responses to variable statements which are related to the five measured components as shown in table 2.6

Table 2.6: Results Assessment Matrix (Source: Makanga and Smit 2010)

	Components	**Organisational**			**Legal**		**Funding**			**Technical Data**			**Metadata**			**Overall**
Region	**Country**	**1A**	**1B**	**1C**	**2A**	**2B**	**3A**	**3B**	**3C**	**4A1**	**4A2**	**4A3**	**4B1**	**4B2**	**4B3**	**SDI Score**
South	Botswana	4	3	2	3	1	1	1	1	2	2	2	2	2	1	27
West	Burkina Faso	2	2	1	2	3	1	1	1	2	3	3	1	1	1	24
Central	Cameroon	1	2	1	1	1	1	1	1	3	3	2	3	1	1	22
West	Chad	3	1	3	1	2	1	1	1	1	1	3	2	1	4	25
West	Congo	1	3	3	2	1	2	1	2	3	3	3	3	3	1	31
North	Egypt	2	3	2	2	1	1	1	1	2	1	2	1	2	2	23
East	Ethiopia	4	4	1	1	1	1	2	2	2	2	2	2	2	2	28
Central	Gabon	4	4	4	4	4	1	4	4	4	3	4	4	4	4	52
East	Kenya	4	3	3	1	1	3	3	2	1	2	2	2	2	4	33
South	Lesotho	3	4	1	1	1	1	1	1	1	1	1	1	1	1	19
North	Libya	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
South	Madagascar	2	3	1	2	3	3	3	3	1	2	3	3	3	2	34
South	Malawi	4	3	1	1	2	1	1	1	3	1	3	2	1	1	25
West	Mali	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4

North	Morocco	4	4	1	1	1	4	4	4	4	3	1	2	1	1	35
South	Namibia	2	2	1	2	1	1	2	1	1	1	3	3	2	1	23
West	Niger	4	3	4	2	3	4	3	4	3	4	4	4	3	3	48
West	Nigeria	4	4	4	4	3	4	4	4	2	2	1	2	2	2	42
East	Rwanda	2	4	4	4	1	2	2	2	4	3	4	4	4	3	43
West	Senegal	3	0	0	0	0	0	0	0	1	0	0	0	0	1	5
West	Sierra Leone	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
East	Somalia	1	1	1	3	1	1	1	1	2	2	3	3	2	1	23
South	South Africa	4	3	3	2	2	3	4	2	1	3	2	1	2	1	33
North	Sudan	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
South	Swaziland	4	3	3	3	2	2	2	2	3	2	1	2	2	1	32
South	Tanzania	4	2	3	3	2	3	3	2	3	2	2	2	3	2	36
North	Tunisia	4	3	3	2	2	3	4	2	1	3	2	1	2	1	33
East	Uganda	3	3	3	1	1	2	1	1	3	1	3	2	1	1	26
South	Zimbabwe	3	1	1	1	1	1	2	2	2	1	2	1	2	1	21

The results on table 2.6 are used here to refer to the topic of study and scope the study area. In this case countries of Botswana, Lesotho, Namibia, South Africa and Swaziland (Kingdom of eSwatini) have been highlighted with a blue colour and will be extracted for further use in Chapter 3.4 in illustrating how these results can be used alongside the theory of constraints to scope and order the measured elements for solutions and on-going SDI improvement.

In case of SDI Readiness Index, the results of Mwange *et al* (2016) are presented in table 2.7.

Table 2.7: Contribution of SDI Readiness Index by each factor (Source: Mwange et al, 2016)

Country	Organisation	Informational	Human	Technology	Financial	SDI Index
Botswana	0.1357	0.2345	0.5244	0.6530	0.4665	0.3477
Ethiopia	0.5466	0.4000	0.3820	0.4340	0.3038	0.4058
Ghana	0.6459	0.6837	0.5537	0.5904	0.5673	0.6063
Kenya	0.5676	0.5500	0.5178	0.6148	0.5500	0.5592
Malawi	0.5960	0.6837	0.2668	0.3382	0.2030	0.3755
Nigeria	0.7468	0.6205	0.3742	0.5390	0.7274	0.5841
Rwanda	0.8411	0.6837	0.5263	0.5225	0.7274	0.6489
Senegal	1.0000	0.7714	0.5802	0.5729	0.6069	0.6893
South Africa	0.7114	0.7348	0.6039	0.6649	0.5130	0.6404
Tanzania	0.2802	0.2500	0.4158	0.4468	0.3038	0.3307
Zambia	0.5500	0.5500	0.4627	0.4517	0.5673	0.5140
Zimbabwe	0.2924	0.3708	0.4433	0.5664	0.1531	0.3342
Overall	0.5761	0.5444	0.4709	0.5329	0.4741	0.5030

Bringing the two sets of results under a common microscope, the similarities in the components measured are readily noted. In the case of Makanga and Smit (2010) there are five main indicator components measured being: organisational, funding, legal, technical (Data), and

Metadata. In Mwange *et al* (2016), the measured components are the following: organisation, informational, human, technology and Financial. These components without doubt exhibit entrenched similarities despite the method of assessment utilised. Thereby confirming the resounding importance of these components in SDI development and assessment progression. It should be understood that the two methods stand for the state of development (Makanga and Smit, 2010) and readiness to develop SDI (Mwange *et al*, 2016). The earlier assessment focussed on the actual state of development and six (6) years down the road, the second assessment focussed on readiness to develop. These results were comparatively queried so as to see what they are showing. For instance, If the SDI had shown a certain level in component status in 2010 (e.g. 3 in 4), it make sense to say that the related component should exhibit a high level of SDI Readiness Index as evaluated in the next six years or Mwange *et al* (2016) results. If the components do not reveal a high level of readiness, then it will make sense to conclude that the SDI of that country is constrained and requires a plan to foster its improvement especially relating to the constrained component.

To further elaborate, according to the scales of measurement used in Makanga and Smit (2010), Botswana seems to possess a good organisational status, but the results from table 2.7 negate this with a very low value of 0.1357 in relation to the organisation component. Botswana's overall SDI Readiness Index remain firmly low with a total of 0.3477 in 2016 (Mwange et al, 2016). Another country featured in both studies is South Africa, which scored above average in both studies and as per the results, but not much improvement seems to have occurred between 2010 to 2016. In overall, it is conclusive that, the SDI measured quantities for SACU countries are low as their averages readily fall less than the index of 0.5. In the case of Makanga and Smit (2010), the average score for SDI status of the SACU countries is 26.8 which if divided by the total score of 56 will translate into a simple index of 0.479. In case of Mwange *et al* (2016), the average index of the two sampled countries Botswana (0.3477) and South Africa (0.6404) is 0.494.

Further, inspecting the level of SDI Readiness in table 2.7 shows that the average index is 0.5030 or just about 50% across African. Hence it can be concluded that, after more than 30 years since the emergence of the SDI concept, this figure looks worrisome and unequivocally points towards a continent which is generally slow in SDI adaptation and implementation. This study, attributes this unfortunate scenario to constraints, for not being thoroughly identified and exploited with an intention to supporting SDI on-going improvements in African countries'

implementation. This assertion has led to posing of two fundamental questions; (1) why are the readiness indices low? and (2) how can they be improved? These question guides the use of these results as an appropriate starting point, justification and support for this study towards answering these questions and related queries. The study concentrates on SACU countries, as such their results were extracted from the original results of Table 2.6 and Table 2.7 and utilised in Chapter 3 to aid a proposition for SDI On-Going Improvement (SDIOGI) as a way to answering the above questions.

2.5 SDI Assessments

SDI Assessments gained momentum about mid-2000 because the need to evaluate what SDI stood for and their acclaimed benefits had become highly necessary. A stronger manifestation of SDI assessment was witnessed by experts across the globe congregating for an international workshop in The Netherlands. This workshop dubbed "Multi-view framework to assess (National) Spatial Data Infrastructures" was held at Wageningen University from 23 to 25 May 2007, (Crompvoets *et al* 2008, Eds). From this work, SDI Assessment volume was created with a number of methods, for instance: INSPIRE State of Play (Vandenbroucke, Janssen and van Orshoven, 2008), SDI Readiness originally from Delgado Fernández *et al* (2005); Organisational Perspective (van Loenen and van Rij, 2008); Performance-based Management (Steudler, Rajabifard and Williamson 2008; Giff 2008); etc. The overarching SDI Assessment method was in the same resource, coined to take care of the various forms of evaluation and referred to as the Multi-View SDI Assessment Framework (Grus *et al*, 2007; Grus *et al*, 2008). Some applications of these methods have been reported in the previous subsection 2.4.5 to have guided SDI assessments performed by Makanga and Smith (2010) and Mwange *et al* (2016) when reviewing SDIs in Africa. For the purpose of this study it will make sense to review SDI Assessments methods and look at their usefulness to a constraint-oriented approach in advancing SDIs. A realisation is made here that SDI assessments should be able to guide us to detect a bundle of constraints that are inherent in its implementation and development.

2.5.1 SDI Assessment Key Indicators

The fundamental undertones of SDI assessment emphasise what is commonly referred to as 'key indicators' in most of its literature. A succinct definition of Indicator is found at http://www.businessdictionary.com/definition/indicator.html and it reads like this; "*Measurable variable used as a representation of an associated (but non-measured or non-*

measurable) factor or quantity". To its credit the term indicator has been utilised scientifically in several professional fields to make decision-based measurements of products and processes as captured by Heink and Kowarik (2010, p. 584) when they say; "*the term "indicator" is frequently used at the interface between science and policy*". Heink and Kowarik (2010) went on to give various definitions of indicator as promulgated by past researchers by bundling them into classifications. The classifications of these definitions by Heink and Kowarik (2010) led to the following indicators; those of descriptive, normative and hybrid measurements. Examples of the term indicator are found in a number of fields such as economics (Stock & Watson 1989) and ecology (Dale and Beyeler, 1989; Heink and Kowarik, 2010). In Dale and Beyeler (1989) an intriguing bundle of characteristics of indicators were discussed. For ease of reference in this work they are summarised below in table 2.8.

Table 2.8: Indicators characteristics and descriptions. (Adapted from Dale and Beyeler, 1989).

Indicator Characteristics	**Description**
Simplicity	This refers to ease of measure and understanding of indicators by all
Sensitivity	This refers to how the indicator responds to stresses imposed on the System
Predictability	This refers to ambiguity in how the indicator responds to stresses on System
Anticipation	This refers to the indicator being able to guide or lead change
Aversion	This refers to the indicators being able to help management take remedial actions on the face of impending changes
Integration	This refers to a full suite of indicators being used to inform decisions
Responsiveness	This refers to indicators having known and well-documented responses
Variability	This refers to the ranges of variation of indicators in response to stress

With this short brief, defining what an indicator is, we turn back and concentrate on SDI Assessment. The brief has clearly shown that indicators are commonly used within complex settings, for instance economics and ecology as examples. Indictors are important in status quo reporting and making correlations between various sets of systems that are expected to exhibit similar kind of results or quantities when measured. The quantities are useful in sectioning a complex system for further developments and revision majors. SDI itself has been defined as a complex environment (Grus *et al*, 2008; Grus, 2010) and therefore its performance can be subjected to indicators with similar characteristics with table 2.8. As such a number of SDI Assessments which have been done so far are being summarised here by critically evaluating the aspect of their indicators.

2.5.2 SDI Assessments

Among the earliest SDI assessments, is the work of Crompvoets and Bregt (2004) which focussed on evaluating what was popularly referred to as clearinghouses. The clearinghouse itself being a concept originating from the banking sector going as far back as 1773

(Crompvoets and Bregt, 2008). According to Crompvoets and Bregt (2008, p. 135) clearinghouse is defined as "*an electronic facility for searching, viewing, transferring, ordering, advertising and/or disseminating spatial data from numerous sources via the Internet*". Further to this definition Crompvoets and Bregt (2008) described a clearinghouse as a key feature in SDI setup and as such they first made its assessment in a longitudinal format from the year 2000 to 2002. This assessment focused on evaluating the various SDI components that are found within a clearinghouse, the following were evaluated; access networks, people, data, policy and standards. In addition to these popular SDI components the history of the clearinghouses studied were also evaluated. According Crompvoets and Bregt (2004) their assessment was based on four main objectives being; analysing SDI worldwide developments, describing them, to understand the reasoning that is associated with them and report on their critical success factors. What is important to note here is that, they chose to use the SDI components as key indicators to address their objectives and this can be evaluated for consistency with table 2.8, for example, to show that assessment focussing on SDI components is an easy thing to do.

In Europe another longitudinal kind of assessment was carried out and named SDI State of Play (Annoni and Craglia, 2005; Vandenbroucke *et al*, 2008). The State of Play (SoP) assessment came about in 2002 with the aims of finding why SDIs were not widespread in Europe by evaluating national status of European countries. The INSPIRE State of play heavily relied on SDI components as generic factors or key indicators of assessment namely: '*Organisational issues, Geographic data, Metadata, Access Services, Legal Framework and Funding Mechanism*'. The SoP methodology was developed over a number of years (2003 – 2007) by comprehensively studying country reports, web sites and interacting with INSPIRE SDI experts and workgroups across Europe (Vandenbroucke *et al*, 2008). During its work, 30 indicators were identified and associated with the key indicators or SDI components across 32 European countries.

Another notable early SDI Assessment is the work of Kok and van Loenen (2005), where 'indictor' terminology was used leading to a proposition of an organisational SDI maturity framework featuring vision, leadership, communication and self-organising ability as key indicators. Kok and van Loenen (2005) went on to test this framework using USA and The Netherlands which have been acknowledged in 2.2.1 to be among the pioneers of SDIs. According to the authors, the two countries scored differently on these indicators, but their

SDIs were reported as having advanced very well. This method in comparison with the clearinghouses approach carried out by Crompvoets and Bregt (2004) focussed on understanding developments in one component of an SDI, in this case its organisational influences.

Learning from the approaches of their contemporaries (Crompvoets and Bregt, 2004; Kok and Van Lonen, 2005), Delgado-Fernández *et al*, (2005) using fuzzy logic came up with an assessment method they called "SDI Readiness Index". In the SDI Readiness Index, Delgado-Fernández *et al* (2005) had come to realize that, despite SDIs' wonderful intentions in data distribution, sharing and exchange, a number of countries were at the time still faced with obstacles of establishing clearinghouses as per the assessment in Crompvoets and Bregt (2004). The work of Crompvoets and Bregt (2004), had exposed that most of the countries facing obstacles in clearinghouses development were developing nations. Therefore, SDI Readiness Index was primarily developed with the idea of shaping SDI advancement in developing countries and was first applied in Cuba. The key indicators of this method were clearly stated by Delgado-Fernández et al (2005, p. 1) when they said that;

> "*the model proposed in this paper for determining an SDI readiness index integrates factors from several points of view: organizational (politicians vision-commitment-motivation, institutional leadership, national legal (umbrella) agreements); information (providers' motivation, digital cartography availability, knowledge of standards); access network (web connectivity; technological infrastructure, geospatial software availability/in-house development); people (educational level, SDI culture, individual leadership) and financial resources (government sources, private sources, national geospatial initiatives).*"

From the above quote it can be denoted that the key indicators are organizational, information, access network, people, and funding. The development of this method of assessment which is said to be longitudinal in nature was also discussed in Delgado-Fernández, Delgado Fernández and Andrade (2008) where it was applied in a number of countries across world.

In more recent times, Vandenbroucke *et al* (2013) came up with yet another SDI assessment method based on measuring SDI performance within the auspices of organisational work processes. This method for performance measurement is said to operate in a narrow and broad sense. For the narrow sense Vandenbroucke *et al* (2013) defined indicators in relation to the

maturity on the issues of access, use and sharing, basically, focussing on what the core of SDI is all about. The broad sense on the other hand has indicators which are focused on the wider economic relevance and governance. One can hasten to add that, this kind of measurement can be more useful only where the SDI is mature.

SDI assessment methods has at best been intuitive, single component focussed and region specific (Grus, Crompvoets, and Bregt, 2007; Crompvoets 2006; Delegado-Fernandez *et al*, 2005). These methods have been tried out in regions where they were not originated. In the African region Makanga and Smit (2010) used the terminology "indicators" to review SDI commencement following the SoP method. The main class of indicators in Makanga and Smit (2010) were the following; organisational, funding, legal, technical (data) and Metadata. Another assessment carried out to review Africa SDIs was by Mwange *et al* (2016) which was focussed on readiness indices and the term 'indicators' was once more used, referring to the following; organisation, informational, human, technology and Financial.

Looking at key indicators or factors that are assessed in SDIs one gets to appreciate that, it's mostly evaluation of how far SDI components have evolved over time. In order to improve on these SDI assessments Grus, Crompvoets and Bregt (2007) has recognised a need for an all-inclusive assessment with multi-view capabilities, flexibility and reduced biasness. Grus, Crompvoets and Bregt (2007) named this all-inclusive SDI assessment approach Multi-View Assessment Framework.

2.5.3 Multiview Assessment Framework

This is an aggregated evaluation which takes into consideration a number of methods of SDI Assessment within the frameworks of the complex adaptive systems. This framework as presented in figure 2.20 takes into consideration three major tenets in assessment which are; Accountability, Development and Knowledge (Grus, Crompvoets and Bregt, 2007). According to this Multi-View SDI Assessment Framework, the three underlying tenets of accountability, development and knowledge can be satisfied through the use of one assessment approach or several of them. This Multi-View SDI Assessment is important in that it allows for flexibility and reduction in bias. A number of methods suggested under this framework are still subject to further development and refinement for instance the generational approach.

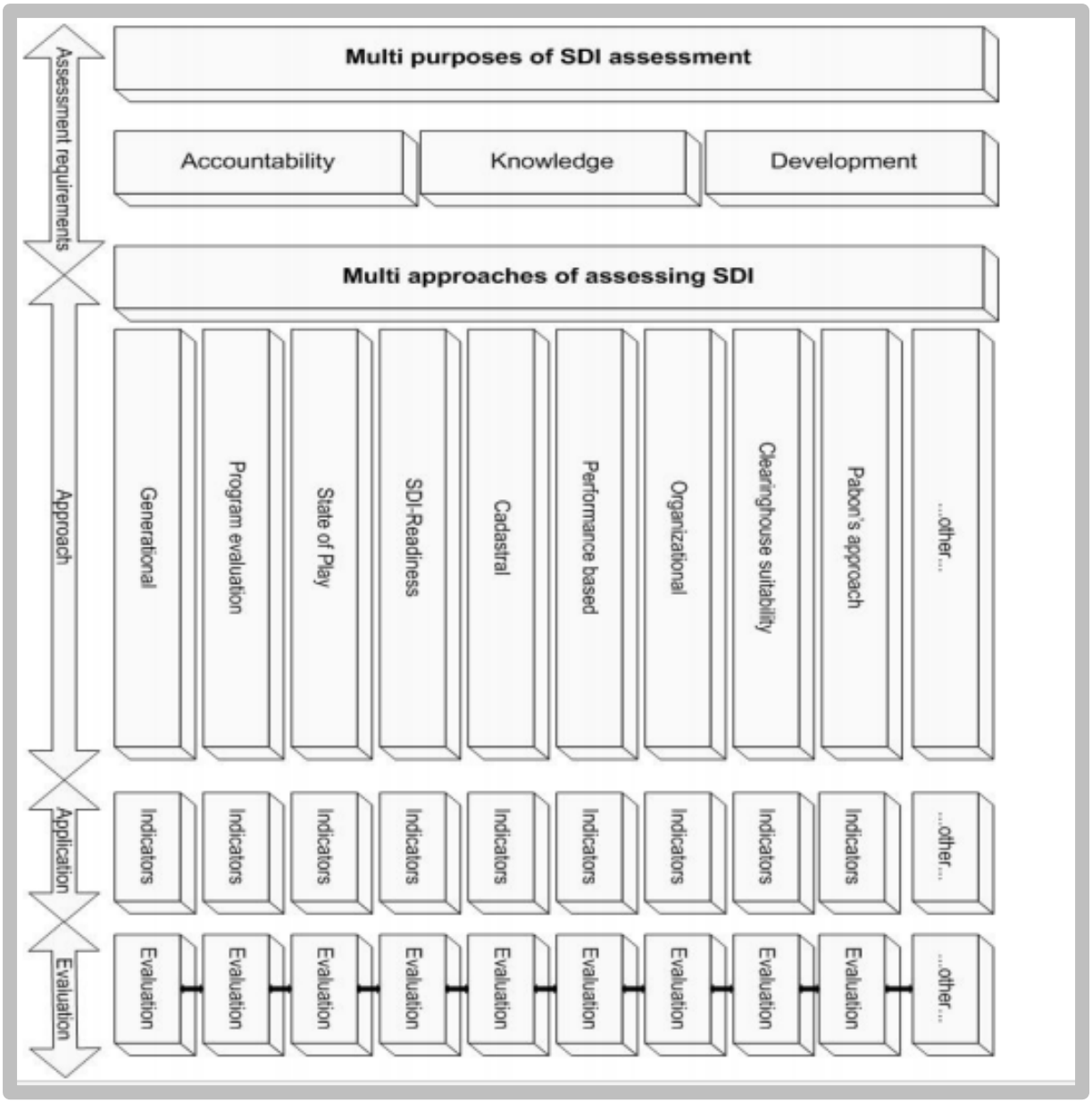

Figure 2.20: The Multi-View Assessment Framework (Grus, Crompvoets and Bregt, 2007)

The above SDI Assessment framework provides a dynamic platform to respond to the evolving nature of SDI. It gives us a solid base to consider SDI directions into the future through research. For elaboration, a succinct depiction of SDI future directions is elaborated in section 2.6

2.6 SDI Future Directions

Future directions of SDIs have been given in the past by various scholars for instance (Rajabifard and Williamson 2001; Rajabifard 2002; Rajabifard, Feeney and Williamson, 2003;

Masser 2005; Binns and Masser 2006; Budhathoki, (Chip) Bruce and Nedovic-Budic, 2008). The future directions are useful in guiding the direction that the research agenda ought to take in SDIs development and general discourse. In order to address this issue, two main considerations are put here rather to justify this research and why the countries under study must overcome whatever obstacles they might be having and develop their own SDIs. The two considerations are the following;

- SDI Complexities
- SDI constraints

The SDI complexity aspect is an intriguing one in which Hendriks, Dessers and van Hootegem (2012) have identified four main areas responsible for its intensification with time as SDI implementations progress. The four areas of complexity sources identified by Hendriks, Dessers and van Hootegem (2012) are; (a) *the objectives that SDI should serve*, (b) *user roles and the viewpoints* (Hjelmager *et al*, 2008), (c) *coordination and alignment of its components to foster development* and (d) *miscellaneous sources which include SDI dynamic nature* (Rajabifard 2002), *SDI hierarchies* (Rajabifard *et al*, 2003) *and multi-discipline interests*. These complexity points are helpful in thinking deeply of the resourcefulness of SDI in the face of, increasing demands for geospatial data as a commodity and a new way of enabling various mandates within an economy. These complexities are heavily influenced by emerging technologies and stakeholders which are now well spread across the global terrain, (Budhathoki, (Chip) Bruce and Nedovic-Budic, 2008). To put this into perspective concepts from Rajabifard *et al* (2007) of "*spatially enabled societies*" and Masser *et al* (2008) of "*spatially enabled governments*" are acknowledged, (Hendriks, Dessers and van Hootegem, 2012, p. 1481). Therefore, it is imperative for countries to introspect because they form vital hierarchical nodes in SDI as a global phenomenon. The question to answer is, are SACU countries progressing well with development of their SDIs so as to have '*spatially enabled governments*' that are capable of participating meaningfully in a spatially enabled world?

A spatially enabled world make emphasis on the third SDI generation, evolution and development by recognising other frames of data capture, handling and storage such as: Volunteered Geographic Information (VGI) which recognises the role of independent geospatial data collectors (*Cooper et al, 2011; Coleman, 2010*); Crowd Sourcing (CS), which according to Goodchild (2007) can be taken to mean the same thing as VGI, it mainly refers to the use of informal social networks and Web 2.0 technology as means to generation of map

products and services (Goodchild, 2007; Cooper *et al*, 2011; Coleman, 2010; Crooks *et al*, 2016). VGI/CS have now been accepted to be making vital contributions to national discourses such as wild fires, volcanic disasters, flora and fauna conservation, urban design etc, and their role in SDI is seen as a mandatory in the current times (Goodchild, 2007; Cooper *et al*, 2011; Coleman, 2010; Crooks *et al*, 2016); Cloud-based storage and processing, underpins the use of the ubiquitous internet computing and networked infrastructures for the purposes of processing and storing SDI related data (Schäffer, Baranski and Foerster, 2010; Giuliani *et al*, 2011); Open data focuses on government, policies, structures, technological outlook and data quality, which allow for continued data integration and interoperability to facilitate ready and free access, sharing and exchange of geospatial data among several stakeholders (Lacasta *et al*, 2007). According Lacasta *et al* (2007), Open Geospatial Consortium (OGC) has pursued and promoted the idea of open data and SDIs as beneficial to communities, for example the Web Architecture Service (WSA). These trends call for progression of SDI to be up to desired outlook within and across jurisdictions. If SDI in a given jurisdiction is constrained, then it calls for the need to understand what the constraints are and how they can be solved to keep SDI on track of evolution and development.

On the basis of the above paragraph, studying SDI constraints becomes very important in countries where there are no plausible success stories. The studying of these constraints takes various forms from identifying, collating, analysing, modelling, exploiting to ordering them with the sole reason of supporting SDIs to develop and flourish in those economies. In that sense, the first objective of this study was directed towards proposing an SDI On-Going Improvement (SDIOGI) approach based on what is popularly called Theory of Constraints (TOC). This defining objective of the study was useful in connecting with the rest of the other three objectives to show that SDI assessments should be done to identify constraints in SDI developments. Once the constraints are identified, they have to be used to aid design and fostering of SDI development in manner similar to the expositions associated with TOC to support implementation at whatever hierarchy. An elaborate proposition of aligning of SDI and TOC will be undertaken in Chapter 3.

2.7. Conclusion

This chapter delved on SDI as a concept, its origins and how the originating countries have dealt with its advancement. The purpose is to provide lessons from the countries discussed and

to draw from them to support arguments in this study. The rest of the literature becomes a pre-cursor to answering the study aim, objectives and questions in that its review exposes best SDI practices across a number of countries and regions. To elaborate, the preceding point, the USA example can be considered with its excellent history in handling spatial data since the past two centuries. This could in fact be the major contributory factor to its success story in SDI development. The question is, do SACU countries have a robust dispensation for dealing with geospatial data similar to USA Circular-A16? Conversely the European Union example discussed exposes the power of a functional regional authority in matters of SDI. The European Union through its INSPIRE Directive, has fostered growth in its regional SDI and those of its member states by setting a tone for the countries on its geospatial data requirements. The European countries have responded positively to the requirements of the Directive because they understood its role in their shared goals in development and environmental interests.

From the preceding paragraph it is visible that, countries which have progressed well have robust spatial data handling documents and practices. In addition, they have well established coordinating committees and/or platforms that continually carry out research and innovations that are focussed on advancing their SDI interest. Examples are FGDC in the USA, GeoConnections in Canada, INSPIRE Coordination Team in Europe as per the discussions found at sub-sections 2.4.2 and 2.4.3. Looking at the work and workflows of these SDI coordinating organs, it can make sense to induce that without such a robust outfit then a nation is already constrained in SDI development.

An attempt is also made in this chapter to broadly review the literature in the context of the promulgated objectives. For instance, the section 2.6 focusses the future trends of SDIs with constraints. This is particularly important in countries where SDI development has remained dormant, disorganised and/or slow. Constraints inhibit other nations from keeping up with the rest of the world in SDI implementation. The ripple effect is that, those nations failing to build SDIs are missing out on spatially enabling their communities and contributing meaningfully to concerted global geospatial data efforts. SDI development failure also implies that affected countries will miss out on opportunities that are associated with it regionally and globally e.g. SDI capacity building.

In so far as constraints are concerned, this chapter has made some preliminary findings in relation to the countries under study by delving into the previous results in the case of Makanga

and Smit (2009) read with Mwange *et al* (2016). The results of these two studies reveals that SDIs in these countries are at various levels of development but generally showing characteristics of slowness and disorganisation in implementation. This can inter-alia be treated as an indication of presence of constraints in these countries' SDIs. Though the authors had referred to their findings as indicators of the status of SDI development, in this study, the same indicators are taken to be more resourceful if they were to be treated as constraints. Therefore, based on questionnaire, documents, shared interests and SDI coordinating organs, investigations relating to constraints were done within SACU countries as units of discourse in an attempt to find answers to the aims, objectives, questions of these study and hypothesis.

Chapter 3 : Conceptualising SDI Constraint-Oriented Approach

3.1 Introduction

In Chapter 2, literature has been reviewed to reveal successful SDI advancements across a number of jurisdictions, especially in the developed countries world. In the African region, a number of articles reviewed raised concern indicating SDI developments as slow and disorganised (Makanga and Smit, 2010; Tumba and Ahmad, 2014; Guigoz *et al*, 2015; Siebritz and Fourie, 2015; Mwange *et al*, 2016). Summaries of the various concerns, conclusions and recommendations from these scholars are listed below.

1) Slow speed of NSDI implementations in Africa as articulated by Makanga and Smit (2010)
2) Vague perception of SDI in developing countries articulated by Tumba and Ahmad (2014)
3) Awareness and custodian cooperation in South African Spatial Data Infrastructure development as reported by Siebritz and Fourie (2015)
4) Low to average SDI Readiness Index, e.g. Botswana (0.35) and South Africa (0.64) as it reported in Mwange *et al* (2016)
5) Weak scores of the fourteen SDI indicators in Africa as opined by Guigoz *et al* (2017)

Apart from Siebritz and Fourie (2015) the other studies were conducted across the whole of Africa. For this study, the concerns raised above are viewed as gaps requiring in-depth investigation by looking at the context of countries. In order to study these SDI concerns, they were first conceptualised as constraints. In its simple form, constraint refers to a limiting or restricting situation for something to happen, in mathematics it refers to the process of optimisation of a given variable or problem. In management, constraints are treated in a theory format which seeks to look at an aggregated system development and identify its weak links as responsible for restricting advancement or better output (Geri and Ahituv, 2007; Şimşit, Günay and Vayvay, 2014). The management philosophy referred to by these authors is called the Theory of Constraints (TOC) and it is used in this chapter to conceptualise a constraint-oriented approach in SDI development and assessment. The constraint-oriented approach proposed in this chapter is meant to help organisations, countries and regions to pursue on-going improvement in their SDI implementation programs.

3.2 Research Strategy

Paradigms of research have been largely set in motion on two broad pedestals, the quantitative and qualitative lines of inquiry. Laws and McLeod (2006) citing Zuber-Skerrit (1992, p. 27) has shown the comparative nature of the two methods when used in research. From their work, they have itemised the characteristics of quantitative and qualitative methods as shown in table 3.1. From table 3.1, it can be noted that paradigm 1 is highly deductive and is associated with quantitative research methods, while paradigm 2 is highly inductive and is associated with a qualitative method of inquiry. These methods have been studied to help inform a research strategy in this study. It was realised that research strategies can take the form of quantitative or qualitative or combine the two methods in what is dubbed the mixed-method approach (Johnson and Onwuegbuzie, 2004; McDougall, Rajabifard and Williamson, 2007).

Table 3.1: Paradigms of research (Source: Laws and McLeod 2006 citing Zuber-Skerrit 1992, p.27)

Paradigms of Research

Paradigm 1	Paradigm 2
Natural Science	Human Science
Traditional	Alternative
Experimental	Naturalistic
Prescriptive	Descriptive
Reductionist	Holistic
External	Internal
Nomothetic	Ideographic
Normative	Interpretive
Positivist	Non-positivist

A number of methods have been used in SDI studies, for instance State of Play in Africa (Makanga and Smit, 2010); SDI Readiness (Mwange *et al*, 2016; Delgado-Fernández *et al*, 2005); weak SDI indicators scores in Africa (Guigoz *et al*, 2017). These approaches were used to quantitatively measure stakeholder perceptions as indicators in SDI advancement. The results that were obtained in Makanga and Smit (2010) and Mwange *et al*, 2016 are going to be used to make a case for the methodology of constraint-oriented SDI advancement.

In case of qualitative approach, Laws and McLeod (2006, p. 2) described its robustness in research by saying that "*the qualitative approach strived to understand the perspectives of the*

program stakeholders, looking to first-hand experience to provide meaningful data". According to Laws and McLeod (2006) the qualitative line of inquiry allows us to study documents and other data sources in a holistic manner. This method is interpretive in nature and it allows the context to lead to answers. This approach is going to be heavily utilised in Chapter 5 and 6 in studying the SDIs of the SACU countries.

In case of SDI research, qualitative approaches have been used for example in the study done by Grus (2010) following a case study method with Australia, Netherlands and Poland as samples. This particular study was done to show that SDI does exhibit attributes of complexity similar to Complex Adaptive Systems (CAS). This method of inquiry is usually followed because of four main reasons being; (a) *complexity of phenomenon* (b) *to avoid posing of casual questions which might fail to give sound answers* (c) *to carry out in-depth and holistic study* and (d) *to study the phenomenon with its own context* (Grus, 2010; Pare, 2004). Another study which took the line of qualitative study was that one of studying regional SDI for Asia-Pacific (Rajabifard, 2002). The qualitative approach was used because there were several countries which represented a complex network of regional attributes in terms of country size, political environment, socio-economics and several other factors (Rajabifard, 2002).

Other SDI studies have taken the mixed-method research approach for example McDougall, Rajabifard and Williamson (2007). This particular mixed-method research approach was specifically talking to issues of data sharing and partnerships in the context SDIs. In the case of this study, the mixed-method approach will be evident depending on the line of the constructs and perceptions being interrogated and reported on. SDI belong to Information Infrastructures as defined in Chapter 2.2.2. These are complex social and technical setups, therefore in studying them, methods should retain enough dynamism to respond to prevailing situations and support collection of a wide aspect of data and synthesising to get useful answers. This view can be related to that of Bowker *et al* (2010) which says *"when dealing with information infrastructures, we need to look to the whole array of organizational forms, practices, and institutions that accompany, make possible, and inflect the development of new technology, their related practices, and their distributions."* The various instruments mentioned by Bowker *et al* (2010) are going to be elaborated more explicitly in Chapter 4 which will be focussing on the actual data collection and analysis approaches in respect of the

case studies for SDIs in Botswana, Kingdom of eSwatini, Lesotho, Namibia and South Africa. The research questions of this study formulated in Chapter 1.4.3 require data from both quantitative and qualitative methods to be answered. Example is the question: "How can the critical success and failure factors of a spatial data infrastructure be managed?". This question can be answered by following established SDI Assessment methods as described in Chapter 2.5 with specific quantitative perspectives which are then used to follow an improvement program. Through qualitative research and reasoning, as an example, it can also be inductively determined that prioritisation depending on the exigencies of government could be the major determinant of the critical success of an SDI. The methodical approaches, are depicted through figure 3.1 to reveal designs and analytical frameworks followed.

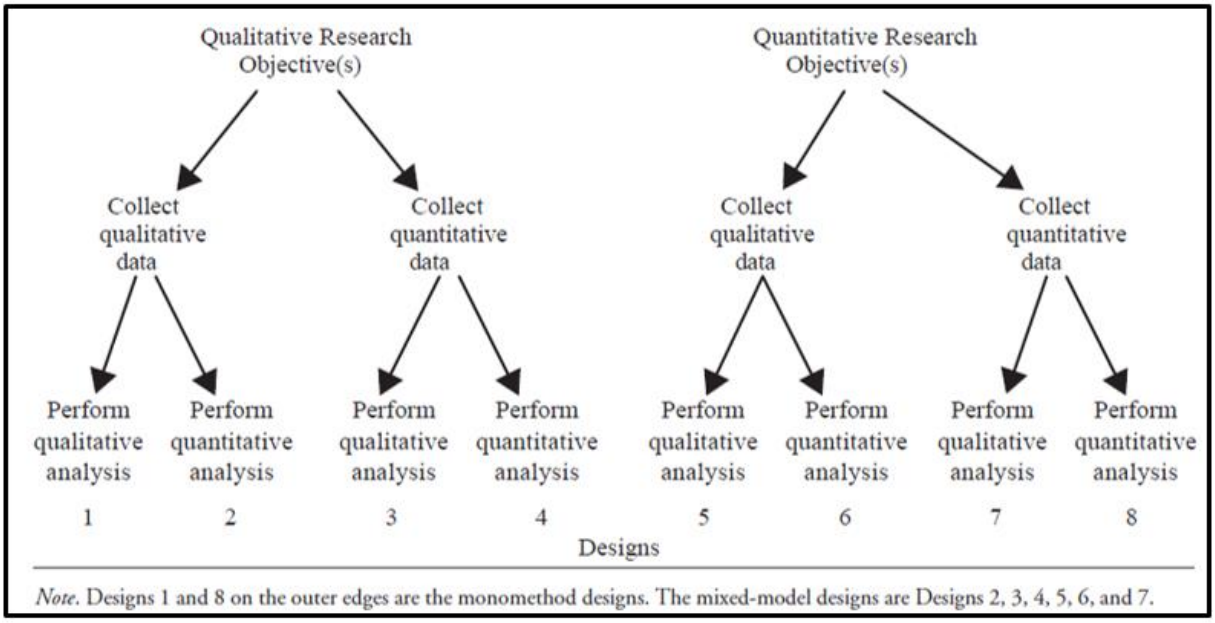

Figure 3.1: Monomethod and mixed-model designs in research. (Source, Johnson and Onwuegbuzie, 2004, p. 21)

The mixed method approach was initially followed in reviewing the existing literature and associated results (Makanga and Smit, 1994; Mwange *et al*, 2016) within the frameworks of the SDIOGI following perspectives of 7 and 8 in figure 3.1. It was also useful in SDI case studies of the countries, allowing for depth and comparative analysis on the basis of their real social and technical scenarios following perspectives 1 and 2 in figure 3.1 (e.g. the case of Botswana SDI in Chapter 5 partly followed perspective 2). This method allowed for synthesising the sequential progressions of the SDIs under study in their own natural settings.

The approach catered a lot towards the researcher responding to local situations which were out of his control. The constraint-oriented SDI advancement, the SDIOGI methodology is proposed in the next sections within the frameworks of TOC. This is done by first justifying its selection among a number of methods, then describing and aligning it with SDI Assessment by utilising the results of Makanga and Smit (2010) and that of Mwange *et al* (2016) to show how TOC can be embedded in SDI development, evaluation and optimisation process. Suffice to mention here that, the results of scholars referenced in this paragraph are used as an illustration of how the SDIOGI approach can work in a quantitative manner in a real developmental environment of SDI hierarchies over time.

3.3 On-Going Improvement Justification and Selection of the Approach

Section 3.1 has set a tone regarding the nature and general SDI outlook in Africa by showing them as weak, slow and being driven by vague perceptions. A number of scholars who studied these African SDIs have recommended that approaches need to be devised to foster improved plans and implementations. In an attempt to address the gaps, this study is proposing an SDI On-Going Improvement (SDIOGI) approach. The defining phrase in this approach is 'On-Going Improvement', which aims at understanding how the SDI efforts were carried out, the challenges encountered, the current attempts, control mechanisms, constraints and movements towards new ways of doing things. In order to conceptualise an appropriate approach, theories and concepts relating to 'improvement' are succinctly reviewed and those with suitable characteristics selected and justified to support SDIOGI proposal.

Theories of improvement are many and they often focus on change, quality management and general improvement of the organisational ways of doing things. A number of approaches available for review and utilisation in this study include the following:

a) **Quality Management Underlying the Deming Management Method (Anderson, Rungtusanatham and Schroeder, 1994):** This is a theory aimed at making positive improvements to organisational outlooks and functions. It was promulgated with the aid of the Deming Management Method. This theory has seven fundamental components of: **Leadership**, with emphasis on it being visionary; **Internal and External Cooperation**, which posits strong partnerships; **Learning**, where training and acquisition of new skills and knowledge are key and should be entrenched within

organisational ethos; **Process Management**, which involves shrewd management of processes and activities in fulfilling key objectives of organisations; **Continuous Improvement**, which underpins the ability to move to new frontiers in creation of products and services coupled with underlying processes; **Employee Fulfilment**, which is anchored on satisfying the workforce and instil a sense of ownership in what they do; **Customer Satisfaction**, where meeting the needs of the users of the system is key.

b) **Diffusion of Innovations Model (Rogers, 1995):** This approach bears the hallmarks of how organisations and nations tend to respond and adopt technology. According to Rogers (1995, p207) "*the more persons involved in making an innovation-decision, the slower the rate of adoption*". The Diffusion Model components are: The number of decision makers in innovation adoption; innovation diffusion channels; innovation complexity; the norms of the social system and change agents. This approach has been used by Camara *et al* (2006) in an evaluation of the transitional nature of the Brazilian geospatial information towards establishment of SDI. According to Camara *et al* (2006) several geospatial information scholars have studied the application of this method, for example Rajabifard (2002). Camara *et al* (2006) makes it clear that for this model to be deployed within geospatial information the qualities of the involved technologies must be determined and known.

c) **McKinsey Model. (Waterman, Peters and Phillips, 1980):** This is an improvement approach which is premised on aiding organisations to improved success statuses. The McKinsey model is supported by the world-renowned McKinsey Global Institute. The main improvement components are: Structure, Strategy, Systems, Superordinate goals, Style, Skill and Staff.

d) **Lewin's Three Step Change Theory (Lunenberg, 2010):** The main persuasion of this theory is to directly deal with instances which foster or hinder changes to happen within organisations. It is a change management approach which deals with three basic steps of unfreezing, changing and freezing as a way of following a development process with appropriate pauses and evaluations.

e) **Kotter's Change Model (Kotter, 1995):** This is credited as an expanded Lewin's Three Step method into eight steps. The first four steps of Kotter's model are associated with "unfreezing" while Stages 5 to 7 facilitate for change to happen or move and stage 8 being the last stage allows for the re-initiation of the change by going again to a freezing state in order to respond to the new changes and associated challenges.

Whittall and Barry (2005) have given their reasoned indication that this model can be utilised in dealing with the ever-changing activities in geospatial information.

f) **Bridge's Transition Model (Bridges, 2009):** The Bridge's Transition Model navigate change through fundamental stages which accounts for the past, the neutral and the future which are respectively seen as certainty, ambiguity and hope. This transitional model seeks to focus the challenges and achievements of change into future periods.

g) **Harris Five Step Model** (Lunenberg, 2010)**:** Is a temporal method which dwells into operational activities of change management in five steps involving: planning and initiation, momentum, problems, turning point and termination.

h) **Technology Acceptance Model (Davis, 1985):** This model was devised by Davis in 1985 in order to address the user acceptance of what he called "computer-based information systems". This method addresses assesses external variables and success indicators of technology usage. This model has been found to be useful but in need of improvement in order to address what Legris, Ingham and Collerette (2002) refer to as "variables related to both human and social change processes".

i) **Prosci ADKAR Model (Boca, 2013):** ADKAR is an acronym coined model which is built on the five components of Awareness, Desire, Knowledge, Ability and Reinforcements.

j) **Greiner's change process model (Lunenburg, 2010):** Change is considered here as a process which must have drivers or actors. The fundamental actor in this case is an individual who foster change as an agent. The change agent usually takes the role of leadership but realizing that for success to happen power should be redistributed around within the frameworks of a developmental process.

k) **Fullan's Change Theme Set (Lunenburg, 2010):** This model came about in 2001 focussing on leadership anchored on the following components; moral purpose, understanding of the change process, building of relationships, building of knowledge and coming up with coherent majors.

l) **SDI Assessment (Grus, Crompvoets and Bregt, 2007):** Has been articulated in Chapter 2.5, with several methods which are consolidated into Multiview SDI Assessment. The parameters which are measured in SDI Assessment generally include the following: Organisation, Technology, Data, Standards, Access networks, People, Financial, Legal and Policy.

m) **Theory of Constraints (Goldratt and Cox, 1984):** This is an on-going improvement method which involves five major focussing steps which reveals weak links as

responsible for slow performance and outputs of organisational operations. The major steps are the following: identifying the constraints; exploiting the constraints; subordinating some constraints; elevating constraints; reviewing to identify new constraint to exploit.

These methodologies spur changes within and across organisations and help them to improve systems, processes, products and services. Looking back on the summarised methods of improvement, it is discernible that most methods have parameters which are similar or possessing common character and they generally deal with organisational processes, resources and ethos. Among these methods, the TOC, Lewin, Kotter, Bridge's and Harris are methodical approaches with clearly defined steps. Pertaining to knowledge search and quick cognition, the TOC approach is self-evident in name and solution process so far as constraints are concerned. Therefore, this reason is used as the first plausible and viable justification as to why TOC should be applied in SDI discourse as a control mechanism in enhancing SDI development, evaluation and prioritisation of solutions.

Secondly, in terms of improvement monitoring, the TOC method stands out as capable of utilising fundamental components of the other twelve (12) methods in a constraint ordering perspective. For instance, if we consider identification of constraints, it is possible to determine the most constrained of the seven Quality Management components either through quantitative and/or qualitative approaches discussed in section 2.2. Once identified, the most constrained component can be deduced or induced as the weak link and be solved by focussing it through the other TOC steps. This reasoning and approach can be applied to the Diffusion Model, McKinsey Model, Prosci ADKAR, Fullan's Change Theme Set and SDI Assessment. Thirdly, to put it into context, a movement to align TOC with SDI Assessment grounded on the results of Makanga and Smit (2010) and Mwange *et al* (2016) is done in this chapter. Therefore, the two improvement methods are selected to aid a theoretical framework and an illustration of a conceptual approach to SDIOGI in the next section.

3.4 The Theoretical and Conceptual Framework

Following the justification on 3.3, the TOC method is explained and intertwined with SDI Assessment to conceptualise SDIOGI. In Chapter 2, comprehensive literature review of SDI and its general discourse were undertaken and in Section 2.5, a scenario was advanced in respect of SDI inherent constraints being indicators of the prevailing SDI Assessment methods e.g. constrained funding of SDI. Therefore, this section is seeking to conceptualise the TOC into the SDI environment. But first a succinct review of the TOC is done.

3.4.1 The Theory of Constraints (TOC)

TOC was originated and largely developed by a Physicist named Goldratt, primarily as a solution to under-performing manufacturing processes in 1979. The TOC methodology has evolved over the years since 1979 as illustrated in figure 3.2 (Watson, Blackstone & Gardiner, 2007). According to Şimşit, Günay and Vayvay (2014, p.930), TOC is defined as "*a management philosophy which is focused on the weakest ring(s) in the chain to improve the performance of systems*." The definition by Şimşit, Günay and Vayvay (2014) refers to improving the systems and this is consistent with the concerns in Section 3.1. Relating to the systems, Dettmer (1998) summarised TOC this way;

> *"TOC can be characterized as a set of concepts, principles, and measurements that focus attention on the ultimate output of the whole system, not just that of a component part of it. It includes a set of logistical tools to optimize the flow of work—whether product, service, or project—through the system, and a set of logic trees to identify core system problems (constraints), design and test solutions, and structure implementation plans".*

To further understand TOC, it is noted in figure 3.2 that, it has metamorphosed through stages starting with optimisation technology pursuits, the goal, system performance measurement and road map to solve for complex undertakings to critical chains (Watson, Blackstone and Gardiner, 2007; Şimşit, Günay and Vayvay, 2014). Of the five scenarios in the preceding sentence, it was the goal which led to the emergence of the five-step method of TOC. In the five-step method of TOC one has to progress by (a) *Identifying the constraints* (b) Exploiting *the constraints* (c) *Subordinating some constraints* (d) *Elevating constraints* (e) *Reviewing to identify new constraint to exploit* (Goldratt and Cox, 1984; Goldratt and Cox, 1992; Ronen and

Spector, 1992; Coman and Ronen, 1994; Watson, Blackstone and Gardiner 2007; Şimşit, Günay and Vayvay, 2014). This constraint identification and exploitation to advance system development is iterative. According to Coman and Ronen (1994), two earlier steps by Goldratt can be added to it to yield a seven-step methodology. The earlier steps indicate that the system itself, should first have an objective goal to be achieved and a stipulated performance measurement (Ronen and Spector, 1992; Coman and Ronen, 1994; Şimşit, Günay and Vayvay, 2014). As such, they are amalgamated into a seven-step suite in this study for dealing with the "Process of SDI On-Going Improvement".

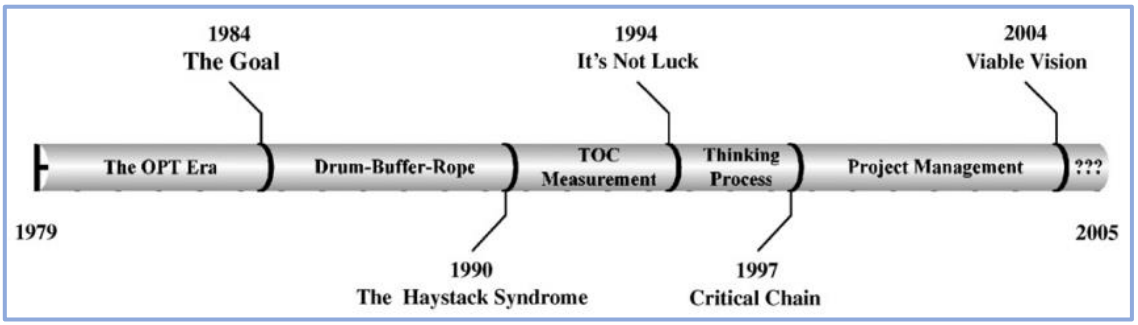

Figure 3.2: Timeline in the major development of TOC (Source: Watson, Blackstone and Gardiner 2007)

The emergence of SDIs in the 1990s coincide with TOC when it was work in progress. This methodology, as reviewed shows itself to hold strong expositions that are useful in relation to studying SDI. Watson, Blackstone and Gardiner (2007) after reviewing several articles, attributed the application of TOC methodologies to be useful in enhancing; (i) *project management* (ii) *retailing* (iii) *supply chain management* (iv) *process improvement* and (v) *a variety of production environments*.

Most of the points in the preceding paragraph are very relevant to SDI, for instance (i), (iii), (iv) and (v). TOC is a revolving methodology, which is capable of simplifying operational activities of a complex infrastructure such as SDI, and it can start of as a project with supply nodes needing management, and once established its operations are subjected to continued improvement. Fundamentally, the main goals of SDIs are to allow for geospatial data collection, processing, distribution, sharing and exchange amongst stakeholders in a variety of production environments and it usually start as a project, and is repeatable. Therefore, TOC is

embraced in this study as a methodology of choice, in tackling problems of slow and often disorganised SDI implementation in the developing countries (Makanga and Smit, 2010; Mwange et al, 2016; Delgado-Fernández et al, 2005; Guigoz *et al*, 2017). For the purpose of this study it is presumed that the five focussing steps of the TOC can be applied to any type of SDI whether it be at inception, certain level of implementation or matured. TOC is a cyclic method subscribing to three fundamental parts being; On-going Improvement (OGI), Thinking Process (TP) and performance measurement (Rahman1998; Kim et al 2008; Sanjika, 2010). Drawing from Rahman (1998) and Kim *et al* (2008), Sanjika (2010) compiled these fundamental parts of TOC as presented in figure 3.3.

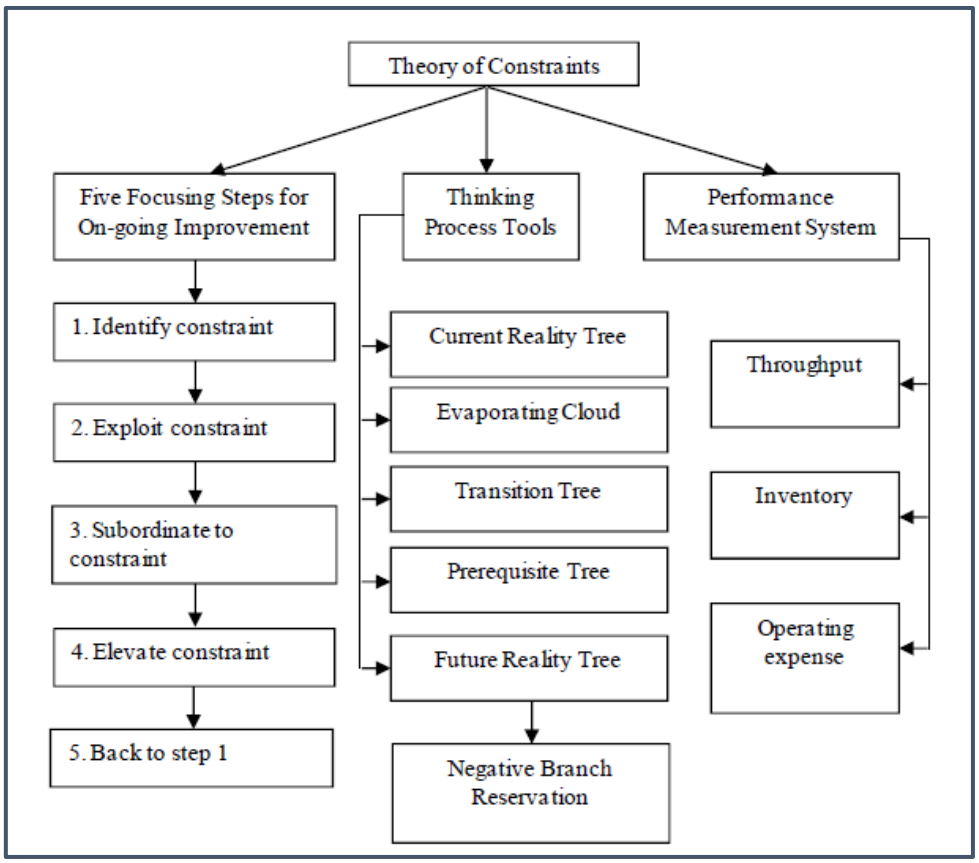

Figure 3.3: Theory of Constraints with its streams. (Source: Sanjika, 2010)

From figure 3.3, it is evident that TOC has three fundamental arms, which deals with improvement, a thinking process and measure of performance. By their nature, these TOC arms can be executed concurrently within an organisational environment in products, services, systems and infrastructure development. The three arms of TOC are briefly explained in the following passages.

- **Five Focussing Steps for On-Going Improvement:** According to Sanjika (2010), this arm of TOC "*provide an approach to continually solve systems problems and hence improve the performance of organisations*." This is a cyclic improvement process that is used to determine the performance capabilities of a product, service, system or infrastructure subject to its constraints among which there is what is referred to as the 'major constraint'. A major constraint technically inhibits or blocks any performance beyond itself. For example, in the case of SDI, if competent staffing is an issue in SDI development, then it means staff must be trained and given appropriate competencies for SDI to start regardless of the availability of appropriate technological requirements e.g. software, access networks and data.
- **Thinking Process Tools:** Thinking Process (TP) is as systems design approach and is aptly defined in the words of Arnold and Wade (2015, p. 675) who defined systems thinking as "*a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects. These skills work together as a system"*. TP uses the concepts of interdependency and interconnection between things to build a formidable design or solution for any products, services, systems and infrastructures. Some of the steps associated with this approach are going to be grounded in the results found in Chapter 5 and 6. If we consider the "Current Reality", will be shown in respect of current constraints of the given country SDI.
- **Performance Measurement System:** this is the measurement processes which are largely defined by throughput, inventory and operating expense (Sanjika, 2010). In the context of this study, this TOC arm is assumed to be similar to the SDI performance methodology by Vandenbroucke *et al* (2013). In case of SDI in the SACU countries, geoportals, policies, skills development, infrastructure accessibility will reveal the performance.

In comparison with Manufacturing Resource Planning and Just-in-Time methods, Balderstone and Mabin (1998), did a comprehensive review of TOC literature to gauge its application impact factors across industries globally, and they discovered its achievements in a number of organisations having made fundamental improvements in the following; *(1) mean reduction in lead times; (2) mean reduction in cycle times; (3) mean improvement on due-date-performance; (4) mean reduction on inventory levels; (5) correlation of lead-time and*

inventory reduction; (6) mean increase of revenue/throughput and (7) mean increase of combined financial variables.

These TOC achievements when reflected against concerns raised in Section 3.1, do aid the presumption that, the application of TOC in SDI programs is a conceivable approach to pursue. For instance, the slowness in SDI could be due to non-defined '*lead times*' by implementing organisations, localities, nations and regions in the context of African countries. In terms of *'cycle times'*, it could be that, geospatial data takes long to review and update in a concerned stakeholder corporation or nation. Regarding *'due date performance'* it could be that, stakeholders lack to set or fail to meet their delivery timelines, e.g. failure by SDI standard Work Group in coming up with realisable products for adoption and use by stakeholders within agreed dates, leading to failed or slow SDI implementation. '*Reduction in inventory levels'* can be taken along the auspices of a common concern in Africa, which is, geospatial data availability for the purposes of SDI implementation. The *'correlation'* aspect can be considered along the lines of availability of geospatial data as a subject of time, for instance studies done in Africa by Makanga and Smit (2010); Mwange *et al* (2016), and Guigoz *et al* (2017) exposed SDI developments in Africa to be slow subject to its inception time. African countries, are pronounced as lacking in geospatial data (Guigoz *et al*, 2017), as such it is important to know how the untenable status had been impacted by the times and technology trends. The '*revenue/throughput'* are important as benefits that can be used to quantify the usefulness of establishing an SDI. The financial variables could refer to the funding status of the SDI centrally and across its stakeholders. The following subsection is going to conceptualise and articulate the SDI On-Going Improvement (SDIOGI).

3.4.2 SDI On-Going Improvement (SDIOGI) approach

This section is about identifying and coming up with ways in which constraints can be utilised to support the advancement of SDIs. Some studies done in the past have produced results which confirm slow SDI development and recommended the need for improvement interventions (Makanga and Smit, 2010; Tumba and Ahmad, 2014; Guigoz et al, 2015; Siebritz and Fourie 2015; Mwange et al, 2016). For this reason, a constraint-based SDI improvement approach is being put forward here, first as an application of TOC on SDI Assessment processes to derive focus on SDI constructs in development processes, and secondly as a

movement towards a new kind of information management strategy by governments and organisations. In this study a conceptual framework recognising SDI as an infrastructure with identifiable goals and subject to a number of constraints to development is proposed. A review has been done in the preceding sub-section and TOC found to be a suitable theoretical framework to utilise in addressing the problem of slow SDI development. An approach is proposed here to apply TOC method in SDI implementation processes subject to initial SDI Assessment. This theoretical framework which is iterative in nature, is considered across the whole life cycle of an SDI. The conceptual proposition adapted from Coman and Ronen (1994) is put forward in table 3.2 to illustrate the SDIOGI with SDI equivalent steps proposed along the TOC steps.

Table 3.2: Constraint oriented SDI On-Going Improvement (SDIOGI) Approach

Steps	Theoretical Aspect: Theory of Constraints Process of On-Going Improvement (Coman and Ronen, 1994)	Conceptual Aspect: Spatial Data Infrastructure (SDI) Progression	Spatial Data Infrastructure (SDI) Process Description
1.	Define the system's GOAL.	Define SDI (Corporate, Local, State, National, Regional, Global)	SDI Development set up with vision and mission statements and well-articulated objectives and goals
2.	Determine System performance measurements	State SDI Operations Resources and Performance	This step sets the development agenda for an SDI and pronounce input and output needs over a particular time of implementation
3.	Identifying the System's constraints	Identify SDI Constraints	All development constraints are identified and the primary constraint that is considered highly inhibitive to SDI development to progress is identified. E.g. Legal Framework
4.	Exploiting the System's constraints	Prioritising SDI Constraints	SDI Development processes, being undertaken by ensuring that the SDI constraint(s) identified in step 3 is solved and removed from inhibiting SDI progression. E.g. Ensuring that Legal Framework is in place as a pre-requisite to commencing SDI
5.	Subordinating of System's Constraints	SDI Constraint Subordination	SDI Development processes are subordinated to the identified main constraint to ensure that the identified major constraint is solved first.
6.	Elevation of System's Constraint	SDI Assessment Mechanism	Undertaking SDI Assessment at some point in time to objectively absolve the constraint identified in step 3 and remove it from the weak link bracket
7.	Go Back to Step 1 or 3 but Avoid Inertia.	New Constraints Frontiers back to Step 3	Further Constraint exploitation or Identifying new main constraint (go back to step 3) following SDI Assessment performed in Step 6.

To put the proposition of table 3.2 into more perspective, the objectives of the approach are promulgated as the following:

- To reveal the component which is a weak link (major constraint) in SDI development and/or implementation

- To speed up the SDI implementation processes by aiding focused SDI designs and implementation processes
- To aid comprehensive SDI implementation, which takes care of the heterogeneity of SDI as an information infrastructure.
- To address the complex and underlying aspects of SDI in view of policy and institutional cooperation in development.
- To allow for set temporal reviews of SDI implementation programs on the basis of context determined constraints.
- To establish the role of SDI Assessment approaches in SDIOGI

The framework as summarised in table 3.2 and the objectives thereafter, is meant to focus and give direction to this study. This methodological proposition is used to understand why SDI development has been slow in the context of some jurisdictions and help advance useful implementations. A recognition is made that, there are several SDI assessment methods but the emphasis here is, their results must be carefully analysed for constraints and considered within the frameworks of this approach. A process of actualising this methodology is done under the next sections using the results from State of Play (Makanga and Smit, 2010) interfaced with SDI Readiness Index (Mwange *et al*, 2016). These are SDI Assessments of African countries reported at the two different times and the results of SACU countries are extracted and used to focus the procedure to fulfil study objective 1 which seeks; '*To review SDI discourses and propose a constraint oriented methodological approach as a road map of advancing its development and progression'*. These results (Makanga and Smit, 2010; Mwange *et al*, 2016), are used to illustrate an approach where SDI Assessments can be used alongside TOC to foster improvements in SDI implementations.

3.4.3 Pragmatic Utilisation of SDIOGI

This section is essentially going to utilise the previous studies on SDI investigations to illustrate this methodology. The indicators listed in table 3.3 were used by Makanga and Smit (2010) to measure the State of Play of SDI throughout Africa. Through this section a case is advanced that these same indicators be used as a form of identifying and measuring SDI constraints. In the context of the TOC, weaknesses in the five indicator classes pose constraints to the process of SDI development and requires that the weakest component should have been identified,

exploited and solved within the period 2011 to 2016. Step 1 and Step 2 were not articulated in Makanga and Smit (2014), so for this chapter they are going to be explained only and their detailed discussion is grounded on the results in Chapter 5 and 6 which focuses on in-depth study of SDI in the context SACU countries.

3.4.3.1 Step 1: Define SDI

Through this step an SDI has to be well defined in terms of its purpose, objectives, mandates, vision, mission, regulations and strategic plan. The comprehensive components of SDI such as policies, data, skills, technologies and their interactions towards production of a functional SDI must be well articulated. In the review of literature in Chapter 2, Rajabifard (2002) has articulated well the goals of SDI as corporate, local, national, regional and global assets. Therefore, SDI goal setting is very important towards determining the constraints that are associated to it. The INSPIRE SDI is a good example of goal setting, because the directive and its goals were issued, and member states had to gauge their status and constraints and work towards satisfying its requirements. The elaboration of this step will be further pronounced in Chapter 5 and 6.

3.4.3.2 Step 2: State SDI Operations Resources and Performance

This step focusses SDI implementation in terms of the inputs, transformation (workflow and processes) and what the SDI should be able to achieve after a specified time period with specific outputs. It also includes its main players and their responsibilities. Determining the inputs and outputs is very vital to carrying out assessments at later stage, to able to gauge what has been achieved and the constraints that are associated with the SDIs. Just like 3.4.3.1, The elaboration of this step will be pronounced in Chapter 5 and 6 following the context of the SDIs under this study.

3.4.3.3 Step 3: Identify SDI Constraints

After step 1 and step 2 are put in place, SDI implementation should kick-start by identifying constraints. For the purposes of describing this approach, the SDI Assessment done by Makanga and Smit (2010) is used to ground the associated propositions. As point of departure, indicator components and their variables in Makanga and Smit (2010) are regarded as SDI

Constraints as per the literature review and propositions in Chapter 2.5. For purposes of simplicity in referring to the indicator categories, the fourteen-indicator category are referred to as Underlying Constraints and the five-indicator class are referred to as Composite Constraints. This naming convention is consistent with the order of the results since the fourteen indicators are used primarily for data collection as shown in table 3.3 and the five-indicator class are then computed as combination of the Underlying Constraints.

Table 3.3:SDI State of Play Assessment Viewpoints and Indicators (Adapted from Makanga and Smit, 2010)

INDICATOR-CLASS (Composite Constraints)	INDICATOR (Underlying Constraints)		Not Sure	Absolutely False	Slightly False	***Fairly True***	Absolutely True
Organisational	1A	There is a National SDI Coordinating body (Government, Voluntary)					
	1B	There is maximum stakeholder participation (Government, Private Sector)					
	1C	There is an SDI Champion at the Highest Political Level					
Funding	2A	There is a reasonable budget to fund SDI activities					
	2B	The SDI initiative is self-sustaining					
Legal	3A	There is a legal framework governing spatial data pricing					
	3B	There is a legal framework governing spatial data use					
	3C	There is a legal framework governing spatial data creation					
Technical (Data)	4A1	There is a reasonable level of interagency coordination of spatial data creation efforts					
	4A2	The data creation process is formally standardised for all data creators					
	4A3	There is ready access to electronic spatial data through a Geo-portal, CDs and other forms					
(Metadata)	4B1	Metadata is captured for most of the spatial data that is created					
	4B2	Data creators create metadata according to a prescribed standard					
	4B3	There is a clearinghouse(s) that communicates most of the available data resources					

According to Makanga and Smit (2010) these indicators were measured using a Likert type of scale with the following ordering: "***Not Sure = 0, Absolutely False = 1, Slightly False = 2, Fairly True = 3 and Absolutely True = 4.***" These measurement scales portray constraints e.g. 1A which assets that a country has a NSDI body, when answered as "Absolutely False", can be inferred to mean that SDI in the jurisdiction is really constrained organisationally. Therefore, according to the method being suggested it will be necessary to exploit the creation of the NSDI body in the country as founding steps to implementation. If the answer is "Slightly False", it might infer that there is existing organisation which might not be well founded e.g. presence of a temporary SDI Committee which can easily get dissolved. If the answer is "Fairly True" it infers that the organisation is there, though there could be constraining scenarios, for

example SDI body with no clear mandate and organisational passage. The "Absolutely True" answer will infer that a proper body responsible for SDI activities is there - whereby its structure, mandate, capacity, culture etc, can be interrogated for constraints. The rest of the indicators are considered as constraints following this reasoning and their scales of measurements are further summarised in table 3.4 and related to a suggested equivalent in terms of constraints. These scales of measurements are very important in formulating the ordering of the SDI Constraints as their results can be used to aggregate, gauge and prioritise what needs to be solved in order to support the sustained implementation of SDI in the context of TOC.

Table 3.4: Proposed SDI Constraints Scales of Measurement following Makanga and Smit (2010)

Scale	Description	Constraints	Comments
0	Not Sure	uncertainty	This represent ambiguity in the indicator. It can at best be described as over-constrained and ambiguous
1	Absolutely False	Highly constrained	This means the indicator is over-constrained such that it will have an adverse effect on the SDI advancement
2	Slightly False.	Constrained	This means that the indicator is constrained in such a manner that it can be studied and used as the foundations of SDI advancement
3	Slightly True	Slightly unconstrained	This means the indicator is constrained with some level of visibility in the activities of SDI, but they require some interventions and focus
4	Absolutely True	Almost unconstrained	This means the indicator can be okay as it is and if left that way it may not inhibit the overall advancement of the SDI

Table 3.4 above was analysed and associated with the TOC methodology and in the process table 3.5 was produced. The SDI On-Going Improvement column in table 3.5 was obtained from the method as proposed in table 3.2. Each step of the method was related with the Underlying and Composite Constraints which were deduced from table 3.3. In table 3.3 it is deduced that the SDI is a national one as per indicator 1A. The National SDI (NSDI) is usually a conglomeration of various data sets from the lower level SDIs such as corporate, local and state, as such these on their own are considered to possess a bulk of Underlying Constraints. Specified inputs/outputs of the National SDI and those at lower levels are regarded as significant to its performance. The Underlying and Composite SDI Constraints are deduced from table 3.3 and populated accordingly as items of SDIOGI Step 3. From there, the main SDI constraint (weak link) is identified and solved through the whole methodological cycle. Table 3.5 clearly depict the dependencies of SDIs in a hierarchical format as advanced in Rajabifard (2002). This approach effectively demonstrate that lower SDIs are important in the formulation and definition of the SDI that is considered for development or assessment at National level.

Table 3.5: Propagation of Constraints for National SDI

Steps	SDI On-Going Improvement	Composite Constraints	Underlying Constraints
1.	Define SDI	National	State, Local, Corporate, Objectives, Goals
2.	State SDI Operations Resources and Performance	Country Stated Inputs/Outputs	SDI inputs/outputs for State, Local and Corporate
3.	Identify SDI Constraints. (E.g. Makanga and Smit, 2010)	Organisational, Funding, Legal, Technical Data and Metadata with lowest index scale	Coordinator, Stakeholder-Participation, Political-Influence, Budget, Self-Sustenance, Data-Pricing Law, Data Use Law, Data Creation Law, Interagency Data-Coordination, Data Standards, Electronic Data Access, Metadata Captured, Metadata Standard, Clearinghouse data Communications
4.	Prioritising SDI Constraints	Select and exploit Composite Constraint with lowest index scale	Select and exploit all the related Underlying Constraints with lowest index scales
5.	SDI Constraint Subordination	State Composite Constraints Subject to Subordination	State the related Underlying Constraints that will be subject to Subordination
6.	SDI Assessment Mechanism. (E.g. Mwange *et al* 2016)	SDI Assessment based on the Multiview SDI Assessment framework	Institute SDI Assessment based on the Multiview SDI Assessment framework (select suitable method).
7.	New Constraints Frontiers back to Step 1 or 3	Determine new constraint as per the SDI assessment	Determine related primary constraint SDI components

The methodology presents its own hierarchical structure in that Underlying Constraints (UC) are important in the determination of the Composite Constraints (CC). This structure realises that over a period of time the constraints in their hierarchy need to be identified, selected, exploited, prioritised, elevated and then SDI assessment is done again to move to a new frontier of constraints (weak links).

3.4.3.4 Step 4: Prioritising SDI Constraints

This step is actualised through the use of Makanga and Smit (2010) SDI Assessment results. The results of Makanga and Smit (2010) were used to propagate SDI constraints because it is an earlier assessment done across Africa to that of Mwange *et al* (2016). The computations are done, keeping in mind the proposition in the previous section that, the scores of measurements used in Makanga and Smit (2010), actually represent constraints as shown in table 3.5 Step 3. The five SACU countries which form the cases for this study, all participated in the study of Makanga and Smit (2010), and their *State of Play (SoP)* results were extracted in to table 3.6 for ease of reference as they are used to support this approach. To use these values, simple indices were determined based on the total score of the CC Score and Maximum SDI Score achievable.

Table 3.6: SACU Countries Results as Extracted from Makanga and Smit (2010)

	Components	Organisational			Legal		Funding			Technical Data			Metadata			Overall
Region	**Country**	**1A**	**1B**	**1C**	**2A**	**2B**	**3A**	**3B**	**3C**	**4A1**	**4A2**	**4A3**	**4B1**	**4B2**	**4B3**	**SDI Score**
South	Botswana	4	3	2	3	1	1	1	1	2	2	2	2	2	1	27
South	Lesotho	3	4	1	1	1	1	1	1	1	1	1	1	1	1	19
South	Namibia	2	2	1	2	1	1	2	1	1	1	3	3	2	1	23
South	South Africa	4	3	3	2	2	3	4	2	1	3	2	1	2	1	33
South	Swaziland	4	3	3	3	2	2	2	2	3	2	1	2	2	1	32

From the results in Makanga and Smit (2010), these countries, all returned results with UC Scores in the scale range 1- 4. Therefore, the Maximum SDI Score for the 14 UCs is 56 as shown in table 3.7. The results of the CCs Score were computed as sums of the associated UCs Scores. The quantities determination followed a similar assumption made in Makanga and Smit (2010) that, all indicators were having equal weights.

Table 3.7:SDI Index for Extracted Results of Makanga and Smit (2010)

Indicators = Maximum Points		Organisational = 12			Funding =		Legal =12			Technical Data = 12			Metadata = 12			56
Maximum Index		0.214			0.143		0.214			0.214			0.214			1.000
Country	**Constraints Scores**	**1A**	**1B**	**1C**	**2A**	**2B**	**3A**	**3B**	**3C**	**4A1**	**4A2**	**4A3**	**4B1**	**4B2**	**4B3**	**SDI Score**
Botswana	BW Unerlying Constraints	4	3	2	3	1	1	1	1	2	2	2	2	2	1	27
	BW Composite Constraints	9			4		3			6			5			
	BW Index	0.161			0.071		0.054			0.107			0.089			0.482
Lesotho	LS Unerlying Constraints	3	4	1	1	1	1	1	1	1	1	1	1	1	1	19
	LS Composite Constraints	8			2		3			3			3			
	LSIndex	0.143			0.036		0.054			0.054			0.054			0.339
Namibia	NAUnerlying Constraints	2	2	1	2	1	1	2	1	1	1	3	3	2	1	23
	NA Composite Constraints	5			3		4			5			6			
	NA Index	0.089			0.054		0.071			0.089			0.107			0.411
South Africa	ZA Unerlying Constraints	4	3	3	2	2	3	4	2	1	3	2	1	2	1	33
	ZA Composite Constraints	10			4		9			6			4			
	ZA Index	0.179			0.071		0.161			0.107			0.071			0.589
eSwatini	SZ Unerlying Constraints	4	3	3	3	2	2	2	2	3	2	1	2	2	1	32
	SZ Composite Constraints	10			5		6			6			5			
	SZ Index	0.179			0.089		0.107			0.107			0.089			0.571

The Maximum Index for the CCs as calculated are such that; Organisational, Legal, Technical Data and Metadata all yielded 0.214 and Funding is 0.143. These numbers represent the maximum indices that can be associated with each indicator as a constraint and when summed they yield a value of 1. The index value of Funding is smaller because its UCs have only 8 points. After computing the Maximum Index, the SDI Maximum Score was used to divide the Composite Constraints Scores to obtain each Country Index.

Utilising the results from table 3.6 and 3.7, table 3.8 was produced. In table 3.8 the SODIOGI steps are listed as columns against the Underlying and Composite Constraints as rows under each country. For the purposes of identifying the Underlying Constraints needing improvement, all those which returned lowest values were considered to be the weakest links of the given Composite Constraint. From table 3.6, all the countries had a value of "Absolutely False" or 1 on a number of its Underlying Constraints. All Underlying Constraints with a value of 1 are considered to be equally needing exploitation and solution as per SDIOGI. For the Composite Constraints, the one with the lowest index as per table 3.7 was extracted into table 3.8 as SDI's main weak link for a country as of 2010.

Table 3.8: SDI Constraints Scheme for the SACU Countries as per the adapted results of Makanga and Smit (2010)

Country	Constraints Type	1. Define SDI	2. State SDI Operations Resources and Performance	3. Identify SDI Constraints	4. Prioritising SDI Constraints	5. SDI Constraint Subordination	6. SDI Assessment Mechanism	7. New Constraints Frontiers back to Step 1 or 3
	BW Underlying Constraints	Country Definition	Country Stated	Coordinator, Stakeholder-Participation, Political-Influence, Budget, Self-Sustenance, Data-Pricing Law, Data Use Law, Data Creation Law, Interagency Data-Coordination, Data Standards, Electronic Data Access, Metadata Captured, Metadata Standard, Clearinghouse data Communications	2B, 3A, 3B, 3C, 4B3	All others	SDI Assessment and Prioritised Constraint Elevation	Evaluate results of SDI Assement and go back to any of the stated steps as necessary
Botswana	BW Composite Constraints	"	"	Organisational, Funding, Legal, Technical Data and Metadata	Legal	"	"	"
	LS Underlying Constraints	"	"	Same as those of Botswana	1C,2A,2B,3A,3C,4A1,4A2,4A3,4B1,4B2,4B3	"	"	"
Lesotho	LS Composite Constraints	"	"	Same as those of Botswana	Legal, Funding, Technical Data and Metadata	"	"	"
	NA Underlying Constraints	"	"	Same as those of Botswana	1C,2B,3A,3C,4A2,4A3, 4B3	"	"	"
Namibia	NA Composite Constraints	"	"	Same as those of Botswana	Funding	"	"	"
	ZA Underlying Constraints	"	"	Same as those of Botswana	4A1,4B1,4B3	"	"	"
South Africa	ZA Composite Constraints	"	"	Same as those of Botswana	Metadata	"	"	"
	SZ Underlying Constraints	"	"	Same as those of Botswana	4A3, 4B3	"	"	"
eSwatini	SZ Composite Constraints	"	"	Same as those of Botswana	Metadata	"	"	"

3.4.3.5 Step 5: SDI Activities Constraint Subordination Process

Tables 3.6 to 3.8 represent an SDI On-Going Improvement decision making process whereby the weakest links in an SDI development are identified. The results have also exposed the importance of country context in SDI development. According to table 3.8, in 2010, Legal came out as the main constraint affecting SDI development in Botswana, Lesotho and Namibia while Metadata component was perceived as main constraint in South Africa and Kingdom of eSwatini.

From table 3.8, further calculation was carried out by extracting and regularising the Maximum Index to Theoretical Index with value 1. This was done by taking the Maximum Index value under each column and dividing itself to get the Theoretical Index value of 1 for each component. Division by the Maximum Index values of components was also applied to the rest of the Country Index values. The results of this operation are presented in table 3.9 below, with the main constraints for each country highlighted.

Table 3.9: The indices of SACU countries State of play as calculated from results of Makanga and Smit (2010)

Constraint Index	Organisational	Funding	Legal	Technical Data	Metadata	Average
Theoretical	**0.214**	**0.143**	**0.214**	**0.214**	**0.214**	**1.000**
Botswana	0.750	0.500	0.250	0.500	0.417	**0.483**
Lesotho	0.667	0.250	0.250	0.250	0.250	**0.333**
Namibia	0.417	0.375	0.333	0.417	0.500	**0.408**
South Africa	0.833	0.500	0.750	0.500	0.333	**0.583**
Swaziland	0.833	0.625	0.500	0.500	0.417	**0.575**
Averages	**0.700**	**0.450**	**0.417**	**0.433**	**0.383**	**0.477**

From table 3.9, if the SDIOGI is followed, it means Botswana had to solve for its legal status as the main CC, while Lesotho had to come up with ways of solving for the four main CCs of funding, legal, technical data and metadata. South Africa and Kingdom of eSwatini would have had to solve for metadata. When such considerations are done, then other constraints are subordinated to the main CCs, e.g. in case of Botswana all other constraints are subordinated to Legal Framework as the main Composite Constraint. This method takes into full cognisance that, SDI is complex and might require for solutions to these constraints undertaken concurrently. But the emphasis is that, identifying constraints this way is useful in prioritising

SDI implementation such that, solutions are more focused on what could be perceived as the cause and effects in the design and development.

3.4.3.6 Step 6: SDI Assessment Mechanism and Constraint Elevation

Step six focuses on assessing the constraints after some time, and elevating the main constraint once its solved. Step six realises that, if SDI is subjected to on-going improvement then it should be assessed at some point in time using any of the existing Multiview SDI Assessment Framework methods. Following this reasoning, the SDI Readiness done by Mwange *et al* (2016) is brought in as a proxy for this step. The SDI assessment work by Mwange *et al* (2016) involves two SACU countries subject to Makanga and Smith (2010). The two countries are Botswana and South Africa. The time of Mwange *et al* (2016) SDI Readiness Index Assessment, is taken as significant because it happened 6 years after Makanga and Smit (2010) study. Therefore, out of the five (5) SACU countries which were in Makanga and Smit (2010) results, two (2) of them appeared in the SDI Readiness review by Mwange *et al* (2016). By sampling standards this represent 40% of the SACU countries.

It has already been opined in Chapter 2.5 that, components assessed in both studies are very much similar, and a presumption was made that, a certain SDI component in State of Play index in 2010 is expected to exhibit improved readiness in 2016. For the purpose of this sub-section, indices of countries which are both in Mwange et al (2016) and table 3.9 are compiled into table 3.10 for comparison and SDIOGI Step 6 validation propositions. The collated results are presented in table 3.10 whereby organisational and funding are both found to have been used as indicators in both approaches of SDI Assessment.

Table 3.10: Collated indices extracted from table 3.10 and Mwange et al (2016)

Region	**Country**	**SDI Method**	Organisational	Funding	Legal	Technical Data	Metadata	Informational	Human	Technology	SDI Index	Index Differences
South	Botswana	State of Play	0.750	0.500	0.250	0.500	0.417				0.483	-0.136
Mwange et al (2016)		SDI Readiness	0.1357	0.4665				0.2345	0.5244	0.6530	0.3477	
South	South Africa	State of Play	0.833	0.500	0.750	0.500	0.333				0.583	0.057
Mwange et al (2016)		SDI Readiness	0.7114	0.513				0.7348	0.6039	0.6649	0.6404	
Averages		State of Play	0.792	0.500	0.500	0.500	0.375				0.533	
		SDI Readiness	0.424	0.490				0.485	0.564	0.659	0.494	

What has to be noted from table 3.10 is that the variables measured in both assessment approaches are very much the same. This implies that, similar variables are measured and

called by a slightly different name. For instance, according to Mwange *et al* (2016), Legal indicator is now absorbed into the Organisational while Technical Data and Meta-data are bundled together as one under Informational. Perceptions on Technology are measured under the SDI Readiness Index approach. It is concluded here that the two approaches are useful in guiding the constraints-oriented approaches in the implementation of SDI in a jurisdiction. Therefore, it is posited that, if jurisdictions subject to the two SDI assessment methods could have been following the constraints-oriented approach of SDIOGI, they would have easily adapted to these findings.

Taking the case of Botswana, we realise that the Organisational perspective has really back-tracked from what it was in 2010. Going by the State of Play method in 2010 the Organisational index of Botswana was graded at 0.75 but in 2016 it had degraded to as low as 0.139. Considering that the Legal indicator was the most constrained in 2010 for Botswana and the 2016 assessment had it under Organisational, we can infer by this results that it could have possibly contributed towards pulling down the Organisational indicator. Further, in Botswana, Informational which is made of Technical Data and Metadata measured 0.235 by 2016 as opposed to the aggregated Technical Data and Metadata value of 2010 which is 0.4585.

In South Africa, going by the SDIOGI approach, metadata was the main constraint in 2010 study. Even when an average was taken between Metadata and Technical Data in 2010, it yielded 0.4165, but in 2016, the value in its aggregated form under informational is 0.7348. This could reveal the aspect of on-going improvement in those two components, e.g. over the period 2010 - 2016 South Africa developed its Metadata Electronic Catalogue (EMC). In overall, South Africa has seemingly maintained attractive indices over the same period.

A nagging question that can be asked these countries is: since 2010 can you elaborate how you have controlled development of your SDI? Answers to this question can be many, but they are likely going to be suppositions only. With the SDIOGI approach, the belief is that these countries would have gauged and controlled better their SDI development endeavours.

3.4.3.7 Step 7: New Constraints Frontiers back to Step 1 or 3

This step is a cyclic guide for the proposed method. For instance, if Botswana SDI which appeared in both Makanga and Smit (2010) and Mwange *et al* (2016) is considered, it is construed to be really constrained and needing a more focused approach based on SDIOGI. In 2010, Botswana could have identified the legal constraint for exploitation and solving, so as to elevate it. Then in the current times Botswana would be reconsidering its SDI on the basis of the new constraints it is facing. Going by results of both assessments, all constraints have not been well exploited between the two time periods in Botswana. South Africa on the other hand as per Mwange *et al* (2016), seems to have exploited metadata problem when compared to 2010. On the basis of the results of Mwange *et al* (2016) assessment, South Africa and Botswana could be making evaluation of their improvements or lack thereof and refocussing their attentions to new constraints so as to objectively reshape their SDI progressions.

3.4.3.8 Summing up the SDIOGI approach

The proposed methodology becomes more complex when it is related to the various SDI discourses discussed in Chapter 2. Of interest to this methodology are the SDI components and Hierarchies in a complex system (Grus, 2010). In complexity SDI consists of several constraints relating to their components and level of organisation. Through this method the constraints are simply referred to as a "Bundle of SDI Constraints." The Bundle of SDI Constraints are viewed and presented conceptually as figure 3.4. Each layer represents constraints associated with a given SDI component. The SDIs themselves as described by Rajabifard (2002) in their hierarchical structure are presented as underlying and foundation structures upon which these constraints need to be identified, exploited and utilised to support SDI development in a manner similar to what is described in the subsections above.

Figure 3.4: A bundle of SDI constraints

These constraints occur at all the levels of SDI and they are generally transited from one level of SDI to the other. Therefore, it is important to identify what they are, where they occur, their impact on SDI development and how to get rid of them or at least lower them for the sake of

SDI advancement. In a more elaborate format these constraints are represented through a hierarchical summary in figure 3.5.

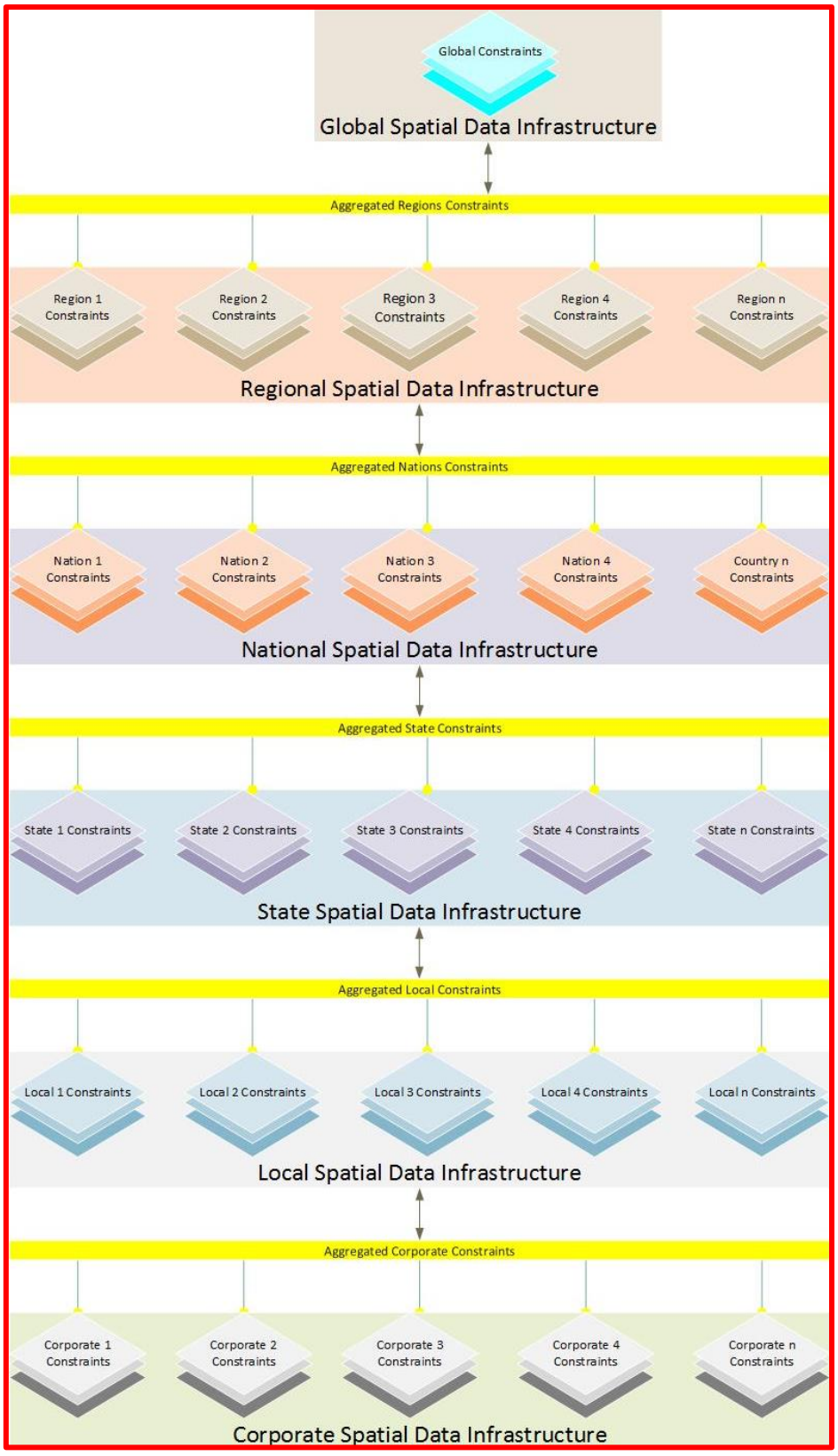

Figure 3.5: SDI Hierarchy Constraints Modelling

According to figure 3.5 SDI constraints need to be studied at all the levels starting with corporate, local, state, national, regional and Global. Therefore, all the constraints so far associated with SDI development in SACU countries can be presented within this framework. To do this, context of the jurisdictions is considered as fundamental, explaining why, Botswana, Lesotho, Namibia, South Africa and Kingdom of eSwatini are under study. The reasons for selecting these countries were the following;

- Influence by the results of Makanga and Smit (2010) coupled with that of Mwange *et al* (2016) as used in the promulgation of the SDIOGI. The results are varied and some of those countries clearly portray low indices in SDI State of Play and/or SDI Readiness.
- Convenience as a sampling approach because of these countries' proximity to the principal place of study (University of Cape Town),
- The need to abide by the stringent study timelines and keeping the cost affordable.
- These countries belong to an economic block known as the Southern African Customs Union (SACU) and the researcher has a motivation to articulate it as a platform towards a Regional SDI and this is done in Chapter 7 of this thesis.

3.5 Methodology Critique

The critique is done to demonstrate the versatility of TOC methodology in SDI discourses. SDI has been pronounced as ambiguous and complex (Grus, *et al* 2006; Grus, 2010). On the other hand, TOC often appears to be a linear approach in dealing with systems and infrastructures (Sanjika, 2010). TOC methodology has largely been used in manufacturing to focus and solve complex business problems – for example; Bethlehem Steel, Ford Electronics, Harris Semiconductor and General Motors since the early 1990s (Dettmer, 1998) – therefore, proposing it in SDI development and progression is a new thing. The use of this approach becomes particularly sensible where, SDI implementing jurisdiction is seeking to focus the SDI development and assessment processes with clear mandates of on-going improvement.

The TOC methodology has been known to be effective in focussing constraints in complex systems and exploiting them towards improvement. That is considered as fundamental for most jurisdictions, where SDI assessment methods are used for evaluation as results can be

structured in the TOC format to aid improvement. SDI reviews have been done in Africa by a number of scholars with conclusions acceding to slowness and disorganisation, with some pronouncements on interventions that can be used to solve the situations (Makanga & Smit 2010; Mwange *et al* 2016; Guigoz *et al* 2017). The methodology proposed here named SDI On-going Improvement (SDIOGI) approach, is adding another view towards systematically tackling the reported problems.

The results of the two SDI methodologies discussed have portrayed striking similarities and some resemblance to the concept of constraint satisfaction (Salido and Barber, 2004). The constraint satisfaction approach is utilised mainly in Artificial Intelligence (AI) to gauge feasibilities by calculating parameters for the constrainedness in search problems. The fundamental categories of the approach range from 'tightest' or over-constrained, to 'too loose' or under-constrained scenarios in AI (Salido and Barber, 2004). The parameter values range from 0 to 1 and can best be shown by figure 3.6 where on the left side the searches constraints are non-ordered and on the right side they are ordered.

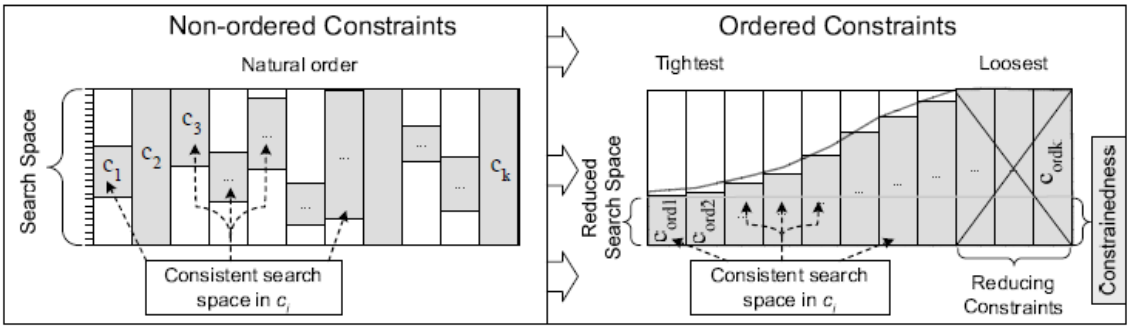

Figure 3.6: From non-ordered constraints to ordered constraints: Constrainedness (Source: Salido and Barber, 2004)

This constraint satisfaction methodology technically resembles the proposed TOC approach. Non-ordered constraints can be related to determining state and/ or readiness of the SDI indicators without a preferred approach to their improvement and ordered constraints is the SDIOGI approach as proposed. The ordered constraints quantitatively resemble indices of the constraints as computed out for State of play and Readiness Index when used to select SDI components to improve based on the status of their constraint status. The redundant constraints

get identified and get eliminated in the AI search problems while in TOC they are subordinated to the over-constrained problems/Indicators.

3.6 Conclusions

This chapter has effectively done two main things; (a) articulated a constrained oriented approach in SDI On-Going Improvement (SDIOGI) and (b) utilised results of Makanga and Smit (2010), and that of Mwange *et al* 2016 to demonstrate how the SDIOGI methodology, could be used in the operational development of SDI. It has been shown that methods such as the SDI State of Play approaches, are useful in collecting stakeholder perspective views data that, are statistically manipulatable to yield indices useful in ordering SDI constraints and their solutions to support the advancement of SDI in a jurisdiction. A statistical procedure (table 3.6 to 3.9) is suggested as a guide in selection of constraints at different levels so that they can be improved to aid SDI development. Another method being the SDI Readiness method is used to demonstrate the last two steps of the SDIOGI in order to inform the usefulness of SDI assessment mechanism in this cyclic methodology.

To further explore and deplore TOC in SDI, it is posited that a comprehensive understanding to SDI constraints can only be well understood through undertaking context-based studies of the nations of interest. In addressing this requirement, the next chapter is going to dwell on articulating an overarching data collection methodology for context-based study of SDIs and their constraints within the SACU member countries as the next phase of the research strategy articulated in Section 3.2.

Chapter 4 : SACU Countries' SDIs Study Methodology

4.1 Introduction

Chapter 3 has largely advanced the constraint-oriented approach with the help of existing SDI assessment results in the formulation of the method. Data from previous studies, being quantitative perceptions to SDI status (Makanga and Smit, 2010) and Readiness Index (Mwange *et al*, 2016) in the SACU countries were utilised with the objectivity of proposing SDI constraint-oriented approach named SDI On-Going Improvement (SDIOGI). At the conclusion of Chapter 3, a case was made which points towards studying SDI constraints in country context. To understand these constraints, it was opined that an in-depth SDI studies within the context the SACU countries being; Botswana, Lesotho, Namibia, South Africa and Kingdom of eSwatini had to be undertaken. In this chapter, the study data collection, discussion and analysis approaches are articulated and applied to each individual country. This is a study methodology which is going to use documents, questionnaires, websites, interviews and workshops as instruments of research so as to construct a picture of the SDI discourse of the involved countries. The methodology being applied is highly qualitative following case study methods and in SDI discourse it has been utilised by Grus et al (2008) and Okuku *et al* (2014). Grus *et al* (2008) focussed on application of the Multiview SDI assessment in a number of American and European countries while Okoku *et al* (2014) concentrated on the assessment of Kenya SDI. The following sections are going to elaborate this as the over-arching methodology of the current study. The results, discussion and analysis based on this methodology will be covered in Chapter 5 and 6.

4.2 The Case Study Approach

The case study methodology is very vital in context-based research (Eisenhardt, 1989; Yin1994; Yin 1999; Paré, 2004). According to Yin (1999), case study approach facilitates the research to straddle over several variables in a given context with ease and depth. In addition, a case study approach allows for qualitative and quantitative lines of inquiry as discussed in Chapter 2.2, to be readily mixed in order to give more rigour to a study (Yin 1999; Paré, 2004). Case study research has been heavily utilised in information systems researches (Paré, 2004; Benbasat *et al*, 1987; Orlikowski and Baroudi, 1991; Alavi and Carlson, 1992; Markus, 1997; Klein and Myers, 1999). Paré (2004) has gone further to emphasize that case study approach has utility in studying; (a) *broad and complex phenomenon* (b) *a phenomenon with insufficient*

body of knowledge to help understand its causal factors (c) *a phenomenon holistically and in greater depth* and (d) *a phenomenon within its context as the only option available to understand it better*.

From the above paragraph all points have relevance to SDI. SDI is an infrastructure formed from information systems which emphasise the presence of geospatial data. Therefore, all the points alluded to Paré (2004) are associable with SDI discourses for instance; complexity (Comprovoets *et al*, 2006; Grus *et al*, 2008; Grus, 2010), insufficient body of knowledge (Guigoz *et al*, 2017), holistic and depth approach in the context of a given country (Rajabifard, 2002; Guigoz *et al*, 2017). The case study method is followed to understand the SDI context within the five SACU jurisdictions. National SDIs (NSDIs) were used as points of entry through coordinating agencies, organisations or committees depending on what was prevailing within the country. Research questions, documents, questionnaire, interviews, websites and workshops were used as the main instruments to study the cases. The utility of these instruments in facilitating a case study is given in table 4.1 with summaries of their strength and weaknesses in guiding the data collection process (Paré, 2004).

Table 4.1: Sources of Evidence in Case Research: Strengths and Weaknesses. (Source: Paré, 2004, pp. 245)

SOURCE OF EVIDENCE	**STRENGTHS**	**WEAKNESSES**
Documentation	• Stable–can be reviewed repeatedly Unobtrusive-not created as a result of the case study. • Exact-contains exact names, references, and details of an event. • Broad coverage-long span of time, many events, and many settings	• Retrievability-can be low Biased selectivity, if collection is incomplete. • Reporting bias-reflects (unknown) bias of author. • Access-may be deliberately blocked
Archival records	[same as above for documentation] precise and quantitative	[same as above for documentation]. Accessibility due to privacy concerns
Interviews	Targeted-focuses directly on case study topic Insightful-provides perceived causal inferences	• Bias due to poorly constructed questions • Response bias • Inaccuracies due to poor recall • Reflexivity-interviewee gives what interviewer wants to hear
Direct observations	• Reality-covers events in real time • Contextual-covers context of event	• Time consuming • Selectivity-unless broad coverage • Reflexivity-event may proceed differently because it is being observed
Participant observation	[same as above for direct observations] insightful into interpersonal behaviour and motives	[same as above for direct observations] bias due to investigator's manipulation of events
Physical artefacts	insightful into cultural features insightful into technical operations	• selectivity • availability

A number of these evidence sources are utilised in concert so as to acquire enough data to validate important facts of the study. SDI as an information infrastructure having geospatial data as a central theme, can be described as pervasive and it is realised that other sources of data such as understanding the status of the telecommunication networks and their capacity would be important (Hanseth and Monteiro, 1998). Pursuing this line of data would have only widen the scope of the current research, thence it is regarded to be beyond the current study. In addition, the data source used were to allow for exploration of the prevailing scenarios to lead to the answers of the identified problem. The sources for data collection as utilised in this study are described in the following subsections.

4.2.1 Research questions

According to McDougall, Rajabifard and Williamson (2007), the case study methodologies are fundamental in answering the 'why' and 'how' questions. In terms of the conceptualisation of this study, the fundamental questions were seeking to understand why the SACU SDIs have been slow and how the pace of their advancement could be improved or made faster into the future. A constraint methodological approach has been suggested in Chapter 3 following the results of Makanga and Smit (2010) interfaced with those of Mwange et al (2016). The results in these studies confirmed SDI implementation across the African continent to be slow and at times disorganised. Deriving from the extensive quantitative processing of Makanga and Smit (2010) results to produce some indices, it was concluded that SDI inherent constraints are responsible for slow development of SDI in Africa. It was then suggested that, a seven-step on-going-improvement, based on a methodical approach of TOC be used to scope and strategize SDI development in the SACU countries.

The why and how questions relating to the slow development of the SACU countries SDIs were posed. For SDIOGI to work, an organisation operational structure similar to that by Kruger (2012) is considered to frame 'why' and 'how' questions in clearer perspectives. This structure is considered, adapted and presented as Figure 4.1. Focussing on SACU countries in the context of figure 4.1 the following study questions were asked:

1. Why are SDI inputs not yielding requisite SDI results?
2. Why is the transformation process of SDI not yielding favourable SDI statuses and readiness for the SACU countries?

3. Why are the outputs of SDI not satisfactory?
4. How can the SDI development be improved?
5. How can the whole life cycle of SDI be controlled to ensure continuous improvement?

Hypothetically questions 1 – 3 are answered with the word "constraints". This means that the various SDI development structures have weak links, therefore, are constraining the whole infrastructure progression. TOC is used for answering the 'how' questions through the SDI On-Going-Improvement (SDIOGI) methodology suggested in Chapter 3.

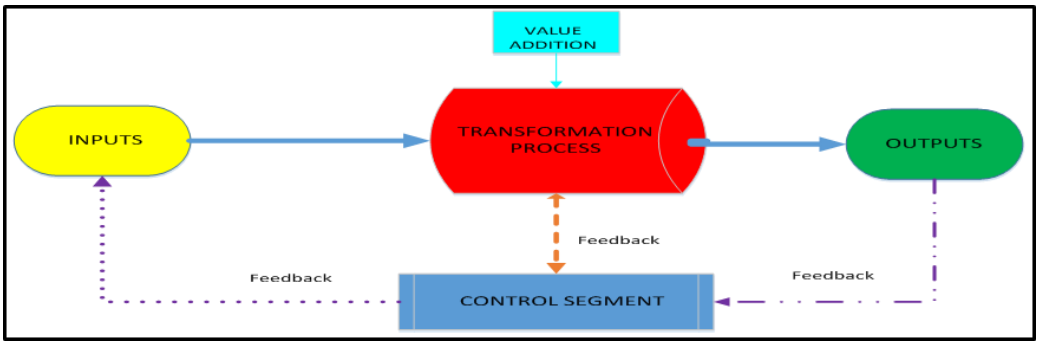

Figure 4.1: Operations Transformation Model (Adapted from Kruger, 2012)

This process is used to study and differentiate between the transforming and transformed inputs, (Kruger, 2012). For transformation to occur gradually, inhibitive agents need to be identified and eliminated. Kruger (2012) emphasize the importance for all the inputs to be included in the transformation processes in order to reap maximum results in the outputs. Research questions raised here points towards understanding that constraints inherent in SDI system are sources for it failing to produce the desired outputs. Questions asked here are instrumental in guiding what needs to be detected when reading documents relating to SDIs development. These questions were also important in formulating the questionnaire summarised in subsection 4.2.4 which is attached to the thesis write-up as Appendix 4.

4.2.2 Documents.

Documents are fundamental in a qualitative research setup (Bowen, 2009; Corbin and Strauss, 2008; Rapley, 2007). According to Bowen (2009), documents are vital in a research process because they do not bear any influence from the researcher and they can be used to generate ideas, questions and shape the general direction of a study. Bowen (2009) further outlines their

advantages as; efficiency, availability, cost-effectiveness, stability, exactness, wider coverage capability and independence. On the other hand, there are a number of disadvantages that can be associated with them. Documents as a matter of fact are there to be selected and care had to be exercised in this study to avoid biased selection. Where details were insufficient in a document, more documents were searched and other methods of research used to fill gaps in missing data. The strength of documents is further realised in that, they exist as a very good evidence of what nations, organisations or regional groupings harbours in their social systems and economic aspirations in regard to development of information infrastructures such as SDIs.

Documents do have categories and according to O'Leary (2014) they fall into three main different types being; (a) public records (b) personal documents and (c) physical evidence. The public records in this study consisted of countries' laws, policies, feasibility studies, implementation and evaluation reports related to SDI. Physical evidence refers to the various artefacts which are associated with a particular topic of discourse (Bowen 2009; O'Leary (2014). According Bowen (2009) and O'Leary (2014) things such as adverts, flyers, training packages, photos and any other evidential material which can be associated with the phenomenon under investigation constitute these types of documents. A well-orchestrated effort was made in selecting and using many documents by; evaluating their originators, year of origin, their content on SDI, confirmation of validity with originators, evaluating the actual implementation of document core and assessment of their associated achievements and challenges. These efforts will be elaborated in the data chapters (Chapter 5, 6 and 7).

The following documents have been interrogated and analysed in the study:

- ***SACU countries SDI scholarly articles***; to capture the focus of discourse on SDI development in each SACU country and align them with the proceedings of this study.
- ***Country laws and policies***; the presence or lack of them has been considered to understand their usefulness in shaping SDI advancement. To understand their level of sufficiency in addressing SDI development and progression. A typical example in this case is the South African Spatial Data Infrastructure Act of 2003.
- ***SDI feasibility studies***; to understand the approaches which were used to advance cases for SDI development in the economies of the case study countries and regions.

Feasibility studies are used to see whether SDI implementation was intuitive or structured. Further to expose and understand how the performance or lack of feasibility might have affected the proceedings in SDI implementation.

- ***Country SDI technical reports***: they are viewed as important in persuading the existing account of what has been done in the country regarding SDI concept implementation. The reports are important in exhibiting the achievements and challenges of countries in the SDI journey. They are also useful in forecasting future SDI development plans and ideas.

The fundamental importance of documents in a study such as this one is summed by the words of Bowen (2009) which says "*documents may be the most effective means of gathering data when events can no longer be observed or when informants have forgotten the details*". These words by Bowen (2009) are read and regarded as a qualification of the documentation utilised to support this study.

Documents used in this study were first collated into a table format. Their relevance and usefulness as data is succinctly revealed through attributes; document title, creator, theme, publisher, source, typology, pages and year as displayed in table 4.2. Documents obtained were reviewed for usefulness in the study. Usefulness was dictated by the content of the document in articulating wishes, plans, implementations, achievements and challenges of the country SDI. The code in this table is associated with the ISO codes of countries found at https://countrycode.org/ which are; Botswana (BW), Lesotho (LS), Namibia (NA), South Africa (ZA) and Kingdom of eSwatini (SZ). The letter 'D' in the code stand for document e.g. BWD1 = Botswana Document 1. The documents are numbered sequentially as they are compiled into the table. The coding is meant to aid ease of referencing in discussion and analysis of the documents and the contents thereon.

Table 4.2: Country SDI documents tabulation with attributes report template

Country SDI Related Documemnts								
Code	Document Title	Creator	Subject	Publisher	Source	Typology	Pages	Year
BWD1								
BWD2								

4.2.3 Websites

The Internet and World Wide Web have become fundamental resources for searching data of all sorts. Their platforms such as websites and/or geoportals are themselves primary sources of data especially where they are developed to meet a certain purpose such as SDIs. Data searches on websites proceeded along two main lines being SDIs website evaluation and document retrieval which were in turn analysed to reveal key variables of the research. In case of evaluation, several SDI related websites/geoportals of the countries under study were searched and evaluated on the basis of their owners, structure and the information portrayal for SDI format. The searches were conducted using two main key phrases being "Country Name + Spatial Data Infrastructures" and "Country name + Geoportals" e.g. "Botswana Spatial Data Infrastructure" and/or "Botswana Geoportals". Other phrases used in carrying internet searches included "Country name + spatial observatories", "country name + geospatial + metadata" e.g. Namibia Metadata. The discovered internet sites and geoportals were used as important platforms for data discovery to reveal how far SDI implementation has advanced in a given case study jurisdiction. A good example of studying websites for purposes of gauging the status of SDI development has been done by Crompvoets (2004). The Crompvoets (2004) line of study was longitudinal in nature, running over a period of about 3 years. In case of this study, a number of websites associated with spatial data were studied and analysed to appreciate their level of development in terms of:

- The data sets they contain
- The use of standards such as International Standards Organisation Technical Committee 211 (ISO/TC211)
- The geospatial metadata and its functionality in supporting data discoveries
- The accessibility of the geoportals and ability to geospatial data retrieval
- The role the country SDI websites and geoportals will play in its future SDI progressions.
- Understand constraining factors that are readily associable to the countries' SDI websites and geoportals.

Attributes such as document title, creator, theme, publisher, source, capabilities, pages and year were used as important attributes as shown in table 4.3. BW as alluded to earlier is the ISO code for the country and the second letter 'W' stand for Website e.g. BWW1 = Botswana Website 1. Websites discovered are described, their functionality discussed and their short

coming articulated in relation to the SDI discourse of the countries as it will be seen in chapter 5 and 6.

Table 4.3: Country SDI Related Website/Geoportals report template

Country SDI Related SDI Related Websites/Geoportals						
Code	Website/Geoportal	Owner	Subject	Data and information capabilities	Capabilities	Year
BWW1						
BWW2						

4.2.4 Questionnaire

Documents and websites as described in the previous two subsections were extensively consulted as empirical materials on SDIs of the case study countries. Context-focused questions were formulated into a research instrument here being described as a 'Questionnaire'. Questionnaires are primary instruments of both quantitative and qualitative lines of inquiry. There are two dominant sets of questionnaires being structured (Likert type) and open-ended ones. Structured questionnaires are used with quantitative research while open-ended ones are used in qualitative studies. In case of mixed-method the two types of questionnaires are integrated.

An open-ended questionnaire was designed for the purpose of understanding SDI implementations in the context of the SACU countries. These was done in recognition of the reviewed literature in chapter 2 and SDIOGI method which was set out in chapter 3 following the quantitative results of Makanga and Smit (2010) and of Mwange et al (2016). The designed questionnaire focused on understanding the following perspectives:

- SDI Origin and its current standing to give insight about the years when the concept was considered in a country and what has been achieved to date.
- Organisational outlook to identify the main players and their interaction towards fostering SDI development in a country.
- Constraints as perceived by those bestowed with the responsibility of SDI development.
- Inputs/Outputs of SDIs and the role they play in its development.
- Benefits/opportunities of SDI as factors that can act as direct justification for its development.

- SDI control processes which seek to understand how its performance and revision is measured in a given country.
- SDI Research and development to understand whether the country does have a concerted effort in directing studies to foster success.
- Specific movements and interest towards SACU SDI as a way to promoting regional activities of spatial data to support environmental and socio-economic interests. Bearing in mind the work of INSPIRE in Europe, SACU as an economic block can consider the development of SDI for environmental protection, promoting its trade processes and integrating any other areas of common interest.

A copy of the actual questionnaire based on the above points is attached to this thesis as Appendix 4. This questionnaire was circulated to the principal informants being country SDI Coordinators through the use of email. Out of the five SACU countries, four responded being Botswana, Lesotho, Namibia and South Africa. The responses to the questionnaire as answered by the individual SACU countries are reported in Chapter 5 and 6. Kingdom of eSwatini did not respond to the emails all together, making it difficult to visit the country for further research.

The answers are recorded in table 4.4 which has been designed for collating the responses of the countries. The responses after being populated in the table are discussed and analysed to detect the discourse of the countries' SDI in terms of the key phrases on the table.

Table 4.4: Questionnaire response template

No.	Question key phrase	Response
1	SDI time origins	
2	SDI Main Players	
3	Recent SDI status	
4	Country SDI interactions	
5	SDI Constraints	
6	SDI Benchmarking within SACU	
7	Further elaboration to 6	
8	SDI inputs	
9	SDI outputs considerations	
10	Country SDI benefits and opportunities	
11	Country SDI coordination and feedback	
12	Country SDI plan	
13	Country views on SDI research	
14	Country views on SACU SDI	
15	Participation in current research	

4.2.5 Workshops

Workshops are eminent in informing development strategies (Hodgkinson *et al*, 2006). Development, implementation and maintenance of systems such as SDIs are usually subject to workshops. It was considered important from the onset of data collection to either conduct or participate in workshops in the jurisdictions under study. The advantage associated with conducting and/or participating in workshops in this study is that they provided a platform for those involved with their country SDIs to share ideas, discuss and critique their SDI development processes and implementation. The workshops where participation was possible were those instituted and conducted by countries themselves. As the researcher, I joined these workshops as a participant. The duration of participation in these workshops ranged from a day up to a week. Participant observation is largely used in sociology, geography and anthropology, to generally describe incidents and perceivable contexts (Jackson, 1983). Therefore, these workshops were attended in order to describe them in terms of purpose and content within subject of SDI. Purpose is considered in terms of SDI capacity building while content forms the basis of active country discussions on status of SDI development, important themes, indicators and constraints.

Initial entry to access countries for workshops was done through email and phone communications with respective countries' SDI Coordinators. After entry was secured into the case study countries, possibilities of workshops were discussed with SDI coordinators. In all the countries, it was not possible to call workshops or informants groupings for the purpose of focussed SDI discussions owing to prospective officers' busy schedules. But countries were willing for an arrangement where, as the researcher I join and participate in their existing scheduled workshops and conferences.

Out of the five countries, Namibia and South Africa gave me the opportunity to participate in their SDI workshops as per their 2017 schedule of activities. As such, SDI workshops were attended in both South Africa and Namibia in 2017. Three workshops were attended in South Africa and one in Namibia. In both Namibia and South African, workshops' key SDI topics were covered and the opportunity of interviewing officers during break times was realised. Two of the workshops in South Africa were attended during the Geomatics Indaba conferences

of 2016 and 2017. The attended Geomatics Indaba conferences also provided opportunities for interaction with several South African Geomatics Industry practitioners.

South Africa and Namibia were quite liberal with attendance of their SDI workshops, but it was not possible to attend all of them due to time and finance constraints. Despite the attendance limitations of some of the workshop activities, the country SDI Coordinators shared the presentations and other documented materials with me. Also, most of the workshops were repeat presentations of concepts, especially in South Africa where same workshops are conducted across the country according to provinces.

Workshops are considered useful as interactive medium of data collection because they expose participants to the broad ideas of SDI implementation in a country. In workshops, a lot of ideas are exchanged regarding strategies and plans towards SDI implementation. In this study, they were regarded as yielding first-hand data on status of SDI generic principles, capacity building, stakeholder interactions and marketing in the case study countries.

- **Generic principles**: are realised through the discussions and participation of SDI stakeholders in shaping the country SDI discourse in terms of its purpose, components, content, coordination and gaps identification.
- ***Capacity buildi***ng: is realised through sharing the ideas regarding SDI concept, function, inception, starting and guiding implementations.
- ***Stakeholder interactions***: Through workshops SDI stakeholder partnerships are established and roles defined e.g. work group for metadata standards.
- ***Marketing***: workshops play vital role in issues of awareness and realisations of the mandates, responsibilities, participations and benefits of the SDI stakeholder communities.

The workshops are going to be reported in a tabular format where by code, presentation title, presenter, theme, source, number of pages and year of presentation forms the main attributes as shown in table 4.5. The code here refers to the country code followed by 'W' for workshop and is to be used for easy of referencing the presentations e.g. ZAWP means 'South Africa Workshop". The tabular structure is depicted below.

Table 4.5: Attended workshop report template

Coubtry Related SDI Workshop						
Code	Presentation Title	Presenter	Theme	Source	Pages	Year
ZAWP1						
ZAWP2						

The presentation title and theme are important in that they signify the content of what the workshop is about. The presenter and source refer to the originator organisation, for example it could be presentation by National Mapping Agency of a given country on a topic of standards. The pages are indicatory of the amount of information contained, while the year signify the currency in the presentation, e.g. a 2017 presentation on SDI Legal Framework.

4.2.6 Interviews

Interviews were carried out in the visited countries of Botswana, Lesotho, Namibia and South Africa across a number of organisations involved with SDI development. For instance, in South Africa interviews were conducted with Department of Rural Development and Land Reform, South Africa Statistical Agency, Western Cape Government GIS Department, Gauteng Province GIS Department. In Botswana; interviews were conducted with Department of Surveys and Mapping; Department of Town and Country Planning; Department of Water Affairs and Sanitation; Ministry of Land Management, Water and Sanitation Project Unit named Land Administration Procedures Capacity and Systems (LAPCAS); Botswana Water Utilities Corporation and Botswana Power Corporation. In Lesotho; Interviews were conducted with Land Administration Authority; Lesotho Bureau of Statistics, Maseru City Council, Lesotho Land Commission, Ministry of Agriculture and the Department of Environmental Affairs. In Namibia, the main respondents were the National Statistics Agency through the SDI Coordinator office and Department of Surveys and Mapping being the Chair of the Spatial Data Committee. Other interviewed agencies included the Geoscience Department and Ministry of Environment and Tourism and Nam Power.

The interviewees were generally allowed to narrate SDIs experiences in their own countries and notes were taken. Questions were unstructured but focussed on the key principles associated with the study e.g. SDI development and bottlenecks. Those who responded could be described as; Country SDI Coordinator, Stakeholder Organisations Representatives, SDI Committee Member or individuals within organisations who once participated in SDI activities

in their country. SDI coordinator organisations are those tasked with the primary responsibility of SDI e.g. The Directorate of National Spatial Information Framework in South Africa, The National Statistics Agency in Namibia and Department of Surveys and Mapping in Botswana. The stakeholder organisations members, are those who identify with SDI development in their area of work. SDI activities in some of these countries were no longer organisationally visible hence the idea of *"individuals within organisations who once participated in SDI activities."* For instance, in Lesotho, the Land Administration Authority (LAA) was identified for this function and through collaboration it guided the researcher to other resourceful organisations in relation to SDI efforts. An interesting experience which occurred during the interviews, is that some of the prospective respondents would refer me back to the SDI Coordinating Organisation. This was usually countered with the request for respondents to just give their views, as their opinions might be useful to their countries' SDI implementations. After the request, most obliged to participate in the interviews.

4.2.7 Sampling

Studies following a qualitative form of inquiry utilise purposive, theoretical, snowball and convenience sampling methods (Paré, 2004; Petty, Thomson and Stewa 2012). A combination of these sampling methods as listed in table 4.6 have been utilised in this study.

Table 4.6: Utilised sampling approaches descriptions. (Following Paré, 2004 and Petty et al, 2012)

Sampling approach	**Description**
Maximum variation	Documents diverse variations and identifies important common patterns (Paré, 2004).
Theoretical	Sample selected on basis of analytical insights and developing theory (Petty et al, 2012)
Snowball or chain	Identifies cases of interest from people who know people who know what cases are information-rich.
Purposeful	This is where information-rich cases are selected strategically and purposefully; the selected cases are usually determined with the help of study purpose and availability of the resources (Paré, 2004).
Convenience	Sample selected according to ease and convenience (Petty et al, 2012). This sampling approach is opportunistic and it allows leads to be followed as they emerge during the data collection stage. It is flexible in nature and takes advantage of prevailing conditions which can support study progression.

Theoretical sampling was based on an analysis done in Chapter 3 to support suggestions of SDI On-Going Improvement (SDIOGI) approach. From Chapter 3, the Southern African Customs Union (SACU) countries were selected based on the low SDI results, their status as a regional economic block and ease of access for study purposes. The ease of access as criteria to selection of these SACU countries, is at best, convenience sampling. Studying the SDI of these

five countries was considered achievable within the study time, as they are easy to access due to their neighbourliness and liberal visa restrictions to me as the researcher. Theoretical and convenience sampling approaches were used preliminarily, but for the rest of the data collection process, purposive and maximum variation sampling were used. Purposive sampling approach was used because of its robustness in line with what Petty, Thomson and Stewa (2012, p. 380) has opined in that samples are "*selected according to relevance to study*". For instance; websites, entry into countries, targeting SDI implementing organisations or committees were all purposefully carried out. To start the data collection, email and telephone were used to communicate with the identified informants across the jurisdictions. Four countries out of five replied to emails sent and express their willingness to participate in the study. This represented 80% of the envisaged sample.

Workshops were envisaged as another form of data collection, meaning that participants had to be organised for the purpose. This particular instrument ended up benefitting from convenience in that some countries which partook in this study were already having established workshop diaries (e.g. Namibia and South Africa). The researcher found it convenient to follow the activities of the countries by attending their workshops. This was a "win-win" approach as data was collected without making the countries to leave their diarised activities for the sake of this study. Therefore, workshops were attended where countries did their own selection of the participants from their SDI stakeholder organisations. The researcher attended these country-driven workshops following the convenience sampling approach and managed to collect study data through workshop presentations, discussions and interviews.

4.2.8 The data Collection Process

Data collection process was framed to address the context focussing on the five SACU countries. Data collection involved; the SDI organisations, committees or bodies responsible as the units of discourse. SDI documents are then identified and collated to inform a preliminary outlook on the SDI discourses of the country. The documents are collated so as to show year of inception, originator, publisher and its typology among others. A similar approach is also adopted for collating websites/geoportals that are associated with the SDI of a given country. Attended workshops are also collated into a formidable evidence that points

towards SDI capacity building processes. In all the countries, the National Spatial Data Infrastructure (NSDI) are used as the unit of data collection for the study.

Data was extensively collected from Botswana, Lesotho, Namibia and South Africa. In Swaziland now called Kingdom of eSwatini, there was no reply despite emails being sent to the office of the Surveyor General which according to literature was linked with the country's SDI activities. Further attempts were made to call the Kingdom of eSwatini Surveyor General, but this was also unsuccessful. For this reason, it should be understood that the questionnaire part of the results will not include Kingdom of eSwatini. The failure to access Kingdom eSwatini SDI coordinators, is also acknowledged as a limitation in terms of interviews, access to that country's unpublished documents and records. Lack of collection of such data from Kingdom of eSwatini has created gaps in the discussions and analysis, specifically where countries' SDI approaches are discussed and compared for possible benchmarking among SACU members. Despite lack of access to Kingdom of eSwatini, any SDI materials about it found through the internet searches was discussed and analysed in support of this study. This include data about SACU as a region, where the five countries' data relating to the SACU mandate are found on its website www.sacu.int and its Secretariat office which was visited in Windhoek during data collection, and organised for advancing Regional SACU SDI concept.

4.2.9 Research Ethics

The first thing towards ethical research was to complete the University of Cape Town Research Ethics Form and getting requisite approval. The approved Ethics Form is attached to this thesis as Appendix 2. The approved research Ethics Form, along the Informed Consent Form (Appendix 3), were availed to research informants in the process of requesting for their participation in research. These two forms were important instruments to get access to research countries and SDI stakeholder institutions. Entry points into research countries was purposefully done through organisations which are primarily dealing with SDI implementations. In other cases, there were no distinctive organisations driving SDI and literature was used to trace some organisation which are connected to SDI in a given country. These forms were then sent through emails to officials who were discovered to be responsible for the SDI activities of their respective countries. The study was executed in keeping with the approved requirements of the ethical conduct as approved by University of Cape Town. The

main theme in the ethical conduct of this research is to aggregate the results and minimise exposure of informants.

4.2.10 Problems Experienced

The main problem encountered in this research is that of informants taking long to respond to email communications and research questionnaires. Email communications were considered to be the cheapest mode of interacting with informants. Though some informants did respond to research questions through email, some only responded after a physical visit was made. One country, Kingdom of eSwatini did not respond to communications at all. Other problems encountered, included unavailability of websites which were purported to be for NSDIs e.g. the Botswana website http://www.ngis.gov.bw/ as reported in Maphale and Phalaagae (2012) is no longer available. Unavailability here means that, the websites are no longer in existence altogether. The other thing was the wide geographical stretch of the locations associated with study data collection; Cape Town, Gaborone, Maseru, Pretoria and Windhoek. Travel between the relevant country centres was both expensive, time consuming, and limiting.

4.3 Data Triangulation

The intention of deploying the above research instruments is to be able to achieve data triangulation. According to Paré (2004, p. 248) "*triangulation is generally considered a process of using multiple perceptions to clarify meaning, verifying the repeatability of an observation or interpretation*". The Emphasis of triangulation are in ensuring that data is collected such that it gives study credibility and rigour (Paton, 1999). There are four fundamental strategies to data triangulation, being; *(a) method triangulation, (b) investigator triangulation, (c) theory triangulation, and (d) data source triangulation*, (Denzin, 1978; Paton, 1999; Carter *et al*, 2014).

According to Paton (1999), *method triangulation* is about collecting data using several methods and checking for consistency in results for given constructs of the study. In case of this the study, instruments articulated in this chapter being; documents, questionnaire, interviews, websites and workshops are meant to detect for similarities and convergence on similar concepts in order to establish credibility and rigour. As an example, constraints specifications are detected from the listed documents and associated with those from the websites, workshops and questionnaire in a given country SDI case study. The convergence in constructs are further

subjected to comparison between countries, so as to suggest foundational approaches for inter-country SDI benchmarking and regional development experimentation.

Investigator triangulation is whereby several investigators carry out simultaneous data collection and analysis on the same concepts and sample (Paton, 1999). Though it could not be implemented directly in the study, the strategy has been to sample similar kinds of studies and note what has been found in the past by other investigators (Makanga and Smit, 2010; Mwange *et al*, 2017; Guigoz *et al*, 2017) and then compare with the current status of SDI discourse in the study case countries. Specific components from the previous studies focussing in the countries, had sought to understand the perceptions relating to SDI in terms of organisational, Finance, Technical Data, Metadata, Human and Legal Framework.

In terms of *theory triangulation*, a number of theories have been followed e.g. the SDI State of Play (Makanga and Smit, 2010) and SDI Readiness Index (Mwange *et al*, 2016) which were found to be quite similar in character in terms of the SDI indicators that the two methods used. The finding gave me confidence to use these indicator components in this study and note their influence on SDI development in a country, e.g. the SDI Legal Framework. These concepts were interfaced with the Theory of Constraints as discussed in Chapter 3, when making a proposition for SDI On-Going Improvement (SDIOGI). In Chapter 7, the components of these SDI assessments are compared with the data emanating from this study and Due Diligence components to enhance the SDIOGI and construct it into a framework based on SDI hierarchies.

Data source triangulation is defined as testing for data consistency from a similar source (Paton, 1999). This aspect was very relevant with the SDI Coordinators as the primary informants to this study. They answered the study questionnaire and participated in interviews. In case of South Africa and Namibia, the SDI coordinators participated in workshops as presenters and discussants. In these workshops, they fielded questions from various SDI interest groups and their answers were recorded for comparison with interviews and the questionnaire responses e.g. the South African Spatial Data Infrastructure (SASDI) Coordinator exhibited consistency regarding progress made. At a SASDI workshop attended in Durban on 22nd August 2017, when fielding a question regarding progress, the Coordinator acknowledged that the development of SASDI was still not comprehensive, by giving lack of

specified mission/vision and a sound strategic plan as examples. This stand point has been repeated in the response to the study questionnaire, as will appear in the results in Chapter 6.

4.4 Conclusion

This chapter has elucidated the data-collection, discussion and analysis approaches of the study. The case study methodology and its associated methods have been explained, to show how they were utilised to extract responses and results which are suitable to answering the study questions and addressing the aims and objectives. The questionnaire had been used to solicit the current views of the SDI Coordinators in the case study countries. The documents, artefacts, workshops and websites were used to extract and express SDI indicator categories of case study countries SDIs e.g. a workshop on spatial data governance in the case of South Africa.

Preliminarily, the results have returned a number of documents for the SACU countries SDIs. Legislative Frameworks could not be found in Botswana and Lesotho. With Kingdom of eSwatini, any evidence relating to SDI Legal Framework was searched in its published on-line Acts and none related to SDI were discovered. Namibia and South Africa on the other hand possess legislative frameworks on SDI. The possession status of the legal framework offered a striking comparison between the countries and is used to formulate Chapter 5 and 6. The possession of the Legal Framework had been found to be critical, so the data reporting and its analysis is divided into Chapter 5 and 6 as SACU countries with and without legal framework respectively.

The responses and results are subjected to discussion and analysis mindful of the constraint indicators articulated in Chapter 3 relating to SDI On-Going Improvement (SDIOGI). These indicators include organisational, Funding, Legal, Technical Data, Metadata, Technology and Human. The analysis also pays attention to contextual constraints indicators as they emerge from the documents, workshops, websites/geoportals, questionnaire and interviews in the case study countries.

Chapter 5 : SACU Countries without SDI Legal Framework

5.1 Introduction

In undertaking the study of the SDIs for the five Southern African Customs Union (SACU) countries being Botswana, Lesotho, Namibia, South Africa and Kingdom of eSwatini an important finding was made that some countries have established legal frameworks and others were still without them. Botswana, Lesotho and Kingdom of eSwatini do not have SDI legal frameworks at all and their results, with associated discussions form the basis of this chapter. Based on the approach promulgated on Chapter 4, the various research instruments such as documents, questionnaires, interviews and websites were utilised to find out how the countries without SDI Legal Framework have proceeded with its implementation and how they can pursue on-going improvement programs. Each case study was kick-started by investigating existing peer reviewed literature relating to SDI discourses in the country. The results and responses in respect of the research instruments are presented and therefore discussed and analysed taking into consideration the implementation processes and the limitations and what is currently being done to facilitate continued SDI development.

5.2 Botswana SDI Case

Botswana obtained independence from the United Kingdom in 1966, has since had an impressive Social, political and economic story (Acemoglu, Johnson and Robinson, 2001). Botswana covers about 586,000 km^2 (Malatsi and Finnström 2013), a population of just over 2 million inhabitants, with only Gaborone as a settlement centre having a population of over 100,000 in the 2011 national housing and population census (Statistics Botswana, 2014). The governance structure in Botswana is organised as central government through ministries and local government across districts. There are 10 districts in Botswana namely; Kweneng, Kgatleng, South East, Central, Ngamiland, Chobe, North East, Southern District, Kgalagadi and Ghanzi. Botswana land management is subject to three tenurial system made of freehold, state land and tribal land. Freehold is 4% and state land accounts for 25% while tribal land is 71% of total Botswana Land surface (Mothibi, Malatsi & Finnström, 2008).

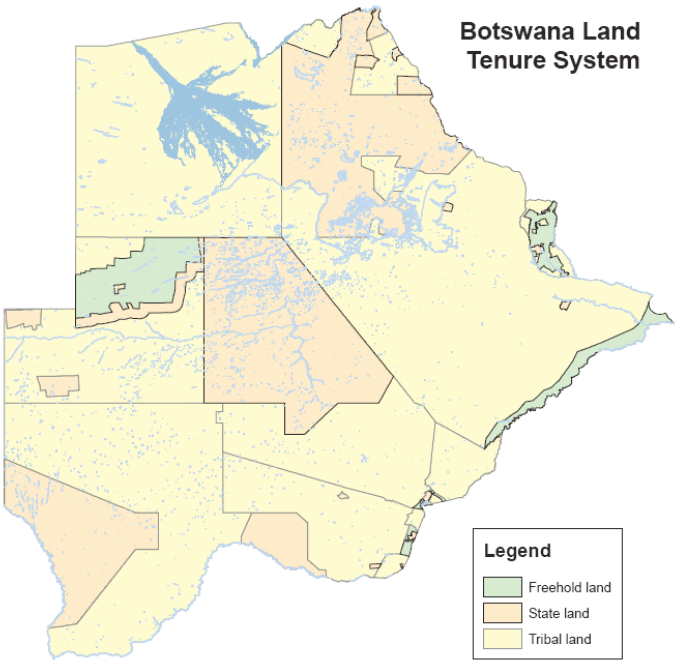

Figure 5.1: Land Tenure distribution in Botswana. (Source: Mothibi, Malatsi and Finnström, 2008)

The country has a number of Acts which are used in land management and they have had a fundamental role in spatial data collection, processing, distribution and discourses. The Land Survey Act is the principal instrument which establishes the Department of Surveys and Mapping with sanctions to be the national agency in matters of spatial data collection, processing and distribution. The Town and Regional Planning Act established the Department of Town and Regional Planning for undertaking the physical planning activities across the country. The Department of Lands is responsible for managing freehold land and state land. The tribal Territories are themselves managed through the Tribal Land Act which establishes Land Boards as the key agents to land management activities. All these Acts are administered centrally through the Ministry of Land Management, Water and Sanitation (MLMWS). Water and Sanitation are new entrants into what used to be called Ministry of Lands and Housing (MLH). Housing has recently been moved to the Ministry of Infrastructure and Communication. MLMWS is important in this study because it has traditionally been viewed as responsible for land management through spatial data collection, processing and distribution across the whole economy while other sectors of the economy were solely viewed as users of MLMWS various products.

The concept of spatial data infrastructure, when initially mooted, was housed at the Department of Computer Bureau, now called Department of Information Technology (DIT). The believe then, was that Geographical Information Systems (GIS) was an Information Technology function (Swedesurvey, 2004). DIT was to form the anchor of SDI implementation in Botswana and this will be elaborated in the findings in section 5.2. The results will also show that, SDI is now identified with MLMSW, in particular Department of Surveys and Mapping as the main convener towards a renewed initiative. With this in mind the SDI discourses in Botswana are briefly previewed.

5.2.1 Botswana SDI Discourses Preview

Botswana has experienced a significant presence in the SDI literature as could be witnessed by the world-wide study which was carried out by Crompvoets *et al* (2004). This study categorised Botswana SDI as a project, meaning that, the country was then, undergoing planning process on how to implement SDI. Makanga and Smit (2010) also undertook a continental SDI assessment in Africa which indicated Botswana as still struggling with how best to implement its SDI. This was followed by the article of Maphale and Phalaagae (2012), which indicate the various trial processes undertaken in transcending spatial data handling leading to the consideration of SDI concept in Botswana. Maphale and Phalaagae (2012, p. 22) posited that the SDI initiative was then being tried through the "e-government strategy", but Tumba and Ahamad (2014) findings revealed that Botswana was among countries which are still struggling and/or have not started their SDI. This effectively meant that by 2014 Botswana was still not having an SDI and therefore could be said to be constrained. The constrained phenomenon can be understood through the work of Mwange *et al* (2016) who reported Botswana SDI Readiness Index to be 0.35 out of 1. This raises the question; why is Botswana SDI Readiness Index still less than 0.5 even after so many trials? According to this study the question can be hypothetically answered by the word "**Constraints**". These constraints are viewed as context-based and can be better understood through in-depth study of Botswana SDI. All these have been done and are reported in the sub-sections below.

5.2.2 Botswana Results and Responses

These constituted of documents, geoportals and response to questionnaire and interviews.

5.2.2.1 Botswana Documents and Discussion

Through physical visit and interactions with departments within Ministry of Land Management, Water and Sanitation, the documents obtained are listed in table 5.1.

Table 5.1: Botswana SDI Related Documents

Botswana SDI Related Documents								
(I) Useful Acronyms								
a. Ministry of Lands and Housing (MLH)								
b. Ministry of Land Management, Water and Sanitation (MLMSW)								
c. Deprtment of Surveys and Mapping (DSM)								
d. Land Admistration Procedures Capacity and Systems Project (LAPCAS Project)								
e. Botswana Document (BWD)								
(II)The Documemnts								
Code	Document Title	Creator	Subject	Publisher	Source	Typology	Pages	Year
BWD1	Master Plan for the Establishment of a National Geographic Information System	Swede Survey	SDI	unpublished	MLMSW	Report	68	2004
BWD2	Information Exchange and Dissemination	MLH	SDI	unpublished	LAPCAS Project	Report	22	2012
BWD3	Information Exchange and Dissemination Draft Agreement on NSDI Cooperation	MLH	SDI	unpublished	LAPCAS Project	Report	21	2012
BWD4	Gis Cluster Report to the e-Government	MLMSW	e-Government	unpublished	GIS-Clusters	Report	12	2011

The critical elements of table 5.1, have been elucidated in the methodology in Chapter 4. Table 5.1 exposes a number of fundamental findings and they are the following:

- SDI implementation documents in Botswana are reports.
- The documents were prepared between 2004 to 2012
- An SDI master plan was composed in 2004
- They were created for the Ministry of Land Management, Water and Sanitation formally Ministry of Lands and Housing.
- These reports are related to projects of the MLMSW e.g. the Land Administration Procedure Capacity and Systems (LAPCAS)
- The total pages for these documents are one hundred and twenty-three (123)
- International collaboration with Swedesurvey is visible in the table 5.1 as originator of the SDI Master Plan.

5.2.2.2 Documents Contents and analysis

As already mentioned in the finding, Botswana SDI documents are draft reports referring to establishment of a National Spatial Data Infrastructure (BNSDI). What is emerging from all the four documents listed in table 5.1 is that, BSNDI has never been initiated in Botswana as a

core project or policy implementation, but rather as spin-off from on-going projects. What is referred to as the "SDI Master Plan" is an after-fact report which resulted from a project started in 2002 aimed at integrating GIS efforts. The other two documents coded BWD2 and BWD3 are spin-offs from LAPCAS project and BWD4 is related to e-government effort dubbed "GIS Clusters". All the other three documents (BDW2, BDW3 and BDW4) are essentially restating the SDI Master Plan Document and their interest are inward looking to the functions of MLMWS. For instance, The LAPCAS project in Botswana is focussing on revamping land administration in Botswana and cannot be strictly referred to as SDI. The mission reports of the LAPCAS project refers to NSDI as a possibility to data sharing within MLMWS. The GIS Cluster is a spin-off from the e-Government Strategy where a cluster focussing on geographical Information was considered. The GIS cluster was suggested as a coordinator responsibility in the process of LAPCAS.

5.2.2.3 Emergence of Botswana National Spatial Data Infrastructure (BNSDI)

According to text in these documents, the emergence of BNSDI dates back to around early 2000, through a Master Plan document which was authored as a result to the activities of Government Computer Bureau (GCB) regarding the National GIS (NGIS) coordination effort. The perception then, was that GIS and its operational structure, belonged to Information Communication technologies (ICT) as elaborated in figure 5.2 in Manisa and Tembo (2003).

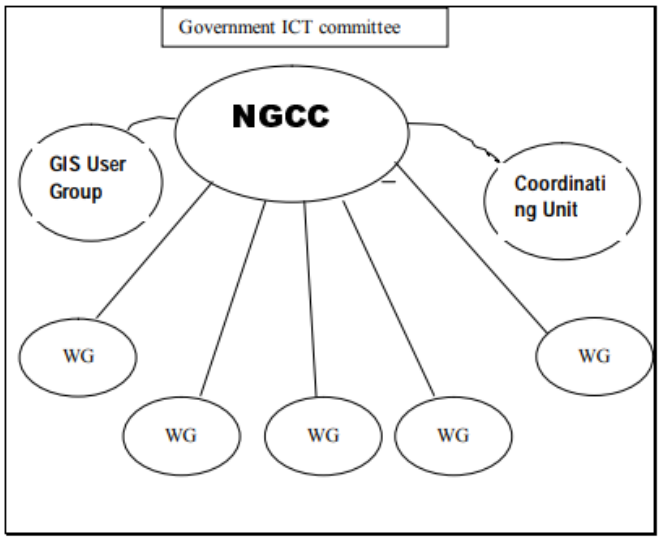

Figure 5.2: Botswana National Geographic Coordinating Committee. (Source: Manisa and Tembo, 2003)

In pursuit of NGIS a committee named National Geographic Coordinating Committee (NGCC) was set. NGCC came up with a conceptual inception of the BNSDI, as captured in table 5.2. In figure 5.2, it is evident that BNSDI in the early stages had workgroups. These workgroups executed their mandates under a Swedesurvey funded project where they came up with a number of products and ideas such as; standard for metadata, metadata service, a website, GIS training guideline, a data exchange model and an inventory database for all GIS projects being done in the country (Swedesurvey, 2004).

Table 5.2: Botswana national Spatial Data Infrastructure (BNSDI) workgroups. (Adapted from Swedesurvey, 2004).

No.	Workgroup	Main Tasks	Leading Stakeholder	Other Stakeholders
1	Fundamental Data	-Analyse the need for Fundamental data -Datasets specifications -Put requirements on the production, maintenance and updating routines	Department of Surveys and Mapping (DSM)	University of Botswana (UB Civil Engineering), Department of town and Regional Planning (DTRP) and Botswana Telecommunications (BTC)C
2	Metadata	-Put requirements on the Metadata Service (MS) -Monitor and Support the development of the MS - Promote and advertise the use of the MS	Department of Water Affairs	Department of Crop Production & Forestry (DCPF), Government Computer Bureau (GCB), Central Statistics Office (CSO), Department of Lands (DoL), DMS
3	Geographic Information Standards	-identify areas needing standards -identify and promote suitable standards -Review and propose changes to standards	Central Statistics Office (CSO)	DSM, Department of Geological Services (DGS), Botswana Bureau of Standards (BOBS)
4	Architecture & Infrastructure	-Requirements on GI and GIS - Guidelines for establishing GI and GIS infrastructure Guidelines for proper GI and GIS maintenance	Government Computer Bureau (GCB) now Department of Information and Technology (DIT)	UB (civil engineering), DTRP, DSM, DCPF
5	Institutional and Organisational Framework	-GI stakeholders should co-operate -Financing -Review of performance	Faculty of Engineering at UB	UB, DSM, BTC, Water Utilities Corporation (WUC), Department of Public Service Management (DPSM), Office of the President (OP)
6	Education and Human Resources	-GIS knowledge and skills audits -Future BNSDI staff requirements - Review the existing GIS education and training courses	University of Botswana (UB)	DSM, DPSM, Ministry of Education, Botswana College of Agriculture (BCA)

On paper this conceptual BNSDI idea looked promising but, in reality, implementation of what was intended was not achieved, resulting in activities of the workgroups to be discontinued in 2007. This could be heralded as the first hurdle to SDI implementation in Botswana. As implied in the documents BDW2 and BDW3, Constraints can be attributed to continued commitment, funding and technical support, following the Swedesurvey ceasing its work in this SDI effort.

5.2.2.4 The Second BNSDI Effort

In 2007 NGCC was discontinued and later replaced by the GIS Cluster Coordinating Committee in 2009 under e-government strategy, which was focussed on a wide strategy of digitalising government operations (Botswana Government, 2011). The GIS Cluster Coordinating Committee made attempts to revive BNSDI with the LAPCAS project as the platform for implementation. GIS Cluster made attempts to re-establish workgroups to deal with Standards, Metadata, Communication and Marketing. These were to be led by Central Statistics Office, now known as Statistics Botswana; Department of Water Affairs (DWA), now Water and Sanitation; and Ministry of Lands and Housing (MLH), now Ministry of Land Management, Water and Sanitation (MLMWS) respectively. This effort has not yielded any tangible results and has manifested into what is now called the second hurdle to BSNDI development. This instigates all interested parties to determine what has been causing all these hurdles e.g. lack of legal framework, organisational structure, commitment, substandard system specifications, concept awareness etc.

5.2.2.5 The Third Effort of BNSDI

Since 2017, the third BNSDI effort, has been delegated to Department of Surveys and Mapping for requirements setting, coordination and advancement. There are no documented materials regarding this new arrangement, but the lead organisation was contacted and a questionnaire administered and the response presented in table 5.4. A discussion on this will ensue following the reported questionnaire response.

5.2.3 Botswana Geoportals/Webs

In Botswana only two websites/geoportals were obtained using the search criteria suggested in Chapter 4, which are "Botswana Spatial Data Infrastructure" and "Botswana Geoportals" or "Botswana Spatial Metadata".

Table 5.3: Botswana SDI Related Websites/Geoportals

Botswana SDI Related Websites/Geoportals						
(I) Useful Acronyms						
a. Botswana GeoScience Institute (BGI)						
b. Regional Centre for Mapping Research and Development (RCMRD)						
(II) Botswana Website/Geortal (BWW)						
Code	Website/Geoportal	Owner	Subject	Data and information capabilities	Capabilities	Year
BWW1	http://geoscienceportal.geosoft.com/Botswana/search.	BGI	Geology	Botswana: Bedrock geology, Topographic map and Datasets for Ngamiland	Multi-Scales Visualisation, Annotation and Data Download - (Limited)	2016
BWW2	http://geoportal.rcmrd.org/	RCMRD	Environment	Land cover, Settlements, Districts boundaries, Major Roads and Rivers	Visualisation and download (SHP, KML, JPEG, PNG, Text, PDF)	2015

Looking at the websites/geoportals as SDI output of Botswana, a clearer picture of the SDI Readiness Index of 0.35 Mwange et al (2016) can be further understood. Maphale and Phalaagae (2012) indicated that Botswana NSDI had website http://www.ngis.gov.bw/, but in the current times it has ceased to exist and there is no substitute. This on its own signify a regression of some proportion in SDI advancement in Botswana.

That effectively means, Botswana no longer have a national SDI geoportal. Geoportal which portrays Botswana geospatial data is the effort that was undertaken by Regional Centre for Mapping of Resources and Development (RCMRD) as indicated in table 5.3. The RCRMD effort focussed on land cover, boundaries, settlements, major roads and rivers. RCRMD effort is external and does not necessarily reflect SDI advancement in Botswana. Another, accessible Botswana geoportal is that of Botswana Geoscience Institute (BGI) as stated above. The BGI effort was a pilot project which was done in the North-West District in conjunction with Geosoft technologies. This BGI example is indicatory of a silo corporate SDI development effort.

5.2.4 SDI Coordinator Questionnaire Results

Botswana response, was obtained from Department of Surveys and Mapping, which is said to be spearheading a committee with the responsibility of advancing the interests of National Spatial Data Infrastructure. Three officers, Department Director and two in the rank of Principal Surveyor responded to the questionnaire and the results were aggregated into table 5.4 in keeping with the research ethical requirements. Response by three officers was not mandatory and it is stated here that the Officers out of their own accord decided to independently respond to the questionnaire.

Table 5.4: Botswana SDI Questionnaire Response

No.	Question Key Phrase	Botswana Reply (Department of Surveys and Mapping, 2017)
1	SDI time origins	*As far back as 1994 when a study was conducted by a Canadian company siting the value of information. a serious attempt was carried out in the early 2000 a committee of which based at the then Computer Bureau through the assistance of Swede Survey. Conceived in 2002, to have started as project but deferred due to financial constraints*
2	SDI Main Players	*Government Agencies (Surveys and Mapping, Town and Regional Planning, Mines, Geological Surveys, Min. of Agriculture, Botswana Power corporation, Statistics Botswana, Meteorology, Land Board), GIMS Botswana (ESRI Distributor), Botswana Institute of Geomatics (Professional Association), Private Sector, De beers, Prospecting companies. Power, WUC, Telecoms, Post office, Geoscience institute, academia.(UB, BUAN, BIUST).*
3	Recent SDI status	*Formation Stage. Still at infancy stages, but some proposals and standards developed*

4	Country SDI interactions	*Part of working groups, NSDI Project Team and Workshops. At technical level the organisation interact very much, the challenge is at political and policy level*
5	SDI Constraints	*Limited funding and understanding of concept, Lack of Mandate from implementing organisations, and lack of support from top management. Lack of understanding and benefits, Lack of funding, Unskilled manpower, Lack of legislation*
6	SDI Benchmarking within SACU	*Not yet, but it is under consideration. Yes we have the Namibia SDI strategic paper and the RSA one.*
7	Further elaboration to 6	*Benchmarking has been done in Sweden, Budgetary constraints are limiting factor. We have not really benched on the southern countries but have documentation from some countries as well as those from abroad and West Africa*
8	SDI inputs	*Institutional framework, Technical standard, Fundamental datasets, Technical framework. a) Standardized data, b) Metadata c) Infrastructure development*
9	SDI outputs considerations	*Reduction of data collection and maintenance costs, Improvement of data quality and consistency, Improved access to data. Share information and data*
10	Country SDI benefits and opportunities	*Avoid duplication of efforts in data collect, Updating off data becomes cheap, Increase spatial data market, Sharing of data becomes easy, Sharing of infrastructure becomes easy, Complex decision becomes easy because of availability of different data sets, Build in cooperation between actors. a) shared information platform, b) informed decision making, c) coordinated approach to development*
11	Country SDI coordination and feedback	*Its coordinated from the National Mapping Department; NSDI steering committee, NSDI unit, NSDI project implementation/interim committee. Mainly coordinated from DSM with other key stakeholders.*
12	Country SDI plan	*It is included in NDP11. In a way yes as there exist some strategies developed by the LAPCAS project and the swede survey before*
13	SDI research	*Its not clear and understandable. Of late University of Botswana has been included on the interim committee, as a way promoting the spirit. Certainly a positive initiative to research on the subject to identify bottlenecks and a possibility to map the way forward*
14	Country views on SACU SDI	*The country advocate regional and global cooperation. Botswana as land locked country has entered or will enter into memorandum of Agreements with its neighbours such as African Union Border Programmes therefore it is essential to have Regional framework. Its something that can be done with right consultation and communication. This could be a welcome development, already the UN and the African Union is advocating for establishment of such initiatives to monitor the implantation of the SDGs.*
15	Participation in current research	*They will be willing with right consultation exercise. More than willing to take part with a view to establish the BSNDI. The following have been done: Feasibility study, Bench marking has been done in Sweden, Joint relationship has been proposed with the Regional Centre for Mapping of Resources for Development (RCMRD). The country through The Department of Surveys and Mapping under the ministry of Land Management, water and Sanitation Services, has an objective to promote partnership on its strategy under NDP11. The objective aim at increasing access to services and to delight the customer. The whole intension is to increase the extent of collaboration more than it has traditionally been, therefore the country through our department is willing to take part.*

The response confirms a critical finding that, even out of so many years of trying, Botswana SDI remains bound at the threshold. This threshold status, considered in relation to initial efforts in early 2000, goes to confirm Botswana SDI development as slow. A number of constraints have been pronounced, among them; financial, awareness, legal framework, organisational mandate and strategic influence. Strategic influence is here regarded as the political involvement and influence of SDI development by top management e.g Cabinet, Permanent Secretaries and Chief Executive Officers. The response in the above questionnaire regards the SDI Master Plan and LAPCAS Project as appropriate foundation blocks for the future effort, and this is viewed to be consistent with the proposition of SDI On-Going Improvement (SDIOGI). In order to enrich the above response, another questionnaire was

designed to seek the multi-sectoral perceptions of Botswana SDI Stakeholders. The questionnaire design, administration and results are presented in the next section.

5.2.5 Perceptions of Botswana SDI Community

This is an effort to increase understanding on why Botswana SDI is constrained by soliciting the perceptions of its current stakeholder community as per the response in table 5.4. In this inquiry, the intention was also to qualitatively demonstrate SDI On-Going Improvement (SDIOGI) whereby SDI goals are identified, performance indicators determined, constraints identified and ways to solving them sought from stakeholders. The questionnaire is described below and its associated results reported and analysed.

5.2.5.1 SDI Stakeholders Questionnaire

An open-ended questionnaire was devised and administered to organisations, currently identified with SDI implementation in Botswana. The designed questionnaire is attached to this thesis as Appendix 5 which is a seven-step methodology seeking to understand the following;

- The goals of NSDI versus the organisational spatial data needs
- Organisational views on national NSDI performance indicators
- Organisational Perspectives on the main NSDI constraints
- Main SDI constraint as viewed by stakeholder organisations
- Solution to identified main constraint as perceived by stakeholder organisations
- Perceived achievement of the NSDI by stakeholder organisations
- Identification of the way forward for the NSDI

The objective of this approach is to extract multi-sectoral perspectives of the organisations involved with NSDI implementation. Botswana SDI can at best be portrayed by the structure in figure 5.3.

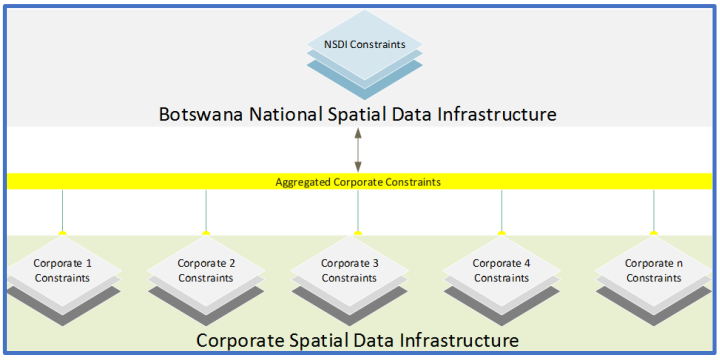

Figure 5.3 The hierarchical structure of Botswana national Spatial data Infrastructures

BNSDI is based on institutions as the main stakeholders. It is therefore imperative to understand their views in regard to BNSDI and identify what they view as National SDI constraints. The views are then aggregated to give indication and guidance on the major constraints affecting implementation in Botswana. Thirty-two questionnaires were distributed to members of the Botswana NSDI Committee coming from these organisations; Department of Surveys and Mapping, Office of the President, Meteorological Services, Ngwaketse Land Board, Botswana Police Service, Tlokweng Land Board, Botswana Defence Force, Botswana Geoscience Institute, Department of Mines, Statistic Botswana, Ministry of Agriculture, GIMS Botswana, Department of Town and Regional Planning, Botswana Power Corporation, University of Botswana Department of Environmental Science, University of Botswana Department of Civil Engineering, Botswana Institute of Geomatics, Department of Water Affairs and Water Utilities Corporation. Out of the thirty-two questionnaires issued out, 14 were returned which represents 43.75% return rate.

5.2.5.2 Questionnaire Results

The results of the questionnaires have been tabulated into table 5.5. The rows represent the questions and the demographic data labels while the columns represent the returned questionnaire responses. The answer statements from various respondents were entered as summary phrases that capture the response. As an example, a particular response could be effectively pointing to issues of duplication of effort which is summarised as 'duplication" and entered as it appears on a number of cells across table 5.5.

Table 5.5: Botswana SDI Stakeholders responses

CODE	BW1	BW2	BW3	BW4	BW5	BW6	BW7	BW8	BW9	BW10	BW11	BW12	BW13	BW14
	Duplication	Digitilasation	Data Sharing	Cost Saving	Data integration	Cost Savings	Duplication	Standards	Data handling	Standards	Standadards	Data sharing	Interoprability	Interoprability
	Cost saving	Efficiency	Access	Access	Data Sharing	Duplication	Cost Saving	Common repository	Metadata	Metadata	Legal framework	Cost Savings	Data sharing	
	Data handling	Users	Cost Saving	Decision-making		Data quality	Data Access	Duplication	Awareness	Legal framework	Duplication	Duplication		
	Decision-making	Interoprability	Data Updates			Cordination	Data quality		Data Sharing	Cooperation	Cost Saving			
	Investment	Metadata	Standards			Data Access			Data governance	Competencies	Data access			
									Standards	Geo Portals				
										Data updates				
Q1	Goals: Consistent	Not stated	Goals: Consistent	Goals: Consistent	Not Stated	Goals: Consistent	Goals: Consistent	Not Stated	Goals: Consistent	Not Stated	Goals: Consistent	Not Stated	Not Stated	Goals: Consistent
	Funding	Data Account	Awareness	Legal Framework	Data Sharing	Data sharing	Cost Saving	Legal Framework	Metadata	Cost Savings	Access	Legal Framework	Data Quality	Standards
	Online services	Data Audit	Legal framework	Data availability	Data Management	Standards	User:Customer Satisfation	Data Standards	Data sharing	Risk	Duplication	Geoportal	Data completeness	Geoportals
	Data Re-use	Digitalisation	Consultation		Commitment		User:Employee satisfaction	Metadata	Standards	Revenue		NSDI office	Cost savings	Legal framework
	Legal framework	Expertise	NSDI office							Standards				Thematic data
	Policy	ICT								Data Access				
Q2	SDI levels													
	Funding	Coordination	Awareness	Data Access	Awareness	Strategic influence	Capacity	Capacity	Awarenes	Funding	Project team	Legal framework	Standards	Straegic Influence
	Legal Framework	Standards	Legal framework	Data Sharing	Legal framework	Silos	Data integration	Strategic Influence		Capacity	Mandate	Funding	Collaboration	ICT
	Data repository	Data Quality	Consultation	Legal framework	Strategic influence	Awarenes	Partnership frameworks	Schedule		Legal framework			Strategic influence	Silos
	Strategic Influence	Awareness	Strategic influence	Coordination	Standards		Funding	Benchmarking		Coordination				
	Awareness	ICT	NSDI office					Milestones						
	Coordination		Metadata											
Q3	SDI Levels		Data Sharing											
Q4	Legal framework	Data Management	Data Sharing	Coordination	Awareness	Strategic influence	Funding	Scheduling	Awarenes	Funding	Ddedication	Legal framework	Strategic influence	ICT
	Engagement	Awareness	Data sharing	Strategic Influence	Strategic influence	Strategic influence	NSDI office	Priority	Collaborations	Cost Saving	Dedication	Participation	Strategic Influence	ICT
	Benchmarking	Data Management	Metadata		Mandate			Strategic Influence	Capacity building	Priority	Funding	common goals		
	Integration	Expertise	standards		Benefits			Milestones		Funding	Strategic Influence	Collaborations		
		Data quality									Capacity			
Q5		Standards												
	Low achievement	Low achievement	Low achievement	Awareness	Bench marking	Low achievement	Awareness	Low achievement	ISO 211 committee	Cooperattion	Mandate	Research done	Low achievement	Projects
	Collapse	Strategic influence		Work groups	Committees			Silos	GIS Cluster	Standards	Data Policy	Volintarism		
	Silo projects	Data Management							proprietary GIS	Fundamental data sets	Draft standards	Collaborations		
	Portals	Stakeholder Access							Agreements		Metdata Template			
	Land Acts reviews	Data quality												
	National Spatial Plan													
Q6	Cabinet Memo													
	Legal framework	Education	Strategic influence	Awareness	Strategic influence	Awareness	Mandate	NSDI office	collaboration	Legal framework	Project consultancy	Strategic influence	Strategic Influence	Involvement
	Involvement	Awareness	Legal framework		Legal framework			Funding	Spatial governance	Capacity building	Capacity building	Awareness		Silos
	Standards	Funding	NSDI Office					Legal framework	Capacity building	Technology		NSDI role		ICT
	Benefits		Awareness											
Q7			Consultancy											
DEMOGRAPHICS														
Profession	Land Survey/GIS	GIS/RS	Cartographer	Military Officer	Meteorolgist	Survey	GIS	GIS	GIS	GIS and Mapping	Land Survey	Land Survey	Land Survey	GIS and Mapping
Position	Deputy Director	Senior GIS Specialist	Senior GIS Specialist	GIS Manager	Meteorologist I	Principal LS	GIS Officer	GIS Engineer	Principal Geospatial Analyst	Principal Land Surveyor	Principal Land Surveyor	Chairman	Mine Survey Supritendent	Cartographer
Experience	19	23	26	6	29	17	22	17	24	30	17	8	15	5
Institution Focus	Surveys and Mapping	Geological Services	Statistical Services	Security	Climate Services	Land Board Services	Agricultural Services	Water reticulation	Water Affairs	Surveys and Mapping	Surveys and Mapping	Professional	Mining	Physical Planning

Table 5.6: Components frequencies of the SDI stakeholder responses

SDI Goals and Needs			Performance Indicators			Constraint Identification			Main Constraint			Main Constraint Solution			Percieved Achivement			Way Forward		
Total Response	14	%	Total Response	14	%	Total Response	14	%	Total Response	14	%	Total Response	14	%	Total Response	14	%	Total Response	14	%
Relevance	8	57	Legal Frmework	6	43	Strategic Influence	7	50	Strategic Influence	2	14	Strategic Influence	6	43	Achievment	6	43	Awareness	5	36
Cost Saving	7	50	Standards	5	36	Legal Frmework	6	43	Funding	2	14	Collaboration	2	14	Standards	3	21	Legal Frmework	5	36
Duplication	6	43	Cost Saving	3	21	Coordination	4	29	Awareness	2	14	Priority	2	14	Committees/workgroups	2	14	Strategic Influence	4	27
Access	5	36	Data Sharing	3	21	Funding	4	29	Legal Frmework	2	14	Funding	2	14	Silos	2	14	Capacity building	3	21
Data Sharing	5	36	NSDI Office	2	14	Awareness	4	29	Coordination	1	7	Standards	2	14	Awareness	2	14	Involvement	2	14
Standards	4	29	Access	2	14	Project progress	3	21	Dedication	1	7	Capacity building	2	14	Agrements	1	7	NSDI Office	2	14
Data Handling	3	21	Metadata	2	14	Standards	3	21	SDI Levels	1	7	Benchmarking	1	7	Benchmarking	1	7	Funding	2	14
Interoprability	3	21	Users	2	14	Capacity building	3	21	Data management	1	7	Benefits	1	7	Cabinet Memo	1	7	ICT	2	14
Metadata	3	21	Geoportal	2	14	Silos	2	14	Data Sharing	1	7	Dedication	1	7	Collaboration	1	7	Benefits	1	7
Coordination	2	14	Funding	1	7	Data Sharing	2	14	ICT	1	7	Mandate	1	7	Cooperation	1	7	Collaboration	1	7
Decision making	2	14	Revenue	1	7	ICT	2	14				NSDI Office	1	7	Mandate	1	7	Mandate	1	7
Data quality	2	14	Commitment	1	7	Benchmarking	1	7				Participation	1	7	National Spatial Plan	1	7	NSDI Role	1	7
Data Updates	2	14	Consultation	1	7	Collaboration	1	7				Project progress	1	7	Research	1	7	Silos	1	7
Awareness	2	14	Risk	1	7	Consultation	1	7				Cost Saving	1	7	Voluntarism	1	7	Data governance	1	7
Legal Frmework	2	14	SDI Levels	1	7	Mandate	1	7				Data integration	1	7	Access	1	7	Standards	1	7
Cooperation	1	7	Data Acount	1	7	NSDI Office	1	7				Data management	1	7	Data management	1	7	Consultancy	1	7
Efficiency	1	7	Data Audit	1	7	Partnerships	1	7				Data quality	1	7	Data quality	1	7	Education	1	7
Investment	1	7	Data availability	1	7	SDI Levels	1	7				Data Sharing	1	7	Metadata	1	7			
Common repositry	1	7	Data completeness	1	7	Access	1	7				Metadata	1	7	ArcGIS	1	7			
Data governance	1	7	Data management	1	7	Data integration	1	7				Awareness	1	7	Geoportal	1	7			
Data integration	1	7	Data quality	1	7	Data quality	1	7				Expertise	1	7	Policy	1	7			
Digitilasation	1	7	Data re-use	1	7	Data Repositry	1	7				ICT	1	7	Acts Review	1	7			
Competencies	1	7	Digitilasation	1	7	Metadata	1	7												
Geoportal	1	7	Duplication	1	7															
			Thematic Data	1	7															
			Awareness	1	7															
			Expertise	1	7															
			ICT	1	7															
			Online Services	1	7															
			Policy	1	7															

5.2.5.3 Results analysis

Most responses presented in table 5.5 boarders on negative aspects of the given answers e.g. duplication, lack of legal framework, funding, strategic influence, commitment, dedication, mandate etc. The status in most of the response points to a constrained SDI advancement in Botswana. In order to make further inferences of these results, they were summarised on the basis of each question asked to see frequency of occurrence in responses. For example, how many respondents indicated the goals of NSDI as being to solve for duplication of effort. The summaries were promulgated into table 5.6 with frequencies for each element which were then converted to percentages by dividing each element frequency by the total number of respondents.

From the table, under the goals and needs, 57% of respondents indicated that SDI was relevant to their business and information needs. The remaining 43% did not make a pronouncement on SDI relevance to their business activities. Other element with significant statistics relating to goals of Botswana NSDI is cost cutting as represented by 50% of the respondents. Other notable goal related elements are Duplication at 43%, Access and data Sharing both at 36% followed by standards and metadata at 29% and 23% respectively. Most of these elements indicate benefits that are associated with SDI. These benefits can be divided into administrative (e.g. relevance, access, data sharing), financial (e.g. duplication and cost cutting) and technical (standards and metadata).

The response relating to performance indicators returned the legal framework ahead of others at 43% with a possibility of 50% in consideration of policy as part of it. Standards at 36%, cost cutting and data sharing at 21% followed by NSDI office, access, metadata, users and geoportal at 14% are also considered as performance indicators by respondents. Standards and Metadata can be aggregated to move to 43%. In the constraint identification category, strategic influence came up on the top with 50% of the respondents. It is closely followed by the legal framework at 43%, then coordination, funding and awareness all at 29% of the respondents. Project progression, capacity building and standards all sit at 21%. After identifying the constraints, when asked what they consider to be the main constraints, the respondents equally mentioned legal framework, strategic influence, awareness and funding at 14%. When considering the constraint identification along the selection of what it is considered to be the main constraint,

it can be concluded that strategic influence and legal framework are the main constraints of SDI advancement in Botswana. Strategic influence is well nested in the constraint's identification, exploitation and the way forward of Botswana SDI. The legal framework straddles performance indicators, constraint identification, exploitation and the way forward. From these results, it can be seen that strategic influence and legal framework can be exploited respectively to support the development of Botswana national SDI. The political leadership of the country need to be more aware of the usefulness of SDI and should develop a legal framework that will apportion mandate to SDI advancement. A call in the previous statement is supported by respondents' affirmation of 43% in relation to strategic influence. This element opened quite a gap to its follower which are collaboration, priority, funding, capacity building and standards which are standing at 14%. Collaboration and priority can both be assimilated to strategic influence and this will raise its value to 71%. Therefore, strategic influence can be concluded as the weak link of Botswana SDI.

In case of achievement, 43% of the respondents made it clear that Botswana has not made any achievements to SDI development. A number of respondents also identified other achievement related elements as lack of functioning workgroups, of standards, cumbersome data sharing and continued silo work approach. When asked about what they perceive to be the way forward, about 36% identified the need of a legal framework, awareness building, 29% mentioned strategic influence on SDI development and 21% referred to capacity building. The way forward conclusively made emphasis on what has been identified as main constraints which continue to act as the weak links toward SDI development in Botswana. According to the respondents, Botswana has to find solutions to strategic influence, legal framework and awareness for its SDI.

Currently there is an SDI committee which is seeking to raise the profile of SDI development in Botswana through a Cabinet Memorandum, which is aimed at pronouncing SDI mandate and funding. This will probably raise the strategic appeal of SDI in Botswana. In terms of the demographics, the experience of those who responded to the questionnaire averages around 18.5 years with responsibilities in the top management of their organisations. Most of these respondents are responsible for the strategic direction of their organisations. The involved organisations have tried unsuccessfully to establish BNSDI without a legal framework. Maybe

with the Cabinet Memo, SDI mandate will be crafted which will be become useful in proper planning and implementation.

This questionnaire required a lot of patience as it took respondents a long time and revisits for them to return the questionnaire. Though a wish was there to administer it across the other jurisdictions, it has to be stated here that, it did not happen due to study period time and financial constraints.

5.2.6 Botswana SDI Constraints

Consistent with the SDI On-Going Improvement (SDIOGI) as suggested in Chapter 3.4.2 in table 3.2, the objectives, goals and performance measurement (SDIOGI Step 1 and 2) of BNSDI are deduced from the Master Plan or BWD1 document as the following:

- To develop what was referred to as a "fully-fledged National Spatial Data infrastructure for Botswana" with fundamental attributes of easiness to finding, accessing and geographic data integration from discrete sources.
- BNSDI main goal was to be an on-going National SDI aimed at improving efficiency and effectiveness of governance and creating new economic opportunities.
- Institutional Framework, Technical Standards, Fundamental Data, Technological Framework were seen as the major composite inputs to BNSDI. Their continued development and fulfilment were seen as outputs which ensures the objectives and goals of the infrastructure.

Despite the above set goals and objectives, a number of constraints, chief among them lack of strategic influence and legal framework have been established. It is posited that, SDI efforts in Botswana have remained Ad-Hoc and lacked progressive focus and the constraints are many. Those considered to be needing immediate attention and solutions are listed with descriptions in table 5.7. This constraints can be critically exploited using the SDIOGI approach through quantification processes associated with SDI assessment on stakeholder perspectives.

Table 5.7: Botswana SDI constraints

Constraint	Description
Strategic Influence	This relates to high level politically influenced decisions which are oriented towards the future SDI development with clear mandates. Lack of political recognition of SDI as a strategic information infrastructure as it has never been accorded entry into important government policies in a similar manor like its contemporaries such as e-government. BNSDI lack mandate and has remained a voluntary entity and inward looking to MLMWS. After a number of years since 2000, BNSDI remains at the threshold with no commendable achievements
Legal Framework	BNSDI does not have supporting Act and Policy framework
Funding	Funding of an SDI with clear guideline and performance indicators to ensure unimpeded progression is not in place
Organisational	Since its inception, SDI concept and its implementation has hoped from one stakeholder organisation to the other. It lacks a dedicated office, reporting and dedication by the stakeholders is said to be very minimal e.g. failure to attend meetings and consistency in stakeholders staff representations in the past efforts.
Marketing	Awareness described as lacking especially at Senior Management and Political levels. Lack of communication plan on the usefulness of BNSDI to Botswana community
Technology	Use of geospatial technologies such as GPS, Remote Sensing and GIS are noted in a number of organisations. Internet based geospatial resources for BNSDI which has been expressed as a performance indicator. At least one SDI stakeholder community can pursue this so that it could be used as an example to demonstrate usefulness. National Website/geoportal repository is not there
Human	The human perspectives emanating from the stakeholder community response suggests availability which needs to be coordinated and harnessed in SDI implementation. Most organisations on average have people with adequate geospatial information skills in their middle-management.
Partnerships	Lack of structured partnerships and agreements between stakeholders
Technical	No dedicated plan on the interface of elements that ensure that BNSDI has a robust technical outlook. Organisation continue to work in Silos in their geospatial data activities without agreed standards on geospatial data and metadata

To commence, the above-mentioned SDI constraints need to be prioritised through the suggested SDIOGI method. As a current reality, Botswana is still struggling with its SDI and has not achieved the goals and objectives set out for its development.

5.3 Lesotho SDI Case

Lesotho is generally accepted to be covering a space of 30,355 km^2 with a population of around 2 million (Letsie, 2008; Chaka, Matela & Makhaphela, 2016; Commonwealth Local Government Forum, 2018). From its inception in 1966, Lesotho governance structure has been styled as a constitutional monarchy. The King of Lesotho is the Head of State in a country where the governance structure is divided into two, being central and local government. The monarchy permeates all structures of governance whereby chiefs are appointed members of all the local government units being district, urban councils and community councils (Commonwealth Local Government Forum, 2018). Land and its associated governance (lands, physical planning and surveying) are under the central government ministry called Local Government and Chiefs Affairs. Under this ministry, there are 10 District Councils with responsibilities which include land governance.

Land governance as pronounced in the Lesotho Land Act, covers physical planning, allocation, titling, mapping and land uses (Lesotho Government, 2010). The Act specifically vests the land of Lesotho into the nationals and hold out the King as the trustee. Another notable responsibility is that of the Commissioner of Lands who is the principal in the processes of land administration in Lesotho. The responsibilities bestowed on the commissioner include; maintaining allocation and accurate cadastre, mapping and spatial databases, leasing, registration, dispute resolutions, land information dissemination, administration of land levies, robust records keeping and transfers (Lesotho Government, 2010). To efficiently achieve these responsibilities, spatial data is required and need to be widely collected considering other stakeholders such as agriculture, statistics, roads, environmental and forestry just to name a few. A movement towards organised spatial data was advanced in Lesotho through a Committee on Environmental Data Management (CEDAMA) since the late 1990s. CEDAMA's principal responsibilities include; coordinate various ministries and other stakeholders for better management of the environment, come up with environmental protection policies, environmental information sharing, avoiding duplication in environmental management efforts and appropriate implementation of the environment law (Lesotho Government, 2008). The parameters of CEDAMA are to some extent representative of those of SDI e.g. avoiding duplication of effort and data sharing. This could go to explain why the SDI concept was considered within CEDAMA frameworks.

5.3.1 Lesotho SDI Discourses Preview

According to Chaka, Matela and Makhaphela (2016), 58% of the land space in Lesotho is mountainous. This make land a lot scarcer, calling for its shrewd management. The desire to manage land better through spatial information has seen Lesotho attempting SDI implementation. SDI attempts in Lesotho are presented in the literature (Moeti 2005; Letsie, 2008; Schwabe and Govender, 2009; Makanga and Smit 2010). Moeti (2005) articulates SDI inception, Letsie (2008) specifically tackled the issues of spatial data sharing, while Schwabe and Govender (2009) coupled with Makanga & Smit (2010) assessed SDI in Lesotho along other African countries.

Following the results of Makanga and Smit (2010), SDI Status was determined in Chapter 3 which yielded a value less than 0.35 out of 1. The status reported gave impetus to this study

as an attempt to understand what could be constraining SDI advancements in Lesotho. Data was collected through the study of documents referring to Lesotho SDI, websites/geoportals, a questionnaire and interviews. Lesotho was visited from 10th to 17th October 2016 as part of executing this study. During the visit a number of organisations were visited and officers interviewed about SDI development in Lesotho. The contact organisation in Lesotho was the Lad Administration Authority (LAA), which had also answered a questionnaire addressed to NSDI coordinators across SACU.

5.3.2 Lesotho Results and Responses

Lesotho results are presented here as documents, geoportals and response to questionnaire and interviews. A case of constraints is then advanced from the results.

5.3.2.1 Lesotho Documents

Through physical visit and online searches, the documents listed on table 5.8 were discovered.

Table 5.8: Lesotho SDI related documents

Leostho SDI Related Documents and Artefacts								
(I) Useful Acronyms								
a. Lesotho Land Adminstration Authority (LAA)								
b. Land Equity International Pty Limited (LIE)								
c. Federation of International Surveyors (FIG)								
d. Deprtment of Lands, Surveys and Physical Planning (DLSPP)								
e. Economic Commission for Africa (ECA)								
(II)The Lesotho Documemnts (LD)								
Code	Document Title	Creator	Subject	Publisher	Source	Typology	Pages	Year
LD1	Development Spatial Data Infrastructure in Lesotho	DLSPP	SDI	ECA	ECA	Report	8	2001
LD2	Spatial Data Infrastructure Development in Lesotho: Overcoming Obstacles	Moeti	SDI	FIG	FIG	Presentation	3	2005
LD3	Systematic Land Regularization and Improvement of Rural Land Allocation Process in Lesotho	LIE	Land Reform	unpublished	LAA	Reprot	97	2011
LD4	Systematic Land Regularization GIS and Data Management Manual	LIE	Data managemnt	unpublished	LAA	Manual	161	2011

The comprehensive documents being LD3 and LD4 from table 5.8 are in the realm of land administration. SDI is mentioned in these documents in no more than five pages. The other two documents are much older and they are related to the inception days of SDI which can best be described as dormant or receiving less priority in Lesotho information infrastructural needs.

Lesotho has had an intent of developing a national SDI but this has never obtained adequate support from government. What appears to be the foundations of its NSDI intent, is contained

in a country report that was made to the United Nations Economic Commission for Africa (UNECA). An attempt was made during the field visit in Lesotho to secure current documents which inform SDI development and status. SDI documents that chronicles current efforts could not be obtained from any of the organisations visited in Lesotho. Therefore, the study relied on the UNECA document reported in table 5.8. This document was authored in 2001, and it exposes the country's move towards SDI whereby a workshop held under the auspices of CEDAMA was conducted with clear emphasis in SDI policies development. According to Moeti (2005), CEDAMA did draft some guiding policies, but these were never endorsed for usage in SDI development in Lesotho. A request to see and peruse these draft policies was futile as the current officers could not produce the copies. Therefore, it could be inferred that, in the current times, Lesotho does not have an SDI, neither related Policies nor Act that can be used to guide its development. SDI approach through CEDAMA have been abandoned and currently there is no body or structure in Lesotho responsible for coordination and amplification of the SDI concept.

Notable reference to SDI, is found in the documents 'Systematic Land Regularization and Improvement of Rural Land Allocation Process in Lesotho" and "Systematic Land Regularization Standard Operating Procedure (SOP) 4.0 - GIS and Data Management Manual" as presented in table 5.8. These documents articulate a land reform process, which is focussed on scaling geographical Information Systems (GIS) and Global Positioning Systems (GPS) technologies to support land administration processes. These documents have facilitated a project which has now been turned into a fully-fledged operation in land allocation and data management centred around Lesotho Land Administration Authority (LLAA). This effort was started through collaboration with Land Equity International (LEI) and Lesotho organisations being; Department of Land Survey and Physical Planning, Maseru City Council, Ministry of Local Government and Chieftainship, The Kingdom of Lesotho and Millennium Challenge Account – Lesotho. From its inception, the system envisaged land regularisation in the city and in the districts as per its operational structure depicted in figure 5.4 (Land Equity International, 2011a and 2011b). The conceptualised structure can be used as foundations to SDI idea and it also informs the core of the fundamental geospatial data sets in Lesotho. This land administration regularisation program has now matured at the LAA.

This effort looks promising but it has mainly focussed on land administration processes. Therefore, it cannot be categorised as Lesotho National SDI (NLSDI). Even on the website of the LAA, there is no portal that facilitates access to geospatial data.

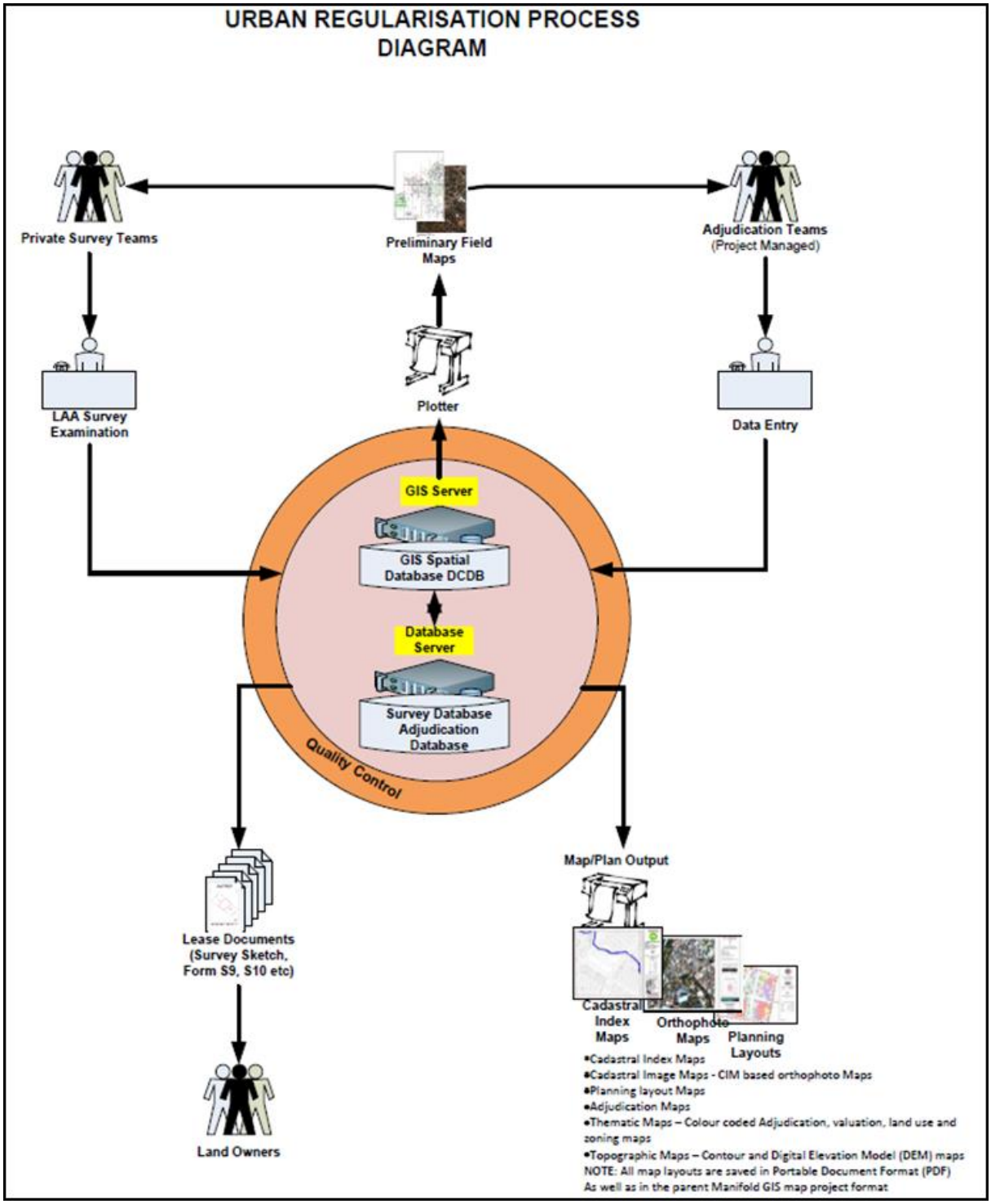

Figure 5.4: Structure of a land regularisation system in Lesotho. (Source: Land Equity International, 2011b, p4)

5.3.2.2 Lesotho Geoportals/Webs

In Lesotho only one website/geoportal was obtained using the search criteria suggested which are "Lesotho Spatial Data Infrastructure" and "Lesotho Geoportals" and results presented in table 5.9.

Table 5.9: Lesotho Related SDI Websites/Geoportals

Leostho SDI Related SDI Related Websites/Geoportals						
(I) Useful Acronyms						
a. Regional Centre for Mapping Research and Development (RCMRD)						
(II)The SDI Related Websites/Geoportals (LW)						
Code	Website/Geoportal	Owner	Subject	Data and information capabilities	Capabilities	Year
LW1	http://geoportal.rcmrd.org/	RCMRD	Environment	Land cover, Settlements, Districts boundaries, Major Roads and Rivers	Visualisation and download ((SHP, KML, JPEG, PNG, Text, PDF))	2015

An attempt to put Lesotho land cover data on the internet is found on the RCRMD which is part of a project that was done for a number of regional grouping's member countries. The RCRMD Lesotho layers were created in collaboration with LAA and they signify a starting point for Lesotho. The collaboration with RCMRD does not have adequate outputs, because Lesotho was not able to acquire the appropriate server with specifications and technical capacity to run the system. Implying, financial and technological constraints.

5.3.2.3 Lesotho SDI Coordinator Response

The response was given by high ranking officer at the Lesotho Land Administration Authority (LLAA). Following convenience sampling approach, LAA was used as a proxy for SDI Coordinator because a link was established with its officers who were met during the Federation of International Surveyors (FIG) working week in Finland in 2017.

Table 5.10: Lesotho SDI questionnaire response

No.	Question key phrase	Lesotho Reply (Land Administration Authority, 2017)
1	SDI time origins	*Around 1999*
2	SDI Main Players	*Ministry of Finance and Development Planning and the Ministry of Works in the department of Works and Transport, National Environment Secretariat, Bureau of Statistics, Land Surveys and Planning and Ministry of Agriculture*
3	Recent SDI status	*Has not started in a formal way. Every organization keeps its data and distributes it as and when requests comes, discretionary. In Lesotho SDI is fragmented. Spatial data exchanges done on ad-hoc basis, existing data sets are not properly documented thus difficult to determine their usefulness and it is not easy to know what spatial datasets institutions have*
4	Country SDI interactions	*Organizations used to hold meetings under the umbrella of a group called CEDAMA – Committee on Environmental Data Management, but due to lack of support from government, this could not be sustained. Later, another initiative driven by Ministry of Finance, was made to find firms or individuals that could propose on the country's SDI, but this was also not well*

		planned and supported, and could not be developed into visible result. Representatives are normally junior officers, hence the issue of SDI is not given enough attention
5	SDI Constraints	• *Lack of understanding of the concept of NSDI* • *Lack of political will to support NSDI* • *Lack of motivation towards people developing NSDI*
6	SDI Benchmarking within SACU	*NO*
7	Further elaboration to 6	*There has never been any interest in this country as to what other countries are doing in NSDI, and this is reflected by the investment in basic structures of data in the country. No. 5 above says it all.*
8	SDI inputs	• *People with right knowledge and motivation* • *Infrastructure (digital)* • *Right software* • *Right policies allowing for data sharing* • *Spatial data*
9	SDI output considerations	• *Easy access to data* • *sustainable land and environmental planning and development* • *Improved and sustainable decision making*
10	Country SDI benefits and opportunities	*It would create an opportunity to test and use different permutations of models of data to achieve targeted development plans in the most economic and sustainable way. These data would be easily obtainable as data depository will be known*
11	Country SDI coordination and feedback	*After the efforts by Ministry of Finance in the early 2000s, no effort was taken on coordination. LAA has been intending to start working on it, but due to the ongoing legal reforms, SDI development has not been a priority*
12	Country SDI plan	*No, not now. This will be better dealt with after the finalisation of legal changes in the survey and mapping profession in Lesotho*
13	SDI research	*It is silent at present, probably because of the legal reforms that will affect the position of the Chief Surveyor and his functions. However, in future he is likely to undertake the development of NSDI*
14	Country views on SACU SDI	*This is a good idea that might have positive effect of the regional bodies/governments that drag behind in this field.*
15	Participation in current research	*The country needs to participate in the research work and learn more about the benefits it could reap by having regional SDI as Lesotho on it's own has not been able to establish its own SDI. However, like now, due to time and staff constraints, we may take longer than expected to attend to some of the issues the research might need.*

The current SDI situation in Lesotho has been captured through the questionnaire in table 5.10 by the authorities at LAA. The response to most questions pronounces SDI in Lesotho as non-existent despite a number of organisations having interest in it. Two SDI attempts are mentioned, being; the Committee on Environmental Data Management (CEDAMA) and the Ministry of Finance. These attempts have not been successful and a number of constraints have been mentioned as cause to that effect.

5.3.2.4 Lesotho SDI Stakeholders Response

When in Lesotho, a number of perceptions in table 5.10 response were buttressed by visiting a number of organisations associated with SDI: Ministry of Agriculture, Commissioner of Lands, Department of Environment, Maseru City Council and Lesotho Bureau of Statistics. Officers associated with spatial data in all these departments were requested for SDI related documents and none were returned. In addition, interviews about SDI were conducted

following defining questions of why SDI has not been making progress and how the situation could be turned around. The interviewed officers have all shown interest in SDI for Lesotho as a centralised spatial data system, which should be accessible to stakeholders. A number of the interviewees have acknowledged that they are not much aware of the SDI concept. The stakeholders in Lesotho do possess geospatial data but a number of them acknowledge that it is not consistent, for example, place names differing in maps. These organisations accede that SDI in Lesotho would go a long way in helping with their activities but then government does not treat it as a priority.

5.3.2.5 Lesotho SDI Constraints

In terms of objectives, goals and performance measurements, no useful evidence was obtained from Lesotho organisations to help align with Step 1 and 2 of the SDIOGI approach. SDI in Lesotho is currently non-existent and highly constrained and some of the constraints are identified in the constraints are identified from responses and results emanating for the above subsections. The constraints are summarised into table 5.11.

Table 5.11: Lesotho SDI constraints

Constraint	Description
Definition	The SDI concept has not been adequately defined and attempted
Organisation	There are currently no institutions and interventions styled at advancing SDI. As such it could not be established as to who is mandated with advancing of Lesotho SDI.
Legal Framework	There is no supporting act and policy for advancing SDI
Funding	Lacks funding
Strategic Influence	Lack of political recognition of SDI as a strategic information infrastructure. Even at lower governance structures there are currently no SDI influencers nor active advocates.
Human	Low capacity and high staff turnover, South Africa was said to be the main destination for Lesotho's skilled geospatial information practitioners. Even LAA and Commissioner of Lands possesses no more than 20 experts in geospatial training. Lack of exchange and sharing GIS knowledge between stakeholders
Technology	Information Communication and technology infrastructure and the use geospatial technology are still a challenge. Their use is very minimal among stakeholder organisations and there is a lot of dependence on donor organisations. Lesotho does not have either a geoportal or a website for SDI.
Partnerships	This implies collaborations between organisations for the purposes of advancing SDI. For purposes of data sharing and exchange, partnerships between Lesotho organisations are informal. There are no codified agreements between organisations which were discovered

Technical	Lack of metadata and spatial data standards. Place names maps were found to be one example which clearly points to lack of standardisation. This is said to be directly impacting on geospatial data quality, processing, reliability and costs.
Marketing	SDI concept is not marketed at all in the Lesotho and awareness appears to be very low among stakeholders

Activities meant to advance SDI in Lesotho are not clear. There is no particular organisation which is tasked with the primary responsibility of organising and advancing SDI concept. A full-fledged approach will be required to advance SDI in Lesotho economy and it will need to be legislated, funded and its implementation supervised. It can be concluded from these results that Lesotho SDI is highly constrained organisationally and technically.

5.4 Kingdom of eSwatini SDI Case

Kingdom of eSwatini did feature in the work of Makanga and Smit (2010) with results almost at par with the Republic of South Africa. With the intention to impugn these results, undertaking an in-depth study of eSwatini SDI in its current form was envisaged. This has, to a large extent not been possible because, unlike the other SACU countries efforts to reach organisations associated with SDI in eSwatini were futile. Despite that, an attempt was made through internet searches for documents and websites that could help us to see the current SDI situation in eSwatini. The results are reported and analysed in sub-sections below.

5.4.1 Swaziland (Kingdom of eSwatini) Documents

Through online search, only one document was discovered as shown in the table 5.12.

Table 5.12: Swaziland SDI related documents

Leostho SDI Related Documents and Artefacts								
(I) Useful Acronyms								
a. Government of Finland (GF)								
b. Economic Commission for Africa (ECA)								
(II)The Lesotho Documemnts (LD)								
Code	Document Title	Creator	Subject	Publisher	Source	Typology	Pages	Year
SWD1	Kingdom of Swaziland National Information and Communication Infrastructure	ECA/GF	ICT	www.ellipsis.co.za	Website	Policy	172	2012

The above document was perused and mention of SDI is found in one page in a table 5.12. There is no comprehensive explanation as to its role within the eSwatini developmental setup

nor is there a clear process chronicling how it should be implemented. In the document presented in table 5.12, SDI is just mentioned as one of the technological and data communication systems requiring development without illustrating any fundamental approaches, requirements and directions to it.

5.4.2 Kingdom of Swaziland (eSwatini) Geoportals/Webs

Kingdom of eSwatini website/geoportal was obtained using the search criteria "Swaziland Spatial Data Infrastructure" and "Swaziland Geoportals". One geoportal belonging to RCRMD was found as displayed in table 5.13.

Table 5.13: Kingdom of eSwatini SDI related Websites/Geoportals

Swaziland SDI Related Websites/Geoportals						
(I) Useful Acronyms						
a. Regional Centre for Mapping Research and Development (RCMRD)						
(II) Swaziand (eSwatini) Website/Geortal (SWW)						
Code	Website/Geoportal	Owner	Subject	Data and information capabilities	Capabilities	Year
SWW2	http://geoportal.rcmrd.org/	RCMRD	Environment	Land cover, Settlements, Districts boundaries, Major Roads and Rivers	Visualisation and download (SHP, KML, JPEG, PNG, Text, PDF)	2015

Regarding table 5.13, evidence of SDI activities in Kingdom of eSwatini, are found with RCMRD. This effort does not have a repository of any geospatial data of Kingdom of eSwatini.

Kingdom of eSwatini has not been visited for in-depth study of spatial data infrastructures progression. A questionnaire was sent to the organisation closely linked with SDI (Surveyor General), but a response was not received. In the data tables 5.12 and 5.13, it has not been possible to make any useful inferences of the SDI objectives, goals, performance measures and related constraints.

5.5 Conclusion

This chapter has elucidated the data-collection activities followed in gathering data for SACU countries without legislative framework. The case study methodology and its associated methods have been utilised whereby responses and results were obtained. The questionnaire has been used to solicit the current views of the SDI key stakeholders in the case study countries. The documents, artefacts, interviews, questionnaire and websites were used to

extract expressed SDI indicator categories of case study countries. Constraints associated with these countries' SDIs are varied but the results confirm they lack SDI legislative framework, mandate and direction to development. Those attempting to implement the SDI experience frustrations and uncertainty on the way forward. Funding is constrained because there is no mandatory prescription to developing SDI. Taking these constraints in to cognisance, SDI On-Going Improvement (SDIOGI) is being put forward as a means to constraints determination and ordering to aid implementation. In Chapter 3, a quantitative approach based on SDI assessments results was proposed to show case SDI constraints exploitation process. In this chapter a context based qualitative approach has been done in case of Botswana. The qualitative method of SDIOGI is based on investigating what the stakeholders of SDI consider to be its main constraints and how to solve them.

In Botswana, early awareness of SDI concept is acknowledged to be 1994 – whereas an attempt to its implementation is more associated with several projects which started in 2002. Botswana SDI development has remained constrained at the threshold despite the early start and several efforts. Botswana continues to strive with the idea of developing SDI but lack of strategic influence, legislative framework, mandate and awareness seems to be major constraints in its course. Botswana, which appeared in both Makanga and Smit (2010) and Mwange et al (2016) does have a number of SDI related documents which can be used to guide the way forward. Comparatively, Lesotho, is faced with lack of legislative framework, funding, understanding and mandate, which have all adversely affected SDI development and it is currently not pursued. Kingdom of eSwatini could not be accessed for a more comprehensive data collection and literature also did not show much regarding its SDI efforts.

In overall the development statuses of SDIs in the two visited SACU countries, Botswana and Lesotho are constrained. In relation to the workshop activity, it appears to be minimal and Botswana's original SDI internet platform is no longer available. Lesotho seem to be really behind because the documents obtained does not explicitly refer to SDI and how it is being tackled. They do not have country SDI websites/geoportals. These three countries have subscribed to the geoportal of Regional Centre for Mapping Resources and Development (RCRMD) based in Kenya. This is a regional effort, but in terms of data only Botswana geospatial data can be viewed and downloaded from the RCRMD geoportal.

Chapter 6 SACU Countries with a Legal Framework

6.1 Introduction

This chapter is focussed on SACU countries which have crafted legal framework made of Acts, Policies, Standards, Strategic Guidelines and Regulations to advance their SDI. The intention is to evaluate how well they have advanced, what is constraining their advancement and consider solutions which are done to ensure progress. Republic of Namibia and South Africa are the only two countries in SACU possessing statutory instruments that are directly supporting the activities of their SDI progression. The report structure of this chapter is quite similar to that of Chapter 5 before it and its reporting is directly linked to the methodology in Chapter 4. Succinct literature reviews to indicate SDI discourse in these countries is done then results presented, discussed, analysed and a conclusion drawn.

6.2 Namibia SDI Case

Namibia has been a country on transition since attaining its independence in 1990. According to Okafor (2011) the country covers 834,295 km^2 with parts of this country covered by two prominent deserts being Namib to the west and Kalahari the east. This vast country, is currently home to a population of about 2.5 million people. Namibia at independence was duly instituted as a republic with a president as head of state, several ministries housing various departments/organisations with specialised national duties e.g. Surveys and Mapping and National Statistics Agency (NSA). Government agencies are bestowed with responsibilities of affording the citizenry quality services across regions shown in the map labelled figure 6.1. The thirteen regions are: Kunene, Omusati, Oshana, Ohangwena, Oshikoto, Kavango West, Kavango East, Zambezi, Otjozondjupa, Omaheke, Khomas, Enrongo, Hardap and Karas. The map depicted as figure 6.1 is obtained from the Namibian SDI geoportal as referenced. This map also depicts some important features such as major roads and the coastal area under Namibian authority. Indicating that, Namibian SDI is focussed in inland and coastal management of its man-made assets, natural resources and social system in general.

Figure 6.1: Namibia with its districts. (Source: https://digitalnamibia.nsa.org.na/)

Namibia Department of Surveys and Mapping, has been instrumental in collecting, processing, collating and distributing of geospatial data across the regions stated in figure 6.1 so as to support and improve decision-making in Namibia's economic transition and transformation. On the other hand, National Statistics Agency (NSA) or the erstwhile Central Bureau of Statistics was tasked with carrying out censuses and resource counts with the objective to Namibians economic emancipation. The work of these two organisations gradually converged leading to the revision of the Statistics Act in 2011 with enactment and infusion of the Spatial Data Infrastructure as Section 47 - 48. In this Act, the Statistician General is bestowed with the responsibility of implementing and housing National NSDI while the Surveyor General is bestowed with the Chairpersonship of the associated committee named Spatial Data Committee (SDC). The two officials as per position, sit in perpetuity in the NSDI committee as opposed to other appointed members who only serve three-year terms (Republic of Namibia, 2011). For the purpose of this study, the Namibian Statistics Act is regarded as a source of primary data because, it depicts a clear government intention for SDI development in Namibia as legislated.

Taking this into cognisance the Namibian case is previewed, response reported, discussed and constraints identified.

6.2.1 Namibia SDI Discourses Preview

In the continental SDI review by Makanga and Smit (2010), Namibia as a country scored very low marks in terms of SDI with an index status around 0.4 out of 1. This low index gives an indication of a limited or constrained SDI during that period in Namibia. As an attempt to understand the context of SDI development and status in Namibia, this study took to investigating the actual discourses associated with it. One fundamental starting point to this determination is the Ministry of Lands and Resettlement (MLR) in Namibia. MLR has for a long-time adopted land reform as a going strategy, whereby, comprehensive land information systems were viewed as suitable instruments to support sustainable development (Mendelsohn, Robertson and Jarvis, 2006). According to Mendelsohn et al (2006), Namibia with the help of Swede Survey, have in the mid-2000s started development of digital cadastral land information systems aimed at integration of spatial data. The fundamental property of this digital cadastre was '*unique parcel identification or numbering*' to make it easy to attach data of all sorts to the land. The land information systems reform approach, was focussed on auditing and moving towards synchronisation of all the activities and information associated with the directorates under MLR.

Emanating from the land reform efforts by MLR in Namibia, National SDI (NSDI) effort can be traced. According to Sinvula *et al* (2013), Namibia SDI was formally legislated in 2011 and was further boosted by draft policy and standards schedule. In recognition of the SDI legislative and policy developments in Namibia, Sinvula *et al* (2013) have utilised the Reference Model for Open Distributed Processing (RM-ODP) in the categorisation of Namibia SDI players. Sinvula *et al* (2013) in their work identified fundamental players in this SDI, such as policy maker, producer, provider, broker, value-added resellers (VAR) and end users. In line with these players, the Office of the President together with line ministries played a fundamental role in policy making while government agencies, commercial mapping agencies, community interest and crowd sourcing were identified as producers. Providers were identified as; all official data producers, and those responsible for distribution e.g. National Statistics Agency and services e.g. Environmental Information System (EIS). Under brokerage, a

number of responsibilities such as crowd-sourcing facilitator, finder, harvester, cataloguer and négociant were identified for various stakeholders. VAR recognised several publications, for example, the erstwhile Polytechnic of Namibia satellite stations, MLR enhanced topographic, NSA, Geological Surveys' maps and Ministry of Agriculture fire monitoring alerts. Sinvula *et al* (2013) further identified the end users of the Namibian SDI which they categorised into two as naïve consumers and advanced users coming from the different national spheres and geospatial data knowledge. With this in mind, the responses and results from the study of the Namibian SDI is discussed and constraints identified.

6.2.2 Namibia Results and Responses

The results from Namibia are compiled in this section as documents, websites, questionnaire and interviews responses. The data sources and their contents are discussed so as to put Namibia SDI into perspective and identify its impending constraints.

6.2.2.1 Namibian Documents and Artefacts

Through physical visit and online searches, the following documents were interrogated;

Table 6.1: Namibia SDI related documents perused

Namibia SDI Related Documents								
(I) Useful Acronyms								
a. Namibian Government (NG)								
b. Spatial Data Infrastructure (SDI)								
c. Naminia Statistics Agency (NSA)								
d. Namibia Document (ND)								
(II)The Documemnts								
Code	Document Title	Creator	Subject	Publisher	Source	Typology	Pages	Year
ND1	Statistics Act	NG	Statistics and SDI	NG	Government Gazzete	Act	38	2011
ND2	National Spatial Data Infrastructure Policy	NSA	SDI	NG	Government Gazzete	Policy	16	2015
ND3	NSDI Strategy and Action Plan 2015-2020	NSA	Strategy	NSA	NSA	Report	45	2015
ND4	Media Release NSDI Strategy and Action Plan	NSA	Communication	NSA	NSA	Media Release	3	2015
ND5	The manner of capturing spatial data including any application for exemption from such manner or specification	NSA	Data Capture	NG	Government Gazzete	Policy	8	2016
ND6	Metadata standard on the manner for the capturing and publishing of Metadata for spatial data and services in namibia	NSA	Metadata	NG	Government Gazzete	Standard	11	2016
ND7	Data quality standard for the purchase, capture, collection, production and dissemination	NSA	Data quality	NG	Gvernment Gazzette	Standard	12	2016
ND9	NSDI Namibia Newsletter	NSA	News	Nsa	NSA	News	4	2016
ND10	Namibia GIS-NSDI Forum 2018	NSA	Forum	NSA	NSA	Program	3	2018

Republic of Namibia has a number of SDI documents associated with it. The principal documents for this SDI as reported in table 6.1 are; "Statistics Act", "National Spatial Data

Infrastructure Policy" and "NSDI Strategy and Action Plan 2015 – 2020". The Act and Policy pronounces the official recognition and status of SDI in Namibia while the strategic plan sets out its vision, mission and goals within a five-year term. These documents articulate that, the inception and structuring of the Namibian SDI as a National NSDI (NSDI).

(a) The Namibia SDI Act

In the Act, Section 47; "*SDI is established as the national technical and institutional framework to facilitate the capture, management, maintenance, integration, distribution and use of spatial data*". The Act further established a Namibian SDI structure with four fundamental anchor authorities being; (a) The Minister of Economic Planning and Director-General of the National Planning Commission as the political authority (b) Statistician General as the Administrator (c) the Spatial Data Committee (SDC) as the Advisory and (d) the Surveyor General as the Chairperson of Committee of Spatial Data. This structure as perceived by NSA is presented in figure 6.3.

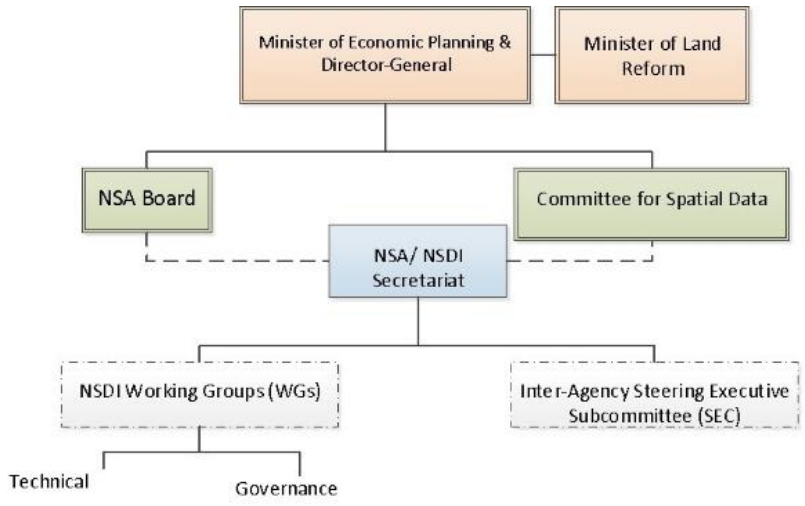

Figure 6.2: The Namibian SDI governance structure. (Source: https://nsa.org.na/page/about-nsdi/).

Other important features of Namibian SDI include its functions and restrictions. The functions are mostly pronounced through the establishment of the Namibian SDI and the Committee of Spatial Data while the restrictions specifically refer to establishing of policies and standards. According to this Statistics Act of 2011, spatial data policies and standards cannot be developed without the sanction of the SDC.

(b) The Namibian SDI Policy

Following the Act and its provisions the SDC was established and NSDI Policy developed and adopted in 2015. Namibia NSDI policy is an end product of a concerted effort since 2003 involving a number of players, such as the erstwhile Central Bureau of Statics, NSA, MLR, visiting consultants and an international body known as Luxembourg Agency for Development Coordination. This policy has been developed to take into consideration Namibia's role in regional (SADC) and international (UN) geospatial information interests. As a means to implementation of Namibia SDI, the policy proposed the establishment of NSDI Secretariat within NSA, which is now established and operational. The NSDI Secretariat responsibilities is in guiding the implementation process by organising custodians of data, development of spatial data and metadata portals.

The Namibian SDI Policy recognises two streams of data sets being the fundamental and thematic. The collation and construction of these data sets is supported by the inclusion and recognition of the International Standards Organisation (ISO) of geomatics into the Policy. Important attributes of the Policy are presented in table 6.2. A number of attributes associated with this policy have been implemented. Attributes which have so far been implemented include: NSA as the coordinating organisation, identification of data sets custodians, education, funding, standards, technology, spatial data and metadata compilation just to name those observed and verified during the study.

Table 6.2: Namibia SDI policy attributes. (Adapted from Namibia SDI Policy listed in table 6.1)

Policy Attribute	Description
Coordination	Lead by NSA with a robust approach which is inclusive of other stakeholders cooperatively and collaboratively
Standards	Subscribe to the International Standards Organisation suite of standards which are relevant to geomatics and geographic information interests
Metadata	Policy put emphasis on metadata and its reliability which can be measured by data quality specifications, reference systems, data identification information, attribute information, data distributor, data synopsis with conformance mechanism.
Objectivity	Data provided by producers should reflect professional correctness and confidence
Timeliness	A schedule known as Advance Release Calendar is to prepared to aid the data processes
Transparency	Data processes to be clearly defined by custodians and special access allowed to minister responsible for SDI
Interference	It empowers the Statistician-General's to act against anyone who impedes the execution of the SDI mandate as per the act
Technology	Surety in provision of Information and Communication Technologies (ICT) to support the NSDI by government
Updates	Regular data updates by custodians emphasised such that all data sets should be so updated at least once every ten years

Data Quality	Data qualities ate going to be set and data producers will be having a duty to using and reporting them. Data not complying with set standards will be rejected and producers requested to follow set standards and resubmit to NSDI portal
Access	Namibia SDI is advanced as highly user-centric where NSDI Secretariat and the custodians ensures unimpeded access to various users locally, regionally and internationally
Dissemination	Dissemination of the data is also highly encouraged through publishing in user friendly mediums using English language and translation to other languages as the need arises
Pricing	An indication has been given for zero-production for all existing and available data. Cost recovery is allowed as necessary. In the future a robust pricing approach will be developed
Storage	A storing and archiving strategy that is spear headed by custodians to ensure that data is not lost. A policy is going to be developed to guide this process.
Government Access	Government employees being allowed free access to the NSDI to facilitate their regular work and delivery
Users	The emphasis placed in user satisfaction are such that custodians should ensure that their data is discoverable and must ensure a robust feedback strategy with the users.
Copyright	It refers to copyright and intellectual property which is vested with government of Namibia and custodians ensuring its realisation.
Confidentiality	Data confidentiality emphasised through data custodians e.g. right to privacy must be protected at all times
Liability	Liability in the process of data access and service based on good faith and practice so as to protect government and employees
Funding	Policy tasks government with the responsibility of funding the SDI.
Capacity	To be kick-started by NSA and sustained by the data custodians
Education	NSDI is viewed as a worthwhile endeavour that should built into Namibia school curriculum and awareness programs designed by NSA and other stakeholders to raise awareness across the whole of the Namibian community.
Implementation	Refers to implementation of NSDI policy guided by good governance, harmonised laws, national vision named "Vision 2030", coordination, outreach programs, value adding partnerships and regional SDI alignment
Review	Regular reviews on implementation process and policy to be undertaken to ensure that the SDI as established remain relevant to the recurring changes in institutional, technological frameworks and other trends.

The government of Namibia through NSA funds NSDI, while the identified data sets custodians provide residual finance within the frameworks of their operations. By the time the research fieldwork was conducted, a number of data custodians were already identified and collaborative partnerships towards SDI started. The identified custodians are the following: Ministry of Mines & Energy; Ministry of Agriculture, Water & Forestry; Ministry of Land Reform; Ministry of Safety & Security (Nampol); Ministry of Education, Art & Culture; Ministry of Urban & Rural Development; Ministry of Works & Transport; Ministry of Health & Social Services; Ministry of Environment and Tourism; Ministry of Fisheries and Marine Resources; Namwater; Nampower; Roads Authority; National Heritage Council; Communications Regulatory Authority of Namibia; Namibia Statistics Agency; Geocarta Namibia; Geo-Business Solutions. These organisations are mostly from government and a few from private sector. The Non-Governmental Organisations (NGOs) are currently not active in the NSDI activities but NSA as the coordinator is pursuing and encouraging them to come forward and participate.

(c) The technical Outlook

In terms of data for Namibia SDI, quality is based on spatial data accuracy, precision and attribute correctness. Data quality standards are articulated through regulatory documents shown in table 6.1, which include: "*The manner of capturing spatial data including any application for exemption from such manner or specification*"; "*Metadata standard on the manner for the capturing and publishing of Metadata for spatial data and services in Namibia*" and "*Data quality standard for the purchase, capture, collection, production and dissemination*".

The document about spatial data capture, explains data sets, typology, their categories and restrictions with respect to the NSDI and associated quality requirements. The documents on Metadata articulates issues relating to their requirements in Namibia focussing on spatial data and services. Metadata categories have been put forward to represent various class of feature data sets such as Administrative boundaries (ADM), Business and Economy (BUS), Cadastral (CAD) and many more. Spatial data capture and metadata documents are reflective of each other and the metadata emphasises data requirements as; Mandatory (M), Conditional (C), Optional (O) and Namibia required (N) following metadata specifications of ISO TC/211. These requirements indicate that data being uploaded to Namibia SDI need to be subjected to data audits and flagged accordingly. The documents emphasise ISO data qualities and the need to make acknowledgement on the thematic nature that is associated with data quality. The quality document listed in table 6.1, pronounces the general guideline of data quality as subject to the following; completeness, logical consistency, positional accuracy, temporal accuracy, thematic accuracy, quantitative thematic accuracy, purpose usage and lineage.

(d) Namibia SDI Strategy

With NSA in the lead, a five-year strategy running from 2015 – 2020 has been coined for the Namibian NSDI. The Namibian National SDI Strategy document pronounces its mission as:

> "*to coordinate, facilitate, and support the implementation of an information infrastructure that ensures efficient production, use, maintenance and dissemination of relevant, quality and accurate spatial information that is fit-for-purpose, particularly in providing evidence-based decision making at all levels of the society*".

This mission statement abundantly reflects the attributes that are associated with the Namibian SDI Policy. When achieved, this mission statement will be mirrored by the associated vision

statement which reads "*to be a leader of quality spatial data delivery in Africa in accordance with international standards and best practice*". The vision statement emphasizes quality not just for the local scenario, but also for the regional and international community. In overall the mission and vision statements set out quality at the centre of the Namibian SDI.

The Namibian SDI strategy is scaled up against other fundamental national economic developments such as the National Development Plans (NDP), e-Government Strategy and Vision 2030. The realisation and inclusion of NSDI in the NDP is a big political achievement, as it means SDI get to be planned and budgeted for among other national development endeavours. With respect to the e-government strategy, an opportunity has been created for technology and associated requirements to be afforded, while in relation to vision 2030, it implies SDI is now recognised to be playing a fundamental role in the overall development perspectives of the Republic of Namibia.

Four goals with measurable variables forms the pillars of the Namibian NSDI strategy. These goals are listed in table 6.3 with their defining objectives and indicators with a proposition for performance measurement scales based on Mwange *et al* (2016). The goals have been coded with one or two words but fully recited so as to appreciate their substance. In addition, a single word to three-word phrase approach is also followed in summarising objectives and indicators related with the goals. What is to be noted is that, these goals are treated as Composite Constraints, while the objectives and the indicators are categorised as Intermediate and Underlying Constraints respectively.

The Namibian NSDI strategy is comprehensive and has clear set dates of the intended achievement of goals and objectives. The ambition set out is that, all the summarised goals and their associated objectives be achieved within the period 2015 – 2020. The inception of this NSDI has been impressive and growth is steady, focussed and bearing a lot of potentials. As this SDI moves towards maturity there is need to optimize its goals through quality structures relating to governance, access, capacity and duplication. These quality structures require equally robust development and evaluation protocols. Table 6.3 forms a proposition for performance measurement of the Namibian SDI at the end of the current plan period in 2020. This is customised SDI On-Going Improvement (SDIOGI) for Namibia.

Table 6.3: Namibia SDI strategic goals, objectives and indicators. (Adapted from Namibia SDI Strategy listed in table 6.1)

GOALS (Composite Constraints)	**OBJECTIVES (Intermediate Constraints)**	**INDICATORS (Underlying Constraints)**	Extremely low = 1	Very low = 2	Low = 3	Medium = 4	High = 5	Very high = 6	Extremely high = 7
GOVERNANCE STRUCTURE: "*An NSDI with governance structure that can efficiently operate the NSDI and sufficient funding to ensure is implementation and long-term sustainability nationwide*".	Administration	Regular meetings							
		Implementation							
		Realisation							
	Coordination and use	Agency participation							
		Partnership Agreements							
		Activity logs							
	Intellectual property	Legislation enhancement							
		Dissemination							
		Use							
	Sensitive Data	Guidelines production							
		Guidelines distribution							
		Guideline implementation							
	Funding	Establishment							
		Temporal							
		Utilisation							
ACCESS: *"An NSDI that facilitates access to, and maximises the use of, quality, timely and accurate spatial data"*	Data acquisition	Inventories							
		Capture							
		Conservation							
		Openness							
		Maintenance							
	Standards	Approval							
		Timeliness							
		Implementation guidelines							
		Compliance							
	Use	Metadata Capture							
		Meta data quality							
		Yearly geoportal visits							
		Pricing							
		licensing							
CAPACITY: *"An NSDI that commits sufficient attention and resources to building capacity nationally to sustain national development and that helps create and informed society"*	Awareness	Communication plan							
		Monitoring							
		User satisfaction							
	Resourcing	Staff competency							
		Help desks							
		Capacity building							
	Information society	User needs							
		User feedback							
		User educational materials							
		Socio-economic benefits							
DUPLICATION:	Cost reduction	Harmonised data acquisition plans							

"An SDI that helps to eliminate duplication of effort in spatial data collection and use and reduces waste of limited resources"		Shared data acquisition							
		Data updates							
		Cost saving projections							

(e) Namibia SDI Communication

Evidence in Communication is inferred from *NSDI Media Release*, *NSDI Namibia Newsletter*, and *Namibia GIS-NSDI* Forum 2018 reported in table 6.1. The media release which was done in 2015 introduced the nation to NSDI in terms of articulating the responsible authorities, required technologies and associated public good products. The newsletter released in 2016 indicate continuity in Namibia SDI as it reports on a number of fundamental milestones such as the spatial data technical standards, NSA collaborations and benchmarking in some European countries i.e. Sweden and Norway. Namibia GIS-NSDI Forum, is a more recent activity as it was done in mid-2018 as a communicative forum which announces the Namibia SDI nationally and internationally. The documents summarised here goes to show clarity on the intention of NSA regarding Namibia SDI communication. The communication portrays consistency and temporal exposure on the progression of Namibia SDI since 2015.

6.2.2.2 Namibia Geoportals/Webs

In Namibia four websites/geoportals were discovered and they are listed in table 6.4.

Table 6.4: Namibia SDI Related Websites/Geoportals

Namibia SDI Related Websites/Geoportals						
(I) Useful Acronyms						
a. Namibian Government (NG)						
b. Spatial Data Infrastructure (SDI)						
c. Naminia Statistics Agency (NSA)						
d. Asplan Viak Internet (Avinet)						
(II)The Nabiabian Websites/Geoportals (NW)						
Code	Website/Geoportal	Owner	Subject	Data and information capabilities	Capabilities	Year
NW1	http://geoportal.rcmrd.org/layers/servir%3Anamibia_sentinel2_lulc2016	RCMRD	Environment	Land cover, Settlements, Districts boundaries, Major Roads and Rivers	Visualisation and download ((SHP, KML, JPEG, PNG, Text, PDF)	2016
NW2	http://norplan.com/namibia-spatial-data-infrastructure/	Norplan	SDI Development	Project brief	Reading	2017
NW3	http://geofind.nsa.org.na/	NG-NSA	Metadata	Various Themes	Visulisation and download	2017
NW4	https://digitalnamibia.nsa.org.na/	NG-NSA	Geoportal	All discovered Namibian geospatial data sets	Multi-scaled and comprehensive ((SHP, KML, JPEG, PNG, Text, PDF)	2017

The geoportal and metadata portal of Namibia have been reported in table 6.4. Existing spatial data and metadata have been developed in collaboration with Norwegian SDI-oriented company. These were constructed following the bench-marking sojourn in Norway which

resulted in utilisation of the Asplan Viak Internet (Avinet) technology. Technologies from Avinet which are open source systems utilising QGIS, Postgress and Map Server are used to support Namibia SDI. Owing to this technologies, portals have since been constructed in 2017 and they can be found at http://geofind.nsa.org.na/ (metadata) and https://digitalnamibia.nsa.org.na/ (geoportal). These portals are functional and accessible and can be accessed by any one with devices having an internet connection. Just like the rest of the other SACU countries, Namibia is featured in RCRMD effort, but commendably, it has endeavoured to develop its own National SDI geoportal and metadata resources.

6.2.2.3 Namibia Response

In Namibia, SDI activities were pointed out by literature to the National Statistics Agency (NSA) where a coordinating unit is established. High ranking officer from this National SDI coordinating unit answered the questionnaire and the response is captured in table 6.5.

Table 6.5: Namibia SDI Coordinator Perspective Views Response

No.	Question key phrase	Namibia Response (National Statistics Agency)
1	SDI time origins	*The current NSDI policy for Namibia has been under development since 2009, but 2003 draft NSDI policy has also been considered during the process.*
2	SDI Main Players	*The Namibia Statistics Agency and its predecessor the Central Bureau of Statistics, the Ministry of Lands and Reform, other producers and users of spatial data, as well as other national and international contributors.*
3	Recent SDI status	*NSDI in Namibia is currently at the early implementation stage of it is first 5 years strategic plan that was approved in October 2015 after the NSDI policy that was gazetted in March 2015.*
4	Country SDI interactions	*The NSDI Secretariat (NSA) has been creating awareness in organisations that are custodians of spatial data in the country, so that they can sign NSDI partnership agreements. Currently, eleven (11) institutions that produce spatial data have signed MoUs and nine (9) of those are represented on the NSDI steering executive subcommittee (SEC) which is collaborative platform for NSDI organisations.*
5	SDI Constraints	• *Lack of co-operation from some organisations* • *Lack of quality data for the infrastructure* • *Lack of metadata for the available data sets* • *Inadequate funds to implement all NSDI projects*
6	SDI Benchmarking within SACU	*The Namibian NSDI policy is aligned with regional and international agreements such as those of United Nations and SADC to which Namibia is a signatory*
7	Further elaboration to 6	*The Namibian NSDI is adopting International Organization for Standardization (ISO) standardisation principles on geographic information and geomatics as embodied in the ISO TC/211 suite of standards*
8	SDI inputs	*Funding to implement all NSDI activities, and have infrastructures that can support the development and maintenance of NSDI systems such as a Geoportal*
9	SDI out considerations	*A spatially-conscious nation that has access to spatial data and uses spatial data to make informed decisions.*
10	Country SDI benefits and opportunities	*Benefits* • *Promote effective management and maintenance of spatial data* • *Promotes the use and sharing of spatial data*

		• *Eliminate duplication in capturing of spatial data in support of spatial planning, socioeconomic development and related activities* • *Facilitates the protection of copyright of the state in works relating to spatial data* • *Facilitate the capture of spatial data through cooperation between government bodies and other organs of state.* • *Create an environment which facilitates coordination and cooperation among stakeholders regarding access to spatial data* ***Opportunities*** • *Develop capacity in government institution responsible for maintaining and managing fundamental datasets.* • *The NSA and other stakeholders shall disseminate information to educate and raise the awareness to the public about their functions and other institutions relating to NSDI.* • *A National Geoportal is being developed to allow on-line access of spatial data and by so doing contribute to developing an informed society.*
11	Country SDI coordination and feedback	*The NSDI secretariat (NSA) coordinates the NSDI activities in the country. Furthermore, the NSDI secretariat is being assisted by the Interagency Steering Executive Sub-Committee (SEC) a collaborative platform for NSDI organisations to coordinate activities related to capture and maintenance of spatial data. The main function of the SEC is determine methods of data capture, quality control and assurance together with other custodians and the NSDI Secretariat, contribute to the national spatial data advance release calendar for new spatial data collection projects or updating projects and budget for the maintenance, management and effective dissemination of fundamental datasets as per its national mandate.* *In order to provide feedback, public consultation workshops are held on quarterly basis. An online survey questioner is normal send to all stakeholders who are on the NSDI mailing list to evaluate workshop and general NSDI implementation. Finally a quarterly newsletter is produced to give feedback on the NSDI implementation progress. Once produced the newsletter is send to all NSDI stakeholders via the mailing list and it is uploaded on the NSDI website.*
12	Country SDI plan	*A five-year strategic plan was developed running from 2015 to 2020 to ensure successful implementation of the NSDI.*
13	SDI research	*No response*
14	Country views on SACU SDI	*No response*
15	Participation in current research	*No response*

The above questionnaire re-iterates the development process of Namibia NSDI but emphasize constraints in terms of organisational cooperation, funding, spatial data and metadata qualities. There was no response to questions relating to the importance of SDI research and country views on SACU SDI. Though there was no response on the willingness to participate in this study, Namibia has actively participated in this research and even afforded the researcher the opportunity to take part in its organised SDI workshops.

6.2.2.4 Namibian Workshops

In Namibia, a 1-week workshop was attended at Heja Lodge near Windhoek on 2nd to 6th October 2017. Presentations relating to the attended workshops are reported in table 6.6.

Table 6.6: Namibian attended workshop presentations

Namibian SDI Workshop Presentation Attended						
(I) Useful Acronyms						
a. National Statistics Agency (NSA)						
b. Ministry of Forestry and Marine Resources						
Namibian Workshop Presentation (NWP)						
(II)The Presentations						
Code	Presentation Title	Presenter	Theme	Source	Pages	Year
NWP1	National Spatial Data and Information	NSA	NSDI overview	NSA	15	2017
NWP2	Review of Existing NSDI Policies and Gazzeted Guidelines	NSA	Policy	NSA	28	"
NWP3	Imminent NSDI Policies and Guidelines	NSA	policy	NSA	34	"
NWP4	Possible cooperation of NGOs and the private sector in the NSDI	NSA	Partnership	NSA	20	"
MWP5	Namibia Aerial Imaging Programme	NSA	Data	NSA	20	"
MWP6	NSDI Compliance Programme	NSA	Compliance	NSA	3	"
MWP7	Oceanographic & living marine resources data	MFMR	Marine SDI	NSA	30	"
MWP8	Assessment of Current State of National Data from the NSDI Data Inventory	NSA	Data	NSA	9	"
MWP8	Data Sharing Agreement	NSA	Data	NSA	2	"

The workshops listed in table 6.6, are evidence of a robust program of awareness, capacity building and outreach to Namibia SDI stakeholders. Topics and discussions associated with these workshops have included the SDI Act, Policy, standards, cooperation approaches with the private sector and NGOs, reviewing the existing spatial data, listing on-going data collection efforts, identifying gaps in data and prioritising future data acquisition processes.

6.2.3.5 Namibia SDI Constraints

NSDI in Namibia is subject to a legislative framework and a 5-year national strategy. The five-year strategy set Namibian SDI objective as National with specific goals set out in table 6.3 emphasising efficiencies in governance, access, capacity and duplication. This is consistent to the SDI requirements set out in table 3.2 of the SDIOGI approach with Step 1 and 2 being eminent. To appreciate the constraints that are associated with this SDI, the response to the questionnaire in table 6.5 mentioned co-operation, quality data, quality metadata and funding as the main perceived constraints. An initial plan to addressing these constraints has been elaborated in the policy and strategy document especially those referring to co-operation and funding. In relation to data quality, Namibia has already made progress in coming up with important data quality standards as mentioned in table 6.1. In overall the constraints of the Namibian SDI should be studied in context by subjecting the attributes in table 6.3 to the proposed measurement process as means to assessment. The measurement scales adopted have followed those used in Mwange *et al* (2016). The Namibian SDI is work in progress and its assessment at the end of its plan period will prove to be more objective and comprehensive.

6.3 South Africa SDI Case

In contrast to its SACU partners which have average populations of merely above 2 million, Republic of South Africa has a population of about 56 million inhabitants with a number of settlement centres with populations between 500,000 – 5 million inhabitants. As shown on figure 6.3, South Africa is the largest country within the union, with its surface area of 1,219,912 km^2 consisting of nine (9) Provinces. The 9 Provinces of South Africa with their administration centres in brackets are; Eastern Cape (Bhisho), Free State (Bloemfontein), Gauteng (Johannesburg), Kwazulu-Natal (Pietermaritzburg), erstwhile Northern now Limpopo (Polokwane formerly Pietersburg), Mpumalanga (Mbombela, formerly Nelspruit), Northern Cape (Kimberley), North West (Mahikeng formerly Mafikeng), and Western Cape (Cape Town). The place name changes of Provincial capitals present itself as an interesting phenomenon in the development and revision of geospatial data in the South African mapping industry and development of infrastructures such as SASDI.

Figure 6.3: South Africa with its provinces. (Source: https://www.nationsonline.org/oneworld/map/za_provinces_map2.htm).

Figure 6.3 further reveals three important capitals being Pretoria (national), Cape Town (administrative) and Bloemfontein (judicial). All these capitals underpin a complex governance structure defined centrally, provincially and locally with the President as the head of the Republic, the Premiers leading Provinces and Municipal Council Mayors/Chairpersons leading local governments (South African Government, 1994). These Provinces resulted from the post-apartheid political and governance reformation associated with the 1994 all-inclusive elections in South Africa. In South Africa, the central, provincial and local governments are involved with various services and economic activities meant to advance the aspirations of all South Africans (South African Government, 1994). These governance hierarchies have been given certain levels of independence or autonomy by the constitution in the process of executing their responsibilities to the diverse South African communities. It is within these governance hierarchies and the existing legal framework that spatial data infrastructures in South Africa has to be understood, as stipulated in SDI Act enacted in 2003. Another legislation with a direct bearing on South African SDI (SASDI) is Spatial Planning and Land Use Management Act (SPLUMA) enacted in 2013.

6.3.1 South Africa SDI Discourses preview

When this study begun, Republic of South Africa had a superior SDI Indices compared to all its neighbours in the Southern African Customs Union (SACU) as reported in Chapter 3. The work of Makanga and Smit (2010) read with that of Mwange *et al* (2016), all prove this superiority in terms of SDI status and readiness indices above 0.6 out of 1. South Africa SDI (SASDI) has been abundantly covered in the literature, for instance: SDI clearinghouse status across countries (Crompvoets et al 2004); metadata challenges (Alford, 2009); address data sharing and implications on SASDI (Sebake and Coetzee, 2013); a comparative SDIs assessment for a number of countries (Cooper *et al* 2014); SDI data custodians and meaningful metadata in South Africa (Fourie, 2015), SASDI hierarchical collaborative approach (Siebritz and Fourie, 2015).

According to Cooper *et al* (2014), SDI in South Africa is linked to the mid-1980s efforts of State Interdepartmental Coordinating Committee for the National Land Information System (CCNLIS) which evolved to the National Spatial Information Framework (NSIF) in 1997. NSIF was deployed as a coordinating Directorate within the Department of Rural Development

and Land Reform (DRDLR) with the mandate to advance SDI interest (Cooper *et al*, 2014; Fourie, 2015; Siebritz and Fourie 2015). In 2003, the NSIF facilitated a legislation known as the Spatial Data Infrastructure Act, which was accepted by parliament and signed in to law in 2004. This Act gave birth to what is now popularly known as South Africa Spatial Data Infrastructure (SASDI). The activities of NSIF and various institutions in pursuit of SASDI development are going to be discussed together with the documents and websites mentioned in table 6.7. SASDI achievements are going to be noted and inherent constraints detected.

It is acknowledged, that SASDI discourses are well discussed in literature and that in most cases its achievements are articulated alongside constraints. That is why Cooper *et al* (2014) have alluded to several organisations involved with this complex SDI structure which are listed as the following;

> "*Chief Directorate: National Geospatial Information (NGI); Statistics South Africa; Municipal Demarcation Board; Independent Electoral Commission; Provincial Departments of Traditional Affairs; South African National Space Agency (SANSA); South African National Roads Agency (SANRAL); Provincial Government; Local Authorities; South African Geographical Names Council (SAGNC); Eskom; Department of Water and Sanitation; Chief Surveyor General; Provincial Surveyors General; Department of Agriculture, Forestry and Fisheries; Registrar of Deeds, and Catchment Management Authorities (CMAs*)".

Regarding some of its achievements, Cooper *et al* (2014) points at adoption and customisation of a number of ISO/TC 211, OGC and South African standards into SASDI. A good example regarding work on standards is the metadata one, where ISO 19115 is customised as SANS 1878-1. According to Cooper *et al* (2014) there is evidence pointing to lack of expertise relating to SDI in South Africa, but NSIF as the secretariat has been committed in undertaking training program and this has been highlighted by workshops listed in table 6.12.

In the study of Alford (2009) supported by the article of Fourie (2015), challenges are indicated regarding spatial metadata in SASDI such that, at worst some data sets did not bear it. Funding, technical capacity, data custodianships, data governance procedures, data relevance, incomplete metadata, metadata maintenance, updates and inconsistent standards were found to

be among the major constraints associated with spatial data in South Africa (Alford, 2009). Siebritz and Fourie (2015) had tackled the issue of collaboration and have found that there is a disconnect between spatial data custodians in South Africa, much to the disadvantage of SASDI development. Some of these problems were noted in Sebake and Coetzee (2013) who used three case studies of organisations (*a municipal authority, national public organisation and private company*) that are highly involved with address data, to evaluate for motivators, barriers and indicators in spatial data sharing and its impact on SASDI. A notable challenge in Sebake and Coetzee (2013) related to collaboration, whereby the organisations used as cases in the study expressed willingness to share data, but held to the belief that their data was the best in terms of quality. Sebake and Coetzee (2013, p. 17) further raised the alarm by saying "*South Africa's high staff turnover problems and resulting lack of technical skills could jeopardize the SASDI implementation, even if all other aspects of SASDI are well managed*". This statement from Sebake and Coetzee (2013) is consistent with the requirements of the SDIOGI which emphasises the importance of identifying the main constraint and solving for it over SDI implementation life-cycle.

6.3.2 South African Results and Responses

The South African SDI results and responses are compiled and discussed in the following sub-sections. The discussions take into consideration fundamental discourses associated with SASDI such as: legislative framework, The Base Dataset Custodians, Strategy, Communication and Marketing, Spatial Data Pricing, SASDI Technical Outlook and Constraints.

6.3.2.1 South African SDI Related Documents

Through physical visit and online searches, the documents listed in table 6.7 were discovered. These documents are not necessarily exhaustive so far as SASDI is concerned but they form a basis upon which to discuss and find solutions for SASDI in terms of the constraints experienced in the process of its implementation. These documents are discussed in terms of the legislative framework, base data custodians, technical outlook, strategy, spatial data pricing, communication and marketing. Constraints, challenges or bottlenecks are identified in the process of the discussions.

Table 6.7: South Africa SDI related documents perused

South Africa Spatial Data Infrastructures Related Documents								
(I) Useful Acronyms								
a. South African Government (SAG)								
b. Council for Scientific and Industrial Research (CSIR)								
c. Gauteng Provincial Government (GPG)								
d. Department of Rural Development and Land Reform (DRDLR)								
e. National Spatiald Information Framework (NSIF)								
f. South Africa Spatial Data Infrastructure (SASDI)								
g. Committee of Spatial Information (CSI)								
h.South African Document (ZAD)								
(II)The Documemnts								
Code	Document Title	Creator	Subject	Publisher	Source	Typology	Pages	Year
ZAD1	Spatial Data Infrastructure Act	SAG	SDI	SAG	Government Gazzete	Act	53	2004
ZAD2	Regulations Made in Terms of Spatial Data Infrastructure Act of 2003	DRDLR	SDI	SAG	Government Gazzete	Regulation	26	2017
ZAD3	Base Data Set Custodianship Policy	CSI	Custodianship	DRDLR	CSI	Policy	11	2015
ZAD4	Policy on Pricing Spatial Information Products and Services	CSI	Pricing	DRDLR	CSI	Policy	10	2015
ZAD5	Draft South African Spatial Data Infrastructure Compliance Guidelines	CSI	Compliance	DRDLR	CSI	Guidelines	18	2017
ZAD6	Draft Framework for the South African Geo-Information Management Strategy	CSI	Strategy	DRDLR	CSI	Framework	18	2017
ZAD7	The South African Spatial Data Infrastructure Newsletter	CSI	SDI	NSIF	CSI	Newsletter	3	2017
ZAD8	The South African Spatial Data Infrastructure Newsletter	CSI	SDI	NSIF	CSI	Newsletter	3	2018

(a) The legislative framework

As already alluded to in Cooper *et al* (2014), RSA enacted SDI Act in 2003 and assented to it in 2004 and started serious work on its mandate in 2010 by constituting the Committee for Spatial Information (CSI). The SASDI Act of 2003 is simply defined as "*the national technical, institutional and policy framework to facilitate the capture, management, maintenance, integration, distribution and use of spatial information*". This definition has been largely adopted by the Namibians and crafted into their Statistics Act of 2011 discussed earlier in this chapter. In sharp contrast to the Namibian Act, RSA act does possess a number of attributes which are fundamental to SASDI progression and general discourses. The SDI Act attributes are compiled in table 6.8.

Table 6.8: SASDI act attributes. (Adapted from South African Spatial Data Infrastructure Act 2003 listed in table 6.7)

Attributes	Responsibilities
Administration	Act is administered by multiple stakeholders reminiscent of the South African governance structure
Standards formulation	SASDI standards are to be formulated by the Minister of DRDLR
Standards Adherence	Data custodians and data vendors
Metadata processes	Data custodians have a duty of capturing and publishing metadata with provision to exemption by the Minister
Access	Control and responsibility acceded to the Information Act of 2000
Supply	This subscribe to the concept of outsourcing whereby the custodians give their data to a vendor for production of value-added products

accountability	In the event of the supply approach, the custodian remains answerable to their data and value-added products in terms of standards and data quality
Agreements	This empowers data custodians, vendors and users to get in to licensed arrangements as way of advance community interests without compromising the copyright of government and other users
Collaborative maintenance	These are data exchange arrangement that can be entered into by various custodians with appropriate timelines and restrictions relating to copyright
Data Quality Reporting	This allows for reporting of deficiencies in data qualities by users to the suppliers
Security	Custodians are bestowed with responsibility of ensuring the security of the data they capture and supply to protect state and individuals against harm
Delegation of powers	These are the powers bestowed on the Minister of DRDLR to give any other employee of government sanctions to this act, but with the restrictions to making regulations.
Regulations	This confers a broad mandate on the Minister of DRDLR to come up with regulatory instruments that support implementation of the act.
Liability	This takes of responsibility of liability where the harm is occasioned in proper execution and well-intended outcomes of the dictates of SASDI.

This Act has been re-enforced by a number of instruments as per the administrative responsibilities of the stakeholders. One such re-enforcement is the regulatory instrument of the Act which was signed into effect by the Minister of DRDLR in 2017. In table 6.8, this regulatory instrument is reported as "*Regulations Made in Terms of Spatial Data Infrastructure Act of 2003*". A number of compliance forms have been included in these regulations and in this study, they are categorised into two main classes being; Administrative Due Diligence Instruments (ADDS) and Spatial Data Due Diligence Instruments (SDDDS). The ADDS are specifically dealing with committee vacancies and appointments – they include: The Minister's response to a decision of CSI, nomination form for membership of the CSI, nomination form for membership of the CSI Subcommittee and declaration form of persons nominated as members of CSI. SDDDS Instruments focus on data handling processes, what is called Data Capture Project Register (DCPR) and the forms include: reporting perceived error deficiencies of spatial information; Request approval from CSI for spatial data capturing by base data non-custodian; informing CSI on spatial data capture intentions by base data custodians. It is fundamental to note the difference between non-custodians and custodians. The non-custodians of base data sets are required to apply for data capture and get appropriate approval from the CSI. The custodians on the other hand already have permission to capture data, but they have to inform the CSI so as to ensure that proper control mechanisms are put in place.

Other instruments relating to SASDI Act are Policies and guidelines reported in table 6.7 as the following: "*Base Data Set Custodianship Policy*"; "*Policy on Pricing Spatial Information Products and Services*"; "*Draft South African Spatial Data Infrastructure Compliance Guidelines*". These were enacted to enhance the SASDI Act and the base data custodians are

identified with objectives for them to provide appropriate and accurate spatial data (authoritative data sets) to SASDI.

(b) The Base Dataset Custodians

The base data set custodian Policy also emphasizes the requirements for cooperative and coordinative frameworks meant to guide all towards achieving the primary duties on spatial data provision. The approach to SASDI data is guided by the Base Data Set Custodianship Policy reported in table 6.7. This policy emphasizes the requirement for the Base Datasets and their custodians as key to advancement of SASDI. In its nature the Base Dataset should possess the characteristics of multi-referencing and use across several sectors of the economy. The Base Dataset has to be accurate and reliable with comprehensive coverage of locations. The NSIF has already done work to define Base Dataset, the criteria for its recognition and identification for custodians (Fourie, 2015). Work done has produced the Base Datasets together with the custodians summarised in table 6.9. According to Cooper *et a*l (2015), 10 Base Data Sets have been defined for SASDI, therefore Social Statistics and Land Use custodian appointments are still under consideration. The 8 data sets defined by far are the following:

1. Administrative Boundaries: which represents the hierarchical outlook of the South African governance structures e.g. municipalities, districts, province and national. In addition, it covers water marks such as rivers as fundamental in boundary determination.
2. Imagery: which represent the comprehensive geospatial data of the whole country through satellite and areal methods.
3. Land Cover: this covers for the extensive South African eco system and its classification as cartographic deductions of imageries.
4. Geodesy: which represents the referencing framework of the country and importance of accuracy and interoperability of geospatial data sets.
5. Transport: represents the fundamental links facilitating transportation processes.
6. Hydrology: represents comprehensive geospatial formation ad spread to water bodies.
7. Conservation: represents South African emphasis on the aspects to environmental protection of historical and fundamental sites.
8. Cadastre: recognises the central role of a cadastre in SDI, interaction with other geospatial datasets and statistical data for completion in evidence-based representation.

Table 6.9: SASDI Base Data Sets and Custodians, Covering 8 of the 10 Pilot Themes. (Source: SASDI Newsletter of 2018 listed in table 6.7).

Theme	Data Sets	Appointed BDSCs
1. Administrative Boundaries		
1.1 Admin Boundaries 1	High Water Marks; Low Water Marks; Maritime Boundary; International, National and Provincial Boundaries	Department of Rural Development and Land Reform: Office of the Chief Surveyor-General
1.2 Admin Boundaries 2	District and local municipalities; Wards; Magisterial districts; and Traditional Authorities boundary	Municipal Demarcation Board
2. Imagery		
2.1 Satellite	Satellite	South African National Space Agency
2.2 Aerial	Aerial Imagery (0.35m - 0.5m)	Department of Rural Development and Land Reform: Office of the Chief Directorate: National Geospatial Information
3. Land Cover	Land Cover	Department of Rural Development and Land Reform: Office of the Chief Directorate: National Geospatial Information
4. Geodesy	Trigonometric Beacons; Town Survey Marks Schemes; Benchmarks; TrigNet GNSS Base Station Network; and Geoid Model	Department of Rural Development and Land Reform: Office of the Chief Directorate: National Geospatial Information
5. Transport	National, Main, Secondary and Other Roads; and Streets	National Department of Transport
6. Hydrology	Water Bodies (e.g. dams, lakes, etc.); Water Resources (e.g. Boreholes and Ground Water); Drainage Network Catchments; and Water Courses and Rivers.	Department of Water and Sanitations
7. Conservation	Conservation and Protected Areas	Department of Environmental Affairs
8. Cadastre	Land parcels and Deeds register attributes	Department of Rural Development and Land Reform: Office of the Chief Surveyor-General

(c) SASDI Strategy

A specific SDI strategy has not been discovered in South Africa but a spatial information management strategy that is aligned with SASDI was found. This strategy was at the time of data collection, still in a draft form and is known as; "*the South African Geo-Information Management Strategy (SAGIMS*)" as reported in table 6.7. This draft strategy recognises society, government, industry and academia as stakeholders in spatial information. The draft strategy defines these stakeholders this way;

> *"Government includes all spheres of government as well as entities/parastatals. Academia includes all institutions providing education and training in the country. The industry refers to the business/private sector, while society includes individual citizens, civil society organizations, religious organisations, and non-government organizations, etc"*

From the definition it can be inferred that stakeholders represent all in South Africa. This strategy is envisaged for review every five years once it is adopted. In its inception, key principles it must address are "*Accessibility, Availability and Usability*" of spatial information for the benefit of its stakeholders. The strategy makes emphasis on far ranging spatial information fundamentals such as governance, data, ICT infrastructure, innovation and capacity building. In summary South Africa spatial information strategy is work in progress, but it does give a clue on its purpose and futuristic intentions. SAGIMS also implies a number of constraints associated with geospatial information management in South Africa, for instance: management, institutional, technology, legal, resources, economic, social, political, global and technology influences.

(d) Communication and Marketing

SASDI activities have been widely communicated within government, academia and to some extent the industry. The society is left behind as revealed by prevailing documents, trainings and technical platforms mentioned in this section. In table 6.7, two documents reported as "*The South African Spatial Data Infrastructure Newsletter*" are important in communication. The newsletters, primarily focus on the interest of government, industry and academia stakeholders with emphasis on capacity building and Base Data Sets Custodians.

A great vacuum still exists in advancing the SDI concept to the society which has been realised in the draft SAGIM Strategy document. What is encouraging, is that the CSI has established a committee which is dedicated for marketing and communication. Information relating to this committee can be found in one of the South African workshops named "*Promoting awareness of CSI activities and the importance of spatial information*" found in table 6.12. The work of this committee cuts across the whole of South Africa, taking all stakeholders into consideration. Through a productive marketing and communication plan, the committee is in the process of reaching out to all stakeholders, to identify with and use SASDI. The committee, has extended responsibilities of communicating SASDI activities with the regional and international communities, which can at this stage, be categorised as key to Regional SACU SDI proposition.

(e) Spatial Data Pricing

Pricing in conjunction with data custodians' Policy, are meant to facilitate open data and accessible spatial data systems. The model that SASDI Pricing Policy advances, is based on cost recovery which basically refers to the actual cost as per the request of the user and it should never go beyond items like printing, USBs, postage etc. This policy promotes a free for all access approach to spatial information by stakeholders in line with *South African Promotion of Access to Information Act* of 2000.

6.3.2.2 SASDI Technical Outlook

The technical view of SASDI is discussed within the frameworks of its technical standards, technologies and systems. Republic of South Africa has developed a number of standards and technologies intended to aid progression of SASDI. These standards and technologies are part of the SASDI training program as reported in Table 6.12, e.g. "*SASDI prescribed standards*" and "*SASDI Enabling Technologies and Systems*". The prescribed standards have been based on ISO 19115 which prescribes and direct how metadata standards should be structured. Through the South Africa Bureau of Standards, the ISO 19115 has been customised and profiled as South African National Standard (SANS 1878-1). Based on this standard an Electronic Metadata Catalogue (EMC) has been developed and hosted through the South African Earth Observation Network (SAEON). Standards, have also been developed for Data Collection Product Register (DCPR) based on ISO 19131:2007 and data classification named SANS 1880:2014. SANS 1880 is a data dictionary. SASDI standards does recognise the use

of various languages in South Africa, which is considered as resourceful in bringing the SDI concept nearer to all users across the country.

6.3.2.3 South Africa Geoportals/Webs

In South Africa, as shown in table 6.10, six (6) websites/geoportals were obtained using the search criteria suggested which are "South Africa Spatial Data Infrastructure" and "South Africa Geoportals" and "South Africa Metadata".

Table 6.10: South Africa SDI Related Geoportals

South Africa SDI Related Websites/Geoportals						
(I) Useful Acronyms						
a. South African Government (SAG)						
b. Council for Scientific and Industrial Research (CSIR)						
c. Department of Rural Development and Land Reform (DRDLR)						
d. National Geospatial Informationg (NGI)						
e. Regional Centre for Mapping Research and Development (RCMRD)						
f. South Africa Spatial Data Infrastructure (SASDI)						
g. Committee of Spatial Information (CSI)						
h. Africa Institute of South Africa (AISA)						
(II)The South African Websites/Geoportals (ZAW)						
Code	Website/Geoportal	Owner	Subject	Data and information capabilities	Capabilities	Year
ZAW1	http://www.sasdi.net/	DRDLR	SDI	Documets,	Read (PDF, text)	2016
ZAW2	https://africaopendata.org/dataset?tags=gis	Code For Africa	Geoportal	Electrical, health, dermacation, Agriculture, Environment,	Visulisation and Download (PDF, SHP, KMZ, tif, HTML)	2013
ZAW3	http://www.engineeringnews.co.za/article/south-african-spatial-data-infrastructure-is-developing-but-not-as-fast-as-desired-2017-04-10	Engineering news	SDI Development	Article	Read (text)	2017
ZW4	http://www.ngi.gov.za/	NGI	Geportal	Topo, Imagery, Geodetic, Maps, News, Events and advisory	Visualise, Read and download (SHP, Text, PDF)	2013
ZAW5	http://gsdi.geoportal.csir.co.za/	CSIR	Geoportal	Atlases, Documents, News, Research	Visualise, Read and download (SHP, Text, PDF)	2000 - 2009
ZAW6	http://geoportal.rcmrd.org/	RCMRD	Geoportal	Land cover, Settlements, Districts boundaries, Major Roads and Rivers	Visualisation and download (SHP, KML, JPEG, PNG, Text, PDF)	2016

SASDI does have a website http://www.sasdi.net/, which is used for awareness and agenda setting, documents repository and some portals. This website has been acknowledged in table 6.10. Other websites which advances the SASDI case have been identified along the SASDI website. These websites include: National Geospatial Information (NGI), South African Earth Observation Network (SAEON) which hosts EMC; Council for Scientific and Industrial Research (CSIR) which supports national SDI research agenda and standards development; Code for Africa; and Regional Centre for Mapping Research and Development (RCMRD) which indicates the regional SDI experience in South Africa. These various technological platforms are indicative of how wide SASDI is involved. These technological platforms may not be exhaustive in case others were undiscovered in the study, but SASDI already pose a complex SDI in a number of areas, for example, Base Data Custodians (BDC). According to

workshop relating to BDC table 6.12, the 10 BDC of SASDI were discovered to be having 43 different standards for software technological site licences which carries with it, serious costs implications and coordination.

6.3.2.4 South African Questionnaire Response

In south Africa, the National Spatial Information Framework within National Geo-spatial Information (NGI) in Cape Town was sent questionnaire who in turn forwarded it to the central NSIF Coordinator in Pretoria where it was answered and the results are presented in table 6.11.

Table 6.11: South Africa SDI Coordinator Perspective views response

No.	Question key phrase	South African Reply
1	SDI time origins	*Early efforts started in 1985 with the formation of a National Land Information Committee and it was on a voluntary basis. The formal framework was established in 2003 with the promulgation of the Spatial Data Infrastructure Act, No. 54 of 2003*
2	SDI Main Players	*The South African Spatial Data Infrastructure (SASDI) is administered by the Department of Rural Development and Land Reform. The Committee for Spatial Information (CSI) is established in terms of section 5 of the SDI Act and the role of the CSI is to advise the Minister and an Organ of state dealing with spatial information. The main players are members of the CSI and other Organs of state (defined in the SDI Act) capturing and managing spatial information.*
3	Recent SDI status	*SASDI is not 100% implemented however the following are in place:* • *The legislative framework, SDI Act.* • *The CSI is in place and performing its functions,* • *The SDI Regulations published,* • *Base Dataset Custodianship policy published,* • *Policy on the pricing of spatial information products and service.* *Still to done:* • *The SASDI Compliance Guidelines must be finalised,* • *Monitoring and inspections must still be done,* • *Formulate a National Strategy/ Road map that will include the private sector.*
4	Country SDI interactions	*They interact through the Committee for Spatial Information and the six subcommittees established in terms of section 10 of the SDI Act.*
5	SDI Constraints	*Funding and Structural location of SASDI within DRDLR. DRDLR is a custodian for a number of datasets (e.g Cadastre and aerial imagery). This makes DRDLR a referee and a player and thereby raising conflict of interest*
6	SDI Benchmarking within SACU	*Not yet*
7	Further elaboration to 6	*N/A*
8	SDI inputs	*Consultation, Collaboration, Communication, Coordination*
9	SDI out considerations	• *Avoidance of duplication – data must be captured once and be reused* • *Data that is accessible – in line the Promotion of Access to Information Act (PAIA) and the Bill of Rights. Information held by the state is for the people.* • *Data that is available – Custodians are appointed to ensure availability of authoritative data sets.* • *Data that can be used – data used always create an opportunity to be improved* • *Data that is freely available - Only pay for the price of the media used to distribute the information.*

10	Country SDI benefits and opportunities	*Availability of base spatial data for planning and decision making. Defining the roles and responsibilities of government and the private sector provide an opportunity for the private sector to create more value out of the base spatial information. Creating value may result in creating jobs and a better life for all.*
11	Country SDI coordination and feedback	*The coordination is through the CSI and its subcommittees. The CSI has a responsibility in terms of the SDI Act to communicate all its activities and to provide feedback to the people and parliament (via the Minister). The SDI Act also demands that the CSI provide the Minister with an annual report at the end of each financial year.*
12	Country SDI plan	*The SDI Act provides a framework in terms of how SDI should be developed. The development of a roadmap/blue print named the South African Geospatial Information Management Strategy will put a comprehensive plan (30 years) in place. Still to be drafted.*
13	SDI research	*The country supports research and development activities on NSDI. RSA is busy formulating a Research Agenda that will guide research on NSDI in an effort to address national imperatives/challenges.*
14	Country views on SACU SDI	*Geospatial information does not respect the boundaries. Establishing a regional SDI will assists in addressing and streamlining issues of geospatial information management along the borders.*
15	Participation in current research	*As the Department of Rural Development and Land Reform, we support initiatives of this nature as they help the department expand its knowledge base*

From this response, it is clear that those coordinating SASDI would want to close certain gaps they consider as inhibitive to development and progression. In recognition of the available legal framework, funding and organisational positioning of SASDI are perceived as constraints which are prohibitive to its smooth advancement. Guidelines, strategy and monitoring of SDI activities are also perceived as areas which are in need of close exploitation in support of SASDI advancement. The response is also indicative of a desire for a research agenda that can help in directing SASDI advancement. The relevance of a regional SDI is also acknowledged, specifically in reference to international boundaries.

6.3.2.5 Workshops and Presentations

The workshops were mostly attended in 2017. The attended Geomatics Indaba 2017 held in Durban from 21st to 23rd August 2017 was instrumental in SDI related presentations and workshops. Another one-day workshop was attended in Cape Town in South Africa on 15th November 2017 at Kromme Rhee Western Cape Government Training Centre. The workshop sessions attended are listed in table 6.12. The training covers the Act, the structure and its main purpose to help stakeholders internalise and identify with the Act and SASDI systems components. The legislative framework is often discussed as a way of engaging with stakeholders to seek direct involvement and contribution to SASDI Act, Policies, Standards, Guidelines and Technical Issues. Challenges are critically identified, whereby lack of data sharing, duplication, user data requirements, failure to use acceptable standards and data qualities are prominently discussed. Marketing and communication are undertaken in the

capacity building workshops to upraise stakeholders, but also to emphasize their usefulness and functions in SASDI advancement.

Table 6.12: South Africa Attended Workshops Presentations

South Africa SDI Workshop Presentation Attended						
(I) Useful Acronyms						
a. Council for Scientific and Industrial Research (CSIR)						
b. National Spatiald Information Framework (NSIF)						
c. Committee of Spatial Information (CSI)						
d. Department of Environmental Affairs (DEA)						
e. Western Cape Provincial Government (WCG)						
f. South African Spatial Data Infrastructure (SASDI)						
g. South African Workshop Presentation (ZAWP)						
(II)The Presentations						
Code	Presentation Title	Presenter	Theme	Source	Pages	Year
ZAWP1	Introduction to South African Spatial Data Infrastructure	NSIF	Introdiction to SASDI	NSIF	12	2017
ZAWP2	Policies and Legislation for SASDI: Factors, challenges, opportunities and implications for its implementation	CSIR	Legislative framework	NSIF	41	2017
ZAD25	Spatial Data Governance	CSIR	Governance	NSIF	16	2017
ZAWP3	Sharing SASDI Experiences and Application at City of Tshwane	City of Tshwane	Local SDI	NSIF	15	2017
ZAWP4	SASDI prescribed standards	CSIR	Standards	NSIF	12	2017
ZAWP5	SASDI Enabling Technolgies and Systems	CSI	Technology	NSIF	14	2017
ZAWP6	Implementing Spatial Data Governance In the Western Cape Government	WCPG	Governance	NSIF	30	2017
ZAWP7	Where can I get SASDI related Training	CSI	Training	NSIF	27	2017
ZAWP8	SASDI Experience of DEA	DEA	Environmental	NSIF	16	2017
ZAWP9	Promoting awareness of CSI activities and the importance of spatial information	NSIF	Awareness	NSIF	20	2017
ZAWP10	How do I fulfill my role as a SASDI custodian?	CSI	Custodianship	NSIF	22	2017

These workshops are important in facilitating education and research agenda, because NSIF/CSI/CSIR use them to identify challenges and gaps in SASDI development. Technologies and systems development are taught, for instance, the Electronic Metadata Catalogue (EMC) developed under SASDI is taught and stakeholders encouraged to follow and use it for metadata capturing and detect its deficiencies. The training framework of SASDI capacity building is summarised into figure 6.5. In these training workshops, case studies signify experiences brought forward and shared by stakeholders. One such case is the GIS advancement in the city of Tshwane. The City of Tshwane example portrays a typical local government initiative which was started from fragmented GIS use in a municipality, and gradually built and harmonised over the years since early 2000. Currently this local government is exemplary in SASDI advancement, so much that, the base Data Custodian and Pricing Policies are being aligned to its GIS strategy.

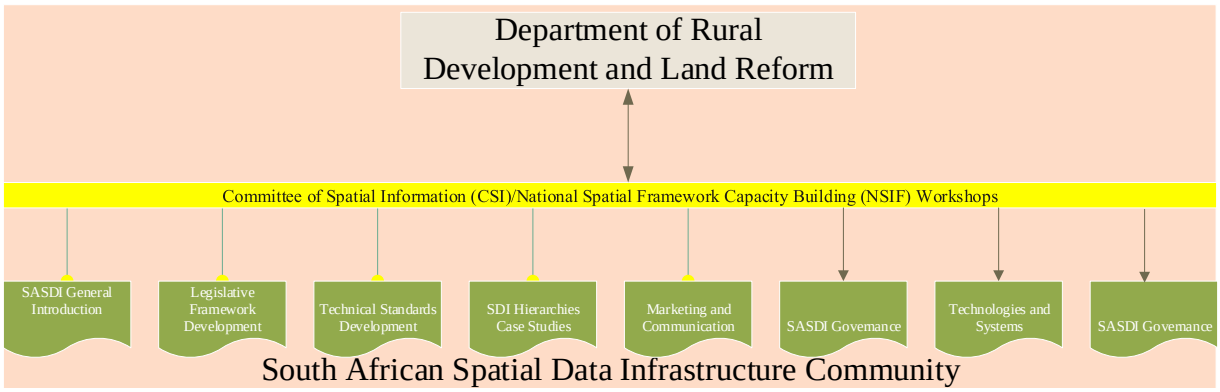

Figure 6.4: SASDI capacity building framework

The second case example presented in training workshops is the Western Cape Government (WCG), which is at the provincial level of governance. Technically WCG does possess various spatial data sets which are usually shared among users across the province, but has been diagnosed that data qualities and processes were incoherent. To address the noted incoherency, spatial governance processes aimed at complying with the SASDI Act, standardized data qualities and skills improvement across producer and user organisations are being pursued. WCG is an advocate for open data sharing and it has developed an open data portal - https://web1.capetown.gov.za/web1/opendataportal/AllDatasets that is host to various fundamental spatial and attributes data sets such as Cape Town imagery, Agricultural land, Air quality, building foot prints, call centre statistics etc. Though the Cape Town open portal is not due to SASDI activities, it is a good example of data repository with about 119 data sets which are downloadable (City of Cape Town, 2018). The two examples mentioned here provide a learning curve for local authorities and provinces to implement SASDI by reconfiguring technical, standards and overall processes to the SASDI Act.

6.3.2.6 South Africa SDI Constraints

In connection to the SDIOGI approach in Chapter 3.4.2, the main objectives of SASDI are deduced from the Act itself. The objectives are led by capture, management, maintenance, use, sharing, duplication, access and copyright state interest in geospatial information. SASDI's main goal is to be a National SDI which is directly linked with various levels of SDIs controlled by Base Data Custodians (BDC). A number of measurable attributes are associated with this SDI and these are recommended for use as performance indicators in line with Step 2 of the SDIOGI. Examples of these indicators include: BDC, SASDI objectives indicators (e.g.

duplication), partnerships and agreements. It is against the back-drop of these performance indicators and the various data sources mentioned in 6.2 that the constraints of SASDI are evaluated.

The work of Siebritz and Fourie (2015) regarding the frameworks of collaboration and coordination further recognized the fundamental role of the South African governance structure of central, provincial and local government in aiding the successful development of SASDI. What this implies is that, the SASDI activities must be permeated through all these structures of governance such that, local SDIs are developed to feed into provincial SDIs which feeds into National SDI or SASDI. Cooper *et a*l (2014, p. 70) had indicated the problematic nature of South African governance structure in relation to SASDI by referring to them as "*multiple stakeholder dynamics*". Cooper *et al* (2014, p.70) describe the scenario this way;

> "*Parliament is responsible for the legislation for SASDI, and DRDLR for the regulations; decision making is with the Committee for Spatial Information (CSI); the main champion is the Chief Director: National Geospatial Information and the secretariat functions are provided by NSIF.*"

The impacts that are occasioned by these stakeholders are gaps that need to be understood so as to advance fitting improvement plans. For this reason, various activities of SASDI are considered to identify gaps and suggest how SASDI could continually be improved, in view of SDI On-Going Improvement (SDIOGI) approach suggested in Chapter 3.

Since 2003 to date, SASDI has been work in progress. Achievements have been made and a lot of challenges met. With the last continental evaluation of SDI in Africa, South Africa scored a readiness index of 0.65 out 1 (Mwange et al, 2016). It can be inferred from the index value that SDI in South Africa, though developing, it is constrained. Through this sub-section, the constraints are identified and presented in table 6.13. These constraints are derived from the various documents listed in table 6.7, evaluation of websites listed in table 6.10, the questionnaire responses found in table 6.11 and contents of workshops listed in table 6.12.

Table 6.13: SASDI Constraints

Constraints	Description
Funding	Funding for SASDI so as to allow it to perform at its envisaged maximum is still found to be a challenge
Organisational Structure	The location of SASDI within its current DRDLR is regarded as problematic and to be possibly adversely affecting its advancement
Governance	Coordination, collaboration and hierarchical organisation of SASDI as per the requirements of the Act. The synchronisation of the local, provincial and national governments in SASDI activities needs to be better modelled.
Marketing	Communication, Consultation, awareness building and feedback processes in respect of stakeholders as defined by SAGMS have challenges. The SASDI concept needs to be packaged to facilitate ownership and participation by the stakeholders. SASDI positive roles in decision making and creating opportunities for stakeholders need to be articulated comprehensively
Human	The requirements of skill sets that are fundamental in SASDI activities. Literally using counts of existing skill sets versus what is viewed as acceptable capacity and skills forecasts.
Standards	These are standards relating to the vital components of SASDI such as data capture and metadata. Accurate, authoritative and dependable data is required to implement the requirements of the Act
Duplication	This is the objective which encourages for data to be collected once then shared and exchanged to advance the economic interest of the state and its people.
Access	This refers to SASDI being freely accessible to the stakeholders to serve their interests
Availability	This is closely related to access but it refers to SASDI being availed at all times to its stakeholders
Usability	This means SASDI must be useful to various interest groups across the country. Stakeholders should be able to discover the data and use it meaningfully
Legal framework	A number of Policies and regulations are still required to guide the implementation of SASDI
Technology	This are the technological specifications and systems that are used and followed in the implementation of the SASDI. The need to regulate the available technologies to meet the requirements of the SASDI.
Strategy	This is a forward-looking framework that SASDI is following in implementation. A research and development agenda must be developed and followed to tackle the various challenges and constraints that are found to be associated with SASDI

The Stakeholders of the SDI in South Africa, as viewed through the proposed strategy document is suggestive that SASDI has become complex. The complexity aspect can be tackled by following the SDIOGI approach by identifying, categorising and ordering constraints for solution. SDI stakeholders are considered better-placed if they identify and seek solutions for their constraints following the SDIOGI proposal.

6.4 Conclusion

This Chapter in comparison to the previous one has exposed the legal framework as fundamental in SDI implementation. SDI implementation processes are far much better in Namibia and South Africa as countries in possession of legal frameworks. Up to until 2011, the Namibian SDI was constrained as originated and did not have any plausible outputs to refer to, but since legislating the SDI concept, a lot has happened. Between 2011 and the end of 2017 Namibia was well on its way to establishing a functional SDI. Another component regarded as important is the institutional framework, and its impact is exposed in relation to coordination issues and lack of dedication of the envisaged stakeholders. For instance, if Republic of South Africa is considered, in 2003, an SDI Act was enacted but SDI

implementation has remained slow due to several reasons related to coordination and lack of focus by stakeholders. SDI implementation in South Africa, has often competed with the core functions of DRLDR and suffered adversely in the prioritisation endeavours. Organisationally Namibia houses its SDI activities under the Finance Ministry at National Statistics Agency and this strikes a fundamental contrast to South Africa which houses SDI under DRDLR.

Republic of Namibia which enacted SDI provision under the Statistics Act in 2011, has made tremendous progress and it continues to benchmark some aspects from South Africa e.g. the geospatial information pricing policy. The constraints, relating to these countries requiring exploitation are more related to processes and outputs for instance; access, usability and availability. SACU countries with SDI legislative framework are more assertive in their implementation programs and identification of the bottlenecks associated with their SDIs.

In this chapter, a context-based SDIOGI evaluation framework has been proposed for the republic of Namibia. The framework is based on the requirements of the SDI strategic framework relating to the Namibia SDI. When administered, the belief is that any goal that tends out to be weak, will act as a bottleneck to the envisaged positive advancement of the Namibia SDI. In comparison, South Africa SDI has been found to be having a much complex governance structure associated with it and its SDI strategy is still work in progress. The structure is legislated in the SDI Act, but undertaking its implementation and management has proved to be a lot demanding and difficult. But South Africa can learn from the Namibian SDI strategy.

Armed with Chapter 5 and 6, the next chapter will concentrate on making a comparative analysis so as to propose an integrated approach in the form of Regional SACU SDI. The belief is that, lower SDIs need to be well established and functional so as to benefit those high in the hierarchy.

Chapter 7 Towards a Regional SACU SDI

7.1 Introduction

SDI is complex and it occurs at various levels of governance (Rajabifard, 2002; Grus, 2010). In chapter 5 and 6, the results and the discussion relating to the five SACU countries have exposed that the concept of SDI within SACU is generally conceived at the national level, but then requiring the intra-organisational structures at different levels to work and be well coordinated for its actual implementation. In addition, the findings in chapter 5 and 6 also exposed that SDIs in the SACU countries are facing various constraints, which needs to be solved to allow for on-going implementation to flourish. A clear-cut difference between these countries has been shown through possession and lack of the legal framework. Two countries that possess SDI legislative frameworks, Namibia and South Africa are experiencing better SDI organisation and progression. Botswana and Lesotho SDI efforts, were found to be without SDI legal frameworks and without much progress in SDI implementation. The SDIs of these countries are considered as vital inputs to the proposition of a regional SACU SDI initiative. The suitability of SACU as a platform for development of a regional SDI is propelled within the frameworks of its structure, mandate and data. The objective of this SDI is put forward in consideration of facilitating SACU economic mandate coupled with environmental concerns.

7.2 Consideration of SACU Regional SDI

South African Customs Union (SACU) is an economic set up between Botswana, Lesotho, Namibia, South Africa and the Kingdom of eSwatini. SACU was instituted in 1910 as a regional integration meant to support and facilitate the economic interests of its members (McCarthy, 2008). As an economic set-up, SACU member states do have common interests defined by what is referred to by McCarthy (2008) as the "*common external tariff*". In pursuit of these interests over the years, SACU has accumulated a lot of attribute data in its operations and this study is proposing a movement towards addition of geospatial data to enhance evidence-based decision making. SACU and its Secretariat are considered as conducive platforms for a Regional SDI capable of aggregating operational efficiencies for the overall good of the region in terms of its economic, socio-political and environmental interests. Though some SACU countries do collaborate in advancing SDIs interests, like Namibia and South Africa, Rajabifard *et al* (1999), recognised collaboration of these nature as cumbersome,

as opposed to the one where the regional members pursue a centralised approach. The scenario on regional collaboration is depicted in figure 7.1 below. According to Rajabifard *et al* (1999), such a centralised regional SDI effort when instituted can go a long way in aiding improved data collection drives, maintenance, partnerships, collaborations, coordination, focus and communication flows within individual member countries and the region.

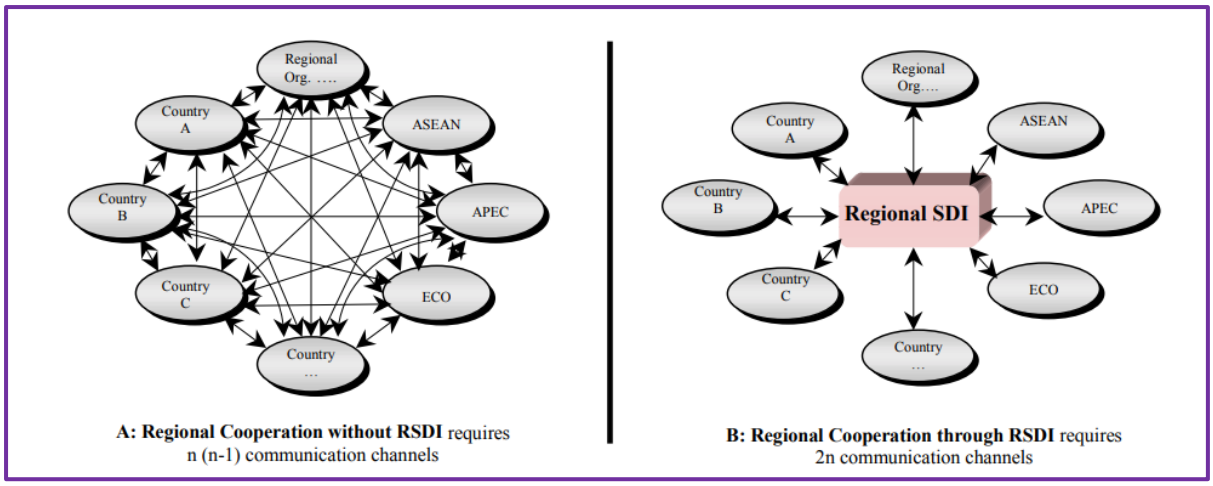

Figure 7.1: Regional SDI collaborative efforts. (Source: Rajabifard et al, 1999)

There are number of studies based around ideas of National and Regional SDIs across a number of countries across the world, for example; the European Union INSPIRE, United States of America National SDI (USA-NSDI) and the Asia-Pacific (Rajabifard *et al*, 1999; Rajabifard, 2002; Comprovoets *et al*, 2006; Comprovoets *et al*, 2018). These examples, in particular INSPIRE and USA-NSDI have been extensively reviewed in Chapter 2 and their successes reported. INSPIRE together with USA-NSDI examples are found to be more suitable to refer to in this study and proposition because, the SACU countries have in their individual SDI endeavours referred to them and have had institutional cooperation on SDI implementation with some members of the European Union, e.g. Sweden and Norway as amplified by Botswana and Namibia cases discussed in Chapter 5 and 6. South Africa in particular has drawn a lot from USA SDI and INSPIRE as can be seen from the comparison which was carried out by Siebritz and Fourie (2015), summarised in table 7.1.

Table 7.1: Comparison of SASDI to INSPIRE and FGDC (Source: Siebritz and Fourie, 2015)

Element		SASDI - National	INSPIRE - International	NSDI - National
		South Africa	**Europe**	**United States**
Institutional	**Coordinating body**	Committee for Spatial Information	INSPIRE Committee	Federal Geographic Data Committee (FGDC)
	Secretariat	National Spatial Information Framework (NSIF).	Joint Research Centre (JRC) is the technical coordinator; Eurostat is the implementing coordinator.	FGDC Secretariat hosted by the United States Geological Survey.
Policy framework	**Legislation**	SDI Act no 54 of 2003: establishes the SASDI, CSI and EMC.	INSPIRE Directive 2007/2/EC: establishes INSPIRE and the EU geoportal.	Executive Order 12906 - Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure establishes the NSDI and national clearinghouse
	Regulations	Draft regulations in terms of the SDI Act for spatial data, spatial information, metadata, datasets and details for the operation of the CSI.	Regulations for metadata, harmonisation of spatial data and services, network services, data and service sharing policies, and monitoring and reporting.	*Not mentioned*
	Policies	i) Data Custodianship; ii) Pricing of Spatial Information Products and Services.	Implementing Rules (IRs) are adopted as Commission regulations/decisions.	i)federal Geographic Data Sharing; ii) Access to Public Information and the Protection of Personal Information Privacy in Federal Geospatial Databases; iii) Support for International Infrastructure Activities; iv) Recognition of non-Federally Authored Standards
Technical Framework	**Metadata facilities**	SASDI (EMC) portal within SAEON Data Portal allows for metadata search and discovery; data may reside with node contributor.	EU geoportal allowing member states to connect their infrastructure; data resides with member states.	National Geospatial Data Clearinghouse; decentralised – metadata is distributed but managed by contributing centrally.
	Dataset custodians	CSI nominates data custodians with legal mandate; process for nomination to be confirmed.	280 Legally Mandated Organisations (LMOs) and 511 Spatial Data Interest Communities (SDICs).	All federal agencies that collect or produce geospatial data either directly or indirectly.
	Base datasets defined	Minimum set of essential datasets that are widely used as a reference base at various administrative levels to accomplish SA's national and international priorities.	*A data set held by a recognised public authority with fiduciary responsibilities to its development, revision and distribution in a given European Union member state jurisdiction. (Defined according to INSPIRE directive Article 4).*	Base cartographic data: the fundamental dataset of geographic data that are normally produced in the preparation of national series general purpose graphic and digital cartographic products.
	No. of data themes	10	34	16

What is pertinent about INSPIRE and USA-NSDI is that they are both subject to legal instruments. Another important point is that these two have been successful as reported in Chapter 2. The INSPIRE and USA-NSDI success stories can be easily inferred on the SDI status of SACU member countries SDIs, whereby Namibia and South Africa are found to have critically done much better as countries possessing legal framework.

In consideration of Regional SACU SDI, the organisations responsible for SDI implementation in the SACU member countries and the Secretariat were used as informants towards that objective. In regard to the organisation responsible for SDI implementation, a questionnaire was used to gauge their views on the proposition of SACU Regional SDI; – Botswana (table 5.4), Lesotho (table 5.10) and South Africa (table 6.11)expressed interest but with minimal commitment while Namibia (table 6.5) did not respond to the relevant questions. But it has been noted in relation to Namibia that its SDI policy puts emphasis in national and regional and international participation regarding its geospatial information. South Africa also depicts the regional and international postures through its SDI capacity building efforts.

Regarding SACU Secretariat, the office of the Executive Secretary was contacted, who directed some officers working in the area of customs, trade data and policy development to assist with data and answering questions emanating from the study. Two officers from Trade Facilitation and Revenue Management and one officer from Policy Development and Research were interviewed regarding the SACU mandate. When interviewed about geospatial information and SDI, the informants acknowledged to be lacking any awareness and understanding of its relevance to SACU mandate and data. In overall, the responses reveal a dim prospective for SACU Regional SDI. Despite the prevailing outcomes in regard to SACU Regional SDI, an opportunity for it is conceptualised through review of SACU mandate with proposed SDI objective, structure, data, SDI efforts of member states and SDIOGI approach.

7.2.1 SACU Mandate versus SDI Objective

SACU mandate is derived from its latest Agreement of 2002 which has eight objectives; (a) improved trans-border trade, (b) equity in economic trade, (c) fair competition practices, (d) increment in investment chances, (e) competitive advantage, (f) global economic integration,

(g) fair revenue distributions and (h) common legislative approaches. According to Gibb (2006, p. 595) the SACU Agreement of 2002 have three main areas being "*institutions and governance, trade liberalisation and regulation, and revenue sharing*". These three SACU areas are juxtaposed with founding objectives of SDI. The value in aligning SDI objectives with SACU economic objectives is that, those of the regional grouping are agreed upon by all member states. According to Masser (1998), motivation for SDI development have always been subject to the following objectives;

1. *Promotion of economic development*
2. *Improvement of governance*
3. *Assist with sustainable environmental management*

The SACU mandate as mirrored by its objectives, is all about economic development for the benefit of members and is consistent with the first stated SDI objective. SDI seeks to improve governance, and in terms of SACU objectives this is emphasised through objectives such as equity, common legislative practices, economic integration and fair competition. Sustainable environmental management is always seen through man's exploitation of the natural resources and in terms of SACU, this could be viewed through the traded commodities which are summarised as agricultural, minerals and industrial manufacturing products. Therefore, deriving from the SACU mandate and SDI Objectives, the SACU Regional SDI is coined to be: "***To promote SACU economic mandate along sustainable environmental concerns***".

In order to fulfil the concept for proposed SACU Regional SDI, countries, institutions and trade data are put forward as agents to inform it. The countries are considered in relation to their National SDI activities. Institutions considered on the basis of their involvement with the SACU economic mandate and SDI functions. SACU trade data is considered on the basis of its propensity to integration with geospatial data of the countries so as to foster economic and environmental management in the region.

7.2.2 SACU Structure and SDI Prospects

The organisational structure of SACU has been derived from Article 7 to 17 of the 2002 agreement by Gibb (2006). The structure is presented in figure 7.2. The structure and its

components are considered to be useful in consideration of regional SDI. The fundamental components here are the involved institutions, policies and technical areas. SACU structure as captured in figure 7.2, is facilitated through a Secretariat which has offices in Windhoek, the Republic of Namibia. The SACU Secretariat is headed by the Executive Secretary with the Deputy responsible for three operational core Directorates; (1) Trade Facilitation and Revenue Management (2) Policy Development and Research and (3) Corporate Services (Gibb, 2006). The SACU Secretariat has two fundamental functions; (a) to provide administrative support to other components (Council of Ministers, Customs Commission Union and Technical Liaison Committees) and (b) Harmonisation of policies. Through this structure and functions, opportunities for Regional SDI are advanced. The connection between the Secretariat and the Technical Liaison Committees is very important. It is important in that; the Secretariat can develop a policy for integrating trade and geospatial data sets for improved visualisation and evidence-based decision making on the traded products. The Technical Liaison Committees on the other hand, will be resourceful in the operational implementation of the trade and geospatial data integration through member countries.

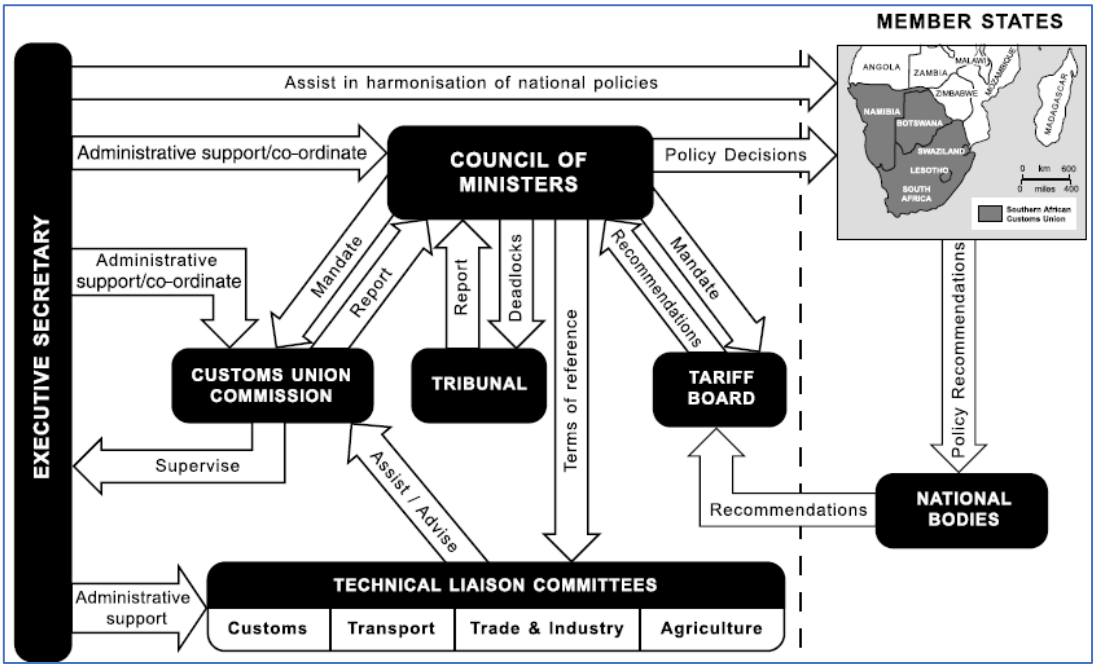

Figure 7.2: SACU Institutional framework. (Source: Gibb, 2006)

Consideration is given to organisations which are reported to be associated with SDI implementation in their countries. In Botswana and South Africa, SDI implementation and

coordination processes are highly associated with National Mapping Agencies and the Lands Ministries. In Lesotho, SDI as a concept is dormant and its organisational placing is not clearly defined. In Namibia, SDI concept is being firmly implemented under the auspices of the Ministry of Economic Planning and Director General of Planning Commission, specifically housed by National Statistics Agency (NSA).

In overall, member countries' Statistics Agencies do feature in their SDI efforts as shown in table 7.2, for instance in South Africa it is recognised as one of the Base Datasets custodians. Statistics agency are linked with member country's Ministries of Finance who are members of the SACU Council of Ministers. Therefore, the role of Statistics Agencies in the various countries are regarded as fundamental and strategic to the proposition of Regional SACU SDI. A more strategically placed among them is the Namibian Statistics Agency (NSA) because of its exploits with Namibia NSDI as reported in Chapter 6.

The importance of institutions in SDI evolvement as a starting point has been described in Sinvula et al (2013) and has been emphasised by practitioners especially in the case of the Namibia NSDI and SASDI discussed in Chapter 5. Following a line of inductive reasoning, the importance of the organisations listed in table 7.2 can be recognised to form fundamental lower structures in a hierarchical SDI being proposed. This precisely explains why this study could be of some use in the event that SACU countries could consider the establishment of a Regional SDI. SACU will need to look at its member states' SDI programs, progression and constraints as a foundation. SACU will also be able to select suitable collaborative organisations for each country in driving such SDI, if it ever arises. The selected organisations will be given responsibilities for undertaking feasibility studies and coordinating collaborative efforts on behalf of their countries. Each of these organisations can make use of the SDIOGI proposed in this study as a mechanism to Regional SACU SDI. The good thing about SDIOGI in such a work, will be that it will facilitate consistency in research and result benchmarking and early cognitive realisation of each countries SDI in terms of achievement and constraints.

Table 7.2 Compiled list of SDI Stakeholders in Botswana, Lesotho, Namibia and South Africa. (Adapted from Chapter 5 and 6)

Countries	Botswana	Lesotho	Namibia	South Africa
Organisations	1. **Department of Surveys and Mapping**** 2. Ministry of Land Management, Water and Sanitation 3. Office of the President 4. Meteorological Services 5. Ngwaketse Land Board 6. Botswana Police Service 7. Tlokweng Land Board 8. Botswana Defence Force 9. Botswana Geoscience Institute 10. Department of Mines, *11. Statistics Botswana* 12. Ministry of Agriculture 13. GIMS Botswana 14. Department of Town and Regional Planning *15. Botswana Power Corporation* 16. University of Botswana 17. Botswana Institute of Geomatics	1. Land Administration Authority 2. Ministry of Agriculture 3. Department of Land Management 4. Department of Environment 5. Maseru City Council *6. Lesotho Bureau of Statistics*	1. ***Namibia Statistics Agency ***** 2. Ministry of Mines & Energy 3. Ministry of Agriculture 4. Water & Forestry 5. Ministry of Land Reform 6. Ministry of Safety & Security (Nampol) 7. Ministry of Education, 8. Art & Culture; 9. Ministry of Urban & Rural Development 10. Ministry of Works & Transport 11. Ministry of Health & Social Services 12. Ministry of Environment and Tourism 13. Ministry of Fisheries and Marine Resources 14. Namwater 15. Nampower 16. Roads Authority 17. National Heritage Council 18. Communications Regulatory Authority of Namibia 19. Geocarta Namibia 20. Geo-Business Solutions	**1. Department of Rural Development and Land Reform (DRDLR)**** 2. *Statistics South Africa* 3. Municipal Demarcation Board 4. Independent Electoral Commission 5. Provincial Departments of Traditional Affairs 6. South African National Space Agency (SANSA) 7. South African National Roads Agency (SANRAL) 8. Provincial Governments 9. Local Authorities 10. South African Geographical Names Council (SAGNC) 11. Eskom 12. Department of Water and Sanitation 13. Chief Surveyor General 14. Provincial Surveyors General 15. Department of Agriculture 16. Forestry and Fisheries 17. Registrar of Deeds 18. Catchment Management Authorities (CMAs)

******Indicates organisations that are responsible for the Spatial Data Infrastructure implementation in the SACU member countries.

From the conclusions in Chapters 5 and 6, SDI progressions in South Africa and Namibia have been found to be more responsive and promising. But as a way of linking the SACU countries activities with SACU Regional SDI proposition, the organisations implementing Namibia SDI are revisited. As alluded to in the previously, Namibian SDI is implemented within the auspices of Ministry of Economic Planning and Director General of Planning Commission. This particular Namibian Ministry has a role within the structure of SACU as a member to the Council of Ministers. This structure places this Namibian Ministry within a strategic setting in relation to Regional SDI proposition. The Namibian SDI as opined in Chapter 6 section 6.2, focusses on economic advancement and spatially enabled nation as fundamental facets in SDI development. Therefore, it is inferred that the placing of the SACU Secretariat within the Namibian society as mentioned earlier, does provide a likelihood for SACU to be impacted by its ambitious SDI drive. In addition, Namibia SDI policy contains national, regional and international emphasis, this can be treated as another point that places Namibia into a strategic posture in relation to regional SDI. With such encouraging national examples, the SACU countries need to start readying themselves for a Regional SDI effort. As such, a concerted and gradual Regional SDI approach for SACU need to be considered now rather than later, in order to pre-empt its possible developments.

7.2.3 SACU Data and SDI Prospects

In relation to data, SACU data is reviewed to identify gaps with the understanding that 80% of data handled by organisations can be related to a spatial component (Rajabifard, 2002; Budic and Pinto, 1999; Lemmens, 2001). Various SACU documents were perused from the SACU website at http://www.sacu.int/ to trace aspects of data used to advance SACU interests. The core of the SACU data was downloaded through the interface found in figure 7.3. When downloading data, a combination of a number of data parameters are specified based on the components of figure 7.3. The components of this interface include, the temporal frequency for downloading SACU data, then selection of a geographic entity of reporting where six parameters are found, being: SACU, Botswana, eSwatini, Lesotho, Namibia and South Africa. The next component is selection of the currency of trade among which are Botswana Pula, South African Rand, United States Dollars and the Euro. The next component deals with selection of the geographic entity which is a partner in trade. The partners include SACU internal trade, Africa, North America, Europe Union, South America and Asia. The flow

component refers to products on the basis of imports, exports and re-exports as a trade matrix between the specified partners.

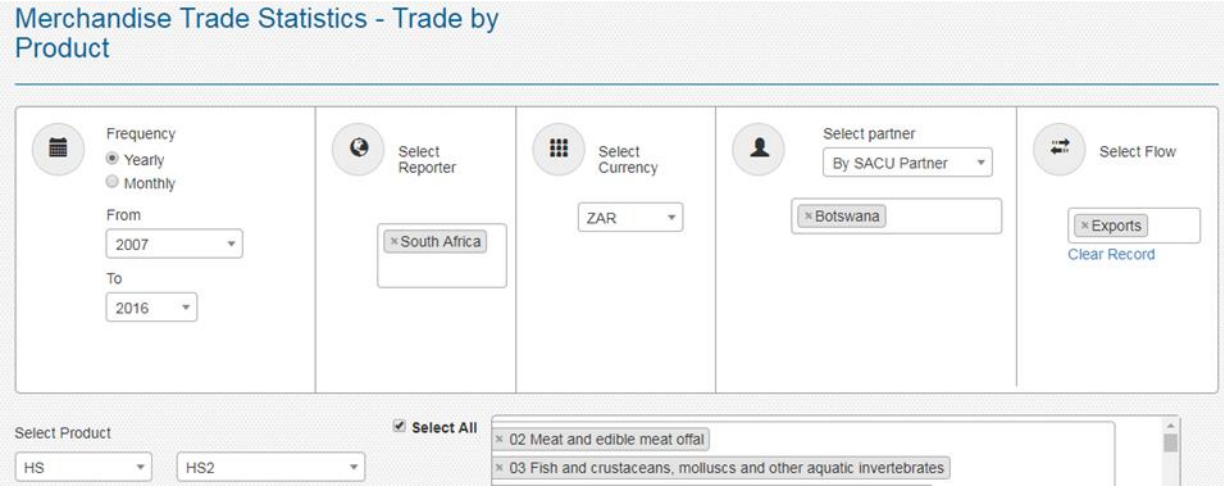

Figure 7.3: SACU trading data downloading interface. (Source: http://www.sacu.int/)

The example of the data download in table 7.3, represents SACU countries export data to the European Union region in 2017, representing twenty SACU traded products. The trade data with same attributes, is similarly downloadable for imports or re-exports. To understand the down loaded data, we need to consider the rows and columns to realise that the rows contain the names of the traded products and the columns reflect the attributes associated with them. For instance, column 1 shows the officially recognised standard codes given to traded commodities, e.g. Product_Code 01 refers to 'Live Animals' regardless of whether traded data for commodities are referring to imports, exports or re-exports. The Column of the "Partner Name" refers to the country or region that is trading with SACU. The "Currency" refers to the currency of trade as downloaded, in case of table 7.3 is the United States Dollars (USD). The currency shows in monetary terms, the actual value of the SACU traded commodities. 'Product_Description' describes the traded commodities within SACU, e.g. 'Live Animals'. The flow depict export, import or re-exports and in table 7.3, it is exports to the European Union. Botswana 2017 refers to exports of traded commodities by value from that country in the stated year, to the European Union. Similarly, with the other columns 2017 exports to European Union are referred, in case of Kingdom of eSwatini, Lesotho, Namibia and South Africa. A close scrutiny of table 7.3 reveals geographic information in reference to the various

SACU countries as the origins of the traded commodities and the European Union as destination.

From the above paragraph, it has to be realised that, the trade data is associable with geospatial data in a basic way and a complex way. In a basic way, reporting reflects SACU countries as the geographic data for origin of traded commodities or exports and as such, a map of each product can be integrated as layers with the basic map of SACU countries. In a complex way, the products can be disaggregated to refer to specific locations within countries. For example, if we take 'Live Animals', a distribution list can be done to show how many are coming from Botswana, which district, which village or which farm and the same goes for the other countries. Mapping of environmental issues associated with locations of origin of 'Live Animals', where attributes such as breed type, origin weather conditions (rainfall, wind and temperature statistics), pasture characteristics and area livestock diseases and patterns can be considered. Further, comparative imports, export and/or re-exports maps of traded commodities can be produced for SACU/International and Regional trade scenarios with intentions to enhance the economies of the member countries and the regional block as per the dictates of the prevailing economic agreement. Environmental maps relating to areas associated with these traded commodities can be produced and juxtaposed with the SACU trade statistics maps for improved decisions and policy enhancements.

In the example of table 7.3, only 20 products are displayed, whereby Product_Code is taken as the primary key and the 2017 exports from various countries are attached to them as an example to indicate first steps towards creating relationships between spatial and attribute data. The data in table 7.3 is further re-organised and adapted into table 7.4 which is now ready for import into the geographic information systems environment anchored on countries as geospatial data items and traded products export prices of 2017 are attributes. A geodatabase is developable if more disaggregation into lower geospatial locations of this data are sought and more attributes attached.

Table 7.3:The first 20 SACU export statistics by country (Adapted from http://stats.sacu.int/v2TradebyProduct.php)

Product_CODE	Partner Name	Currency	Product_Description	Flow	Botswana 2017	eSwatini 2017	Lesotho 2017	Namibia 2017	South Africa2017
01	EU	USD	Live animals	Export	869			167	580920
02	EU	USD	Meat and edible meat offal	Export	45359251			25114656	8859806
03	EU	USD	Fish and crustaceans, molluscs and other aquatic invertebrates	Export		11	137902	350932760	257621025
04	EU	USD	Dairy produce; birds' eggs; natural honey; edible products of animal origin, not elsewhere specified or included	Export				3064	98567
05	EU	USD	Products of animal origin not elsewhere specified or included	Export	20		145535	167486	644717
06	EU	USD	Live trees and other plants; bulbs, roots and the like; cut flowers and ornamental foliage	Export			27307	312645	45165589
07	EU	USD	Edible vegetables and certain roots and tubers	Export			69136	2999669	23964297
08	EU	USD	Edible fruit and nuts; peel of citrus fruits or melons	Export		2566709	775422	14419414	1504849736
09	EU	USD	Coffee, tea, mate and spices	Export		3		60164	7411780
10	EU	USD	Cereals	Export				320	4264417
11	EU	USD	Products of the milling industry; malt; starches; inulin; wheat gluten	Export				800	2261562
12	EU	USD	Oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit; industrial or medical plants; straw and fodder	Export	162348			2349731	57850267
13	EU	USD	Lacs; gums, resins and other vegetable saps and extracts	Export		47345		985	2832501
14	EU	USD	Vegetable plaiting materials; vegetable products not elsewher	Export		2766			378106
15	EU	USD	Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes	Export		8		38992	23060025
16	EU	USD	Preparations of meat, fish or crustaceans, molluscs or other aquatic invertebrates	Export				1222731	23753563
17	EU	USD	Sugars and sugar confectionery	Export		48486622		562	59335283
18	EU	USD	Cocoa and cocoa preparations	Export				1879	1446275
19	EU	USD	Preparations of cereals, flour, starch or milk; pastrycooks' products	Export	29		2	1474	2950547
20	EU	USD	Preparations of vegetables, fruit, nuts or other parts of plants	Export			7736907	2013	132867268

Table 7.4: Re-configured data table for the first 20 SACU trade commodities ready for GIS environment

Country	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
Botswana Exports 2017	869	45359251			20							162348							29	
eSwatwini Exports 2017			11					2566709	3				47345	2766	8		48486622		2	7736907
Lesotho Exports 2017			137902		145535	27307	69136	775422												
Namibia Exports 2017	167	25114656	350932760	3064	167486	312645	2999669	14419414	60164	320	800	2349731	985		38992	1222731	562	1879	1474	2013
South Africa Exports 2017	580920	8859806	257621025	98567	644717	45165589	23964297	1504849736	7411780	4264417	2261562	57850267	2832501	378106	23060025	23753563	59335283	1446275	2950547	132867268

In more comprehensive terms, the SACU trade data is made of about ninety-nine different products as shown in table 7.5, but some of these can be further disaggregated.

Table 7.5: SACU Trade Products Code and Description. (Source: http://stats.sacu.int/v2TradebyProduct.php)

Product_CODE	Product_Description
01	Live animals
02	Meat and edible meat offal
03	Fish and crustaceans, molluscs and other aquatic invertebrates
04	Dairy produce; birds' eggs; natural honey; edible products of animal origin, not elsewhere specified or included
05	Products of animal origin not elsewhere specified or included
06	Live trees and other plants; bulbs, roots and the like; cut flowers and ornamental foliage
07	Edible vegetables and certain roots and tubers
08	Edible fruit and nuts; peel of citrus fruits or melons
09	Coffee, tea, mate and spices
10	Cereals
11	Products of the milling industry; malt; starches; inulin; wheat gluten
12	Oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit; industrial or medical plants; straw and fodder
13	Lacs; gums, resins and other vegetable saps and extracts
14	Vegetable plaiting materials; vegetable products not elsewhere specified or included
15	Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes
16	Preparations of meat, fish or crustaceans, molluscs or other aquatic invertebrates
17	Sugars and sugar confectionery
18	Cocoa and cocoa preparations
19	Preparations of cereals, flour, starch or milk; pastrycooks' products
20	Preparations of vegetables, fruit, nuts or other parts of plants
21	Miscellaneous edible preparations
22	Beverages, spirits and vinegar
23	Residues and waste from the food industries; prepared animal fodder
24	Tobacco and manufactured tobacco substitutes
25	Salt; sulphur; earths and stone; plastering material, lime and cement
26	Ores, slag and ash
27	Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes
28	Inorganic chemicals: organic or inorganic compounds of precious metals, of rare-earth metals, of radioactive elements or of isotopes
29	Organic chemicals
30	Pharmaceutical products
31	Fertilizers
32	Tanning or dyeing extracts; tannins and their derivatives; dyes, pigments and other colouring matter; paints and varnishes; putty and other mastics; inks
33	Essential oils and resinoids; perfumery, cosmetic or toilet preparations
34	Soaps, organic surface-active agents, washing preparations, lubricating preparations, artificial waxes, prepared waxes, shoe polish, scouring powder and the like, candles and similar products, modelling pastes, dental wax and plaster-based dental pre
35	Albuminous substances; modified starches; glues; enzymes
36	Explosives; pyrotechnic products; matches; pyrophoric alloys; combustible materials
37	Photographic or cinematographic products
38	Miscellaneous chemical products
39	Plastics and plastic products
40	Rubber and articles thereof
41	Hides and skins (other than furskins) and leather
42	Articles of leather; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut)

43	Furskins and artificial fur; articles thereof
44	Wood and articles of wood; wood charcoal
45	Cork and articles of cork
46	Wickerwork and basketwork
47	Pulp of wood or of other fibrous cellulosic material; waste and scrap of paper or paperboard
48	Paper and paperboard; articles of paper pulp, paper or paperboard
49	Books, newspapers, pictures and other products of the printing industry; manuscripts, typescripts and plans
50	Silk
51	Wool, fine and coarse animal hair; yarn and fabrics of horsehair
52	Cotton
53	Other vegetable textile fibres; paper yarn and woven fabrics of paper yarn
54	Man-made filaments
55	Man-made staple fibres
56	Wadding, felt and nonwovens; special yarns; twine, cordage, rope and cable and articles thereof
57	Carpets and other textile floor coverings
58	Special woven fabrics; tufted textile products; lace; tapestries; trimmings; embroidery
59	Impregnated, coated, covered or laminated textile fabrics; articles for technical use, of textile materials
60	Knitted or crocheted fabrics
61	Articles of apparel and clothing accessories, knitted or crocheted
62	Articles of apparel and clothing accessories, not knitted or crocheted
63	Other made up textile articles; sets; worn clothing and worn textile articles; rags
64	Footwear, gaiters and the like; parts of such articles
65	Headgear and parts thereof
66	Umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof
67	Prepared feathers and down and articles made of feathers or of down; artificial flowers; articles of human hair
68	Articles of stone, plaster, cement, asbestos, mica or similar materials
69	Ceramic products
70	Glass and glassware
71	Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal, and articles thereof; imitation jewellery; coin
72	Iron and steel
73	Articles of iron or steel
74	Copper and articles thereof
75	Nickel and articles thereof
76	Aluminium and articles thereof
78	Lead and articles thereof
79	Zinc and articles thereof
80	Tin and articles thereof
81	Other base metals; cermets; articles thereof
82	Tools, implements, cutlery, spoons and forks, of base metal; parts thereof of base metal
83	Miscellaneous articles of base metal
84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof
85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles
86	Railway or tramway locomotives, rolling-stock and parts thereof; railway or tramway track fixtures and fittings and parts thereof; mechanical, including electro-mechanical, traffic signalling equipment of all kinds
87	Vehicles other than railway or tramway rolling-stock, and parts and accessories thereof
88	Aircraft, spacecraft, and parts thereof
89	Ships, boats and floating structures
90	Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; parts and accessories thereof
91	Clocks and watches and parts thereof
92	Musical instruments; parts and accessories for such articles

93	Arms and ammunition; parts and accessories thereof
94	Furniture; medical and surgical furniture; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings; lamps and lighting fittings, not elsewhere specified; illuminated signs, illuminated name-plates and the like; prefabricated
95	Toys, games and sports requisites; parts and accessories thereof
96	Miscellaneous manufactured articles
97	Works of art, collectors' pieces and antiques
98	Components of complete industrial plants of chapter 63: power production, incl. production and distribution of steam and hot water
99	Other products

A further discussion and analysis are considered for the data by relating it to the common themes found in SDI implementation. The SACU traded products can be referenced to location such as origins/destinations (villages, towns, cities, farming areas), transportation routes and the overall environment. These products are also summarized into five broad categories into table 7.6 and associated with fundamental geographical data. The association of these trade data with geographical, is an example to emphasize that it can be mapped.

Table 7.6: Aligning SACU trade data with Spatial data

SACU Trade Data	**Spatial Data**
Animals	Origins, area diseases, area pasture quality, transport routes, destinations
Trees and other plants	Origins, environmental issues and transportation routes
Minerals Products	Origins, environmental issues and transportation routes
Manufactured Products	Origins, materials origins and transportation routes
Energy Products	Origins, transportation routes and environmental issues

SACU trade data elements listed in table 7.5 and summarised in table 7.6 are directly related to a number of organisations identified as SDI stakeholders within the SACU countries in table 7.2. Animals and plants are directly related to member countries Ministries of Agriculture. Mineral and energy products are directly related to member countries Mining Ministries and associated organisations e.g. Department of Mines, Geoscience Institutes, Power Utility Corporation etc. Manufactured products are directly related to Ministries of Industry. Underlying all the forgoing are administrative boundaries and cadastre data. Administrative boundaries and Cadastre data are mostly associated with Ministries which are directly dealing with physical planning, land allocation, geospatial data collection, processing and dissemination. In the various countries they are referred by different names: for instance, in Botswana land is coupled with water and sanitation, in South Africa it is a reform paired with

rural development, in Lesotho its related with the monarchy, and in Namibia it is structured along reform concept.

7.2.4 SACU SDI Country Comparative Framework

A comparative framework between SACU countries, is done based on the Reference Model for Open Distributed Processing (RM-ODP) and the organisation operational environment based on input, output and constraints. RM-ODP model is made of five fundamental viewpoints: Enterprise, Information, Computational, Engineering and Technology (Hjelmager *et al*, 2008; Cooper *et al*, 2013; Sinvula *et al*, 2013). Inputs, outputs and constraints are underlying products and precepts within these viewpoints which facilitate an operational environment for SDI development. Through table 7.7 and 7.8, comparisons on major constructs of the RM-OMP and the service/products operations framework are done respectively for Botswana, Lesotho, Namibia and South Africa.

7.2.4.1 RM-ODP evaluation

An analytical framework is devised in this sub-section to make a reflection on the SDIs of the various study countries as discussed in chapter 5 and 6. The comparative analysis framework is prepared as table 7.7 and eSwatini is left out of this comparison because of limited study results. The RM-ODP is used to capture the various views and statuses of SDI between Botswana, Lesotho, Namibia and South Africa in table 7.7.

Table 7.7: SACU countries SDI comparative framework

RM-OMP model Viewpoint	**Elements**	**Botswana**	**Lesotho**	**Namibia**	**South Africa**
Enterprise: *primarily deals with purpose, scope and policies for an SDI*	Purpose	Data Sharing	Not specified	Evidence-based Economic decisions	Evidence-based Economic decisions
	Scope	National	Undefined	National	National, Provincial and Local
	Legislative framework	Draft project reports	None	Possess SDI Act and policy	Possess SDI Act and Policies
Information: *primarily deals with data and its semantics as per the specifications of policy*	Policy	Draft project reports	None	SDI Act and policy	Policies and guidelines
	Product Registries	None	None	Data and Metadata Standards	Data Collection Project Register (DCPR) and Metadata Standards (EMC)
	Services	None	None	Not specified	Not specified
Computational: *primarily addresses the*	Objects	None	None	Metadata Catalogue, Metadata Editor, Map Browser	Metadata elements

objects and interfaces required for a functional SDI.	Interfaces	None	None	digitalnamibia.nsa.org.na	http://www.sasdi.net/
	SDI Function	None	None	Functionality tools e.g. print map, layerpro, myData etc	Documents and metadata downloads
Engineering: *mechanisms and functions required to support distributed interaction between objects within the system*	communication	Not defined	Not defined	Not defined	Not defined
	computing systems	Not defined	Not defined	Not defined	Not defined
	software processes	Not defined	Not defined	Geofind	DCPR and EMC forms
	Network clustering	Not defined	Not defined	Not defined	Not defined
Technology: *Specific technologies selected for use in a SDI*	Software typology	Proprietary	Proprietary	Open Source	Proprietary/open source
	Internet Platform	ArcGIS Enterprise	Manifold GIS	Avinet	Various
	GIS	ArcGIS-ESRI Licence Agreement	Manifold GIS	QGIS, Postgress and Map Server	various

This comparative framework shows that a lot still needs to be done institutionally and technically especially in Botswana and Lesotho. Namibia has made a lot of progress by far and South Africa through its comprehensive capacity building framework possess an opportunity to move towards improved SDI implementation. Success and failure stories of these SDIs are considered to be fundamental inputs of a proposition of a SACU Regional SDI.

7.2.4.2 The Operational Framework

Comparison of the documents and responses from the various countries as presented in chapter 5 and 6 are summarised and collated in table 7.8 defined by inputs, outputs and constraints. In collation, an attempt is made to capture the elements of each category in a single word or at the most two words in respect of inputs, outputs and constraints to NSDIs of countries. A number of these parameters are derived from the questionnaire responses (tale 5.4, table 5.10, table 6.5 and table 6.11) and triangulated with other sources for a specific country.

Inputs

From table 7.8, it emerges that Botswana and Lesotho's input requirements are defined by primary components of SDI (legal, institutional, technical, funding, data and technology). As discussed in Chapter 5, the legal framework in particular, has come out as one input that is highly required so as to help drive mandate, prioritisation and agenda setting towards development of NSDI for these two nations. The legal framework should be able to give direction to the institutions to shape their organisational and technical frameworks suitable for SDI implementation. The ICT infrastructure which is also acknowledged by Namibia as a

fundamental input is a typical macro-economic input that fall outside the influence of SDI implementing organisations. Republic of South Africa SDI implementing stakeholders, see their fundamental SDI inputs as soft and organisation dependent being: consultation, collaboration, communication and coordination.

Table 7.8: SACU countries SDI constraint comparison

Botswana	**Lesotho**	**Namibia**	**South Africa**
Inputs			
1. Legal framework 2. Institutional framework 3. Technical framework 4. ICT Infrastructure	1. Funding 2. Skilled personnel 3. ICT Infrastructure 4. Technology 5. Policies 6. Spatial data	1. Funding 2. ICT Infrastructures	1. Consultation 2. Collaboration 3. Communication 4. Coordination
Outputs			
1. Cost-saving 2. Data quality 3. Access 4. Sharing	1. Access 2. Planning 3. Decision making	1. Spatially-conscious nation 2. Access 3. usage	1. Duplication 2. Accessibility 3. Availability 4. Usability
Constraints			
1. Funding 2. Understanding 3. Mandate 4. Support 5. Skill sets 6. Legislation	1. Awareness 2. Political will 3. Motivation	1. Co-operation 2. Quality data 3. Comprehensive Metadata 4. Funding	1. Funding 2. Organisational 3. Competing interests

Outputs

All these countries realise specific actions as their NSDI outputs, these at best can be defined as intangible in nature. In tangible forms, these outputs, are closely associated with geoportals, appropriate access networks, abundant data and an unimpeded financial system. When relating to these output requirements there is need to answer the question; what should the NSDI do? It has to be accessible to stakeholders, support planning, contain useful data and fundamental decision-making. Therefore, lack of specific performance such as accessing geospatial data online, will infer that the NSDI is constrained.

Constraints

All the countries have returned a number of constraints which they view as pertinent to their SDI progression. Botswana has almost referred to all its inputs as their major constraints, for instance the legal framework is realised as a constraint because of lack of an SDI legislation. Lesotho constraints are largely hovering around lack of strategic influence of SDI due to issues

of lack of awareness and political will. Namibia, maintains funding among its constraints which could infer that ICT infrastructure, though considered an important input, in its current form, they can manage system implementation with it. Other tangible constraints recognised by Namibia are technical and organisational in nature. South African constraints are viewed as financial and organisational in nature. The organisational constraints are consistent with the listed inputs. In overall, SDI implementation road maps for SACU countries and the region need to be subjected to a constraint-oriented framework which is articulated in the following section.

7.2.5 Spatial Data Infrastructure On-Going Improvement (SDIOGI)

Based on Chapter 2, 3 and the National SACU SDIs discussed in Chapter 5, 6 and parts of chapter 7, where several constraints were recorded in SDI development across the countries and the region, SDIOGI instrument is proposed for corporates, countries and Regional SACU SDI. In Chapter 2.5 literature was reviewed focussing on indicators of public interventions such as the SDI. Reasoned arguments were raised to effectively regard these indicators as constraints because their weakness, contribute to the adverse implementation, consistent with the theory of constraints which posits that performance of products, services and infrastructures tend to be as good as their weakest link (main constraint). In line with this proposition, another management concept dealing with ensuring underlying statuses of organisations in processes of acquisition is invoked. In chapter 5 and 6 several constraints were identified for Botswana, Lesotho, Namibia and South Africa. Considering Botswana as an example, the composite constraints listed in table 5.7 are: Strategic Influence, Legal framework, Funding, Organisational, Marketing, Technology, Human, Partnership and Technical and these are found to compare well with the components of Due Diligence, as presented in figure 7.4. Due Diligence is further acknowledged and embraced (Harvey and Lusch, 1995) because its indicators are similar to those discussed in Chapter 2.5. Due diligence as a concept and fundamental basket for indicators has been used widely in a number of areas, for instance: in business acquisition or mergers (Harvey and Lusch, 1995; Horwitz *et al*, 2002) and Information Communication Infrastructure (ICT) addressing cyber network security concerns (Shin, 2009; Shackelford, Russell & Kuehn, 2016). Due Diligence involves researching, assessing and analysing an entity to ensure its status in the event of an integrative undertaking. The Due Diligence indicator basket consists of the following components; macro-environment, legal, marketing, production, management, information systems and financial.

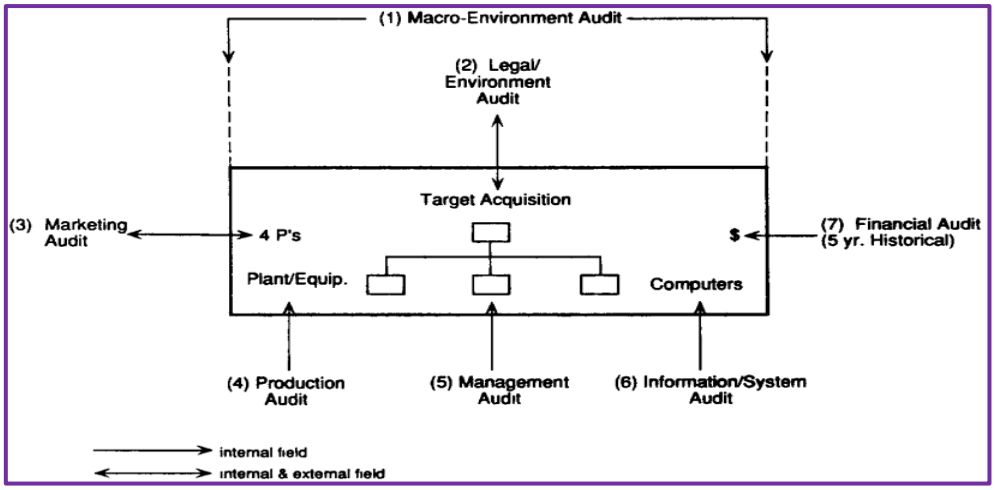

Figure 7.4: Due Diligence Audit Requirements. (Source: Harvey and Lusch, 1995)

This concept when considered within the frameworks of SDI as discussed throughout this thesis, paints a picture of geospatial integration at corporate, national, local, regional, global levels. In the context of this understanding, SACU Regional SDI is looked at as a form of acquisition and/or merger of member countries' geospatial data from several organisations and hierarchies as articulated in Rajabifard (2002). For instance, the boundaries data set held by a National Mapping Agencies being useful to the SDI of a utility company, the national and regional aspects. In order to postulate the framework, Due diligence components in Harvey and Lusch (1995) are compared with SDI assessment approaches of Makanga and Smit (2010) and Mwange et al (2016), which were initially utilised in Chapter 3 proposition of the SDIOGI approach. The seven main Due Diligence components are extracted into a tabular form and are compared with those from the mentioned SDI Assessments and presented in table 7.9.

Table 7.9: Due Diligence Comparison with SDI Assessments

Due Diligence (Harvey & Lusch, 1995)	SDI Readiness (Mwange et al, 2016)	State of Play (Makanga and Smit, 2010)
Macro-Environment		
	Organisational	Organisation
Legal		Legal
Marketing		
Production	Informational	Technical Data and Metadata
Management	Human	
Information System	Technology	
Financial	Financial	Funding

A semblance of these Due Diligence components, depict similarities with the indicator components of SDI Readiness (Mwange *et al*, 2016) and State of Play (Makanga and Smit, 2010). From table 7.9 comparisons, components of an On-Going SDI approach are deduced as the following: Macro-Environment, Organisation, Legal, Marketing, Informational, Management, Technology and Financial. These components are described below and their relevance as indicators of SDI constraints qualified in the context of SDI On-Going Improvement (SDIOGI) in cognition of the results in Chapter 5, 6 and parts of 7:

1) **Marco-Environment**: This component takes the sectorial pursuits and spheres of influences of organisations into recognition. In case of regions it takes priorities in relation to spatial data practices into consideration. SDI potential resides in understanding priorities of organisations/countries in relation to geospatial information and all factors that can sustain their interests in SDI development processes. This particular component was noted in a number of countries visited, for instance in South Africa, it was found that, so long as the SDI implementing stakeholders remain poorly coordinated, its implementation has remained slow and silo oriented. In Botswana and Lesotho, it was found that the legal framework was quite inhibitive in that the SDI lacked mandate and guiding principles in implementation. In Namibia, a rapid positive development was recognised after the macro-conditions of the country in regard to SDI were improved through legislation and policy. In overall, political awareness, influence and priorities of government and stakeholder organisations must be reflected upon and measured to induce understanding of the constraining levels of this component on an SDI implementation and progress prospects. Awareness at a high level of governance is key because, it leads to political influence and priority settings, this statement borrows from the work of INSPIRE which was set through a directive that influenced nations and their priorities in SDI development. This is customisable depending on the level of SDI. For example, if the SDI being pursued is national, awareness and political influence by government has been stated as important in all the visited countries. When implementing SDI at regional level, the awareness of the regional body and member countries is important.
2) **Organisation**: This specifically addresses itself to the existence of the central organisation and office of the SDI with a multi-sectoral responsive strategy. It talks to the mandate of the SDI as stipulated by Acts or other authoritative injunctions like Cabinet and the lines of reporting by stakeholder organisations. In Botswana it has

emerged that, SDI started off at the Department of Information Technology, went dormant and resurfaced at Department of Surveys and Mapping. Despite this organisational setting, need for an independent Botswana NSDI has been mentioned as important to its advancement. In Lesotho, SDI is dormant and no organisation readily embrace it as its responsibility. In South Africa, SDI is instituted under National Geo Information in Department of Rural Development and Land Reform, which some regard as a '*referee and player*' in what is viewed as a multi-sectoral endeavour, hence believe that a dedicated office with clear mandates must be established. In Namibia, SDI is housed under National Statistics Agency (NSA) which currently seems to be doing well, though an acknowledgement exist that some SDI stakeholders are still not coming forward. The greatest challenges associated with organisations are priority settings, culture, and willingness to share data due to aspects of copyrights and privacy in respect to their sectorial governing laws and regulations.

3) **Legal**: The legal component takes into cognisance the establishment of the legal framework specifically referring to SDI and its relation with the existing legislations that apportion sectoral duties to stakeholder organisations. In reference to the case of Botswana and Lesotho, it is confirmed that lack of a legal framework specifically referring to SDI, hold negative connotations to its development, while the case of Namibia and South Africa which both have legal frameworks, confirms a positive commitment and focus for desired SDI inputs and outputs. In terms of constraints, the Act, Policy, Regulations and guidelines are variables that assist SDI progression.
4) **Marketing**: This component deal with aspects of awareness, geospatial data usage, acknowledgement and promotion within stakeholder organisations and their propensity to partake in the activities of SDI. It also talks to the user community which is inclusive of the public. Discussions referring to Namibia and South Africa do confirm the fundamental role of marketing in SDI. In Lesotho, there are no recognisable marketing or even strategies developed to sensitise the stakeholder communities. As for Botswana, stakeholder organisations have had benefits of meeting and discussing on ways of establishing SDI and this effort has remained within government, without bearing much results.
5) **Informational**: This component addresses aspects of geospatial data collection, processing and generation within the stakeholder organisations. Other important properties include data qualities, themes, duplication and technical standards practices by the SDI stakeholder organisation in a production environment. All the SACU

countries acknowledge to possesses spatial data in various formats, but decry lack of centralised standards and metadata as very inhibitive to SDI progression. Another constraint they are concerned with is that of lack of access to data which denies corporations and citizens from harvesting the benefits associated with spatial data.

6) **Management**: This take into consideration skills suitability and needs for SDI stakeholder organisations. It takes into recognition key personnel issues such as organisational leadership in relation to SDI implementation. All the countries of SACU have raised concerns in relation to the SDI skill sets in their territories. From the various country responses, it is inferred that prevailing requisite skills, capacity building and skills projections in SDI related specialisations such as geomatics, planning, geographic information Systems, remote sensing and digital information processing are needed. These are useful as factors towards understanding the available and planned skill sets towards SDI development in a country.
7) **Technology**: It takes in to consideration the usage of technologies such as hardware, software and the information systems within the SDI stakeholder organisation. The way they are currently used and configured; can they be of some use to SDI implementation. The Information Communication Infrastructure (ICT) is one of the primary enablers of SDI through internet platforms and networked computing resources. Most of these countries, Botswana, Lesotho and Namibia have expressed their ICTs to be among the variables needing a lot of improvement in terms of broad band and national connectivity to be able to support SDI development.
8) **Financial**: This component scrutinises the central government funding of SDI as a fundamental feature. It seeks to understand geospatial data funding within the stakeholder organisations. It also talks to the understanding of the ideas of cost saving and revenue generation from the SDI. Most SACU countries have expressed limited resources for national funding of SDI efforts, though South Africa and Namibia do have some level of funding in which they perform a number of capacity building through workshops. Namibia and South Africa are also busy in development of supporting policies such as the one responsible for the pricing of the spatial data resources towards production and revenue generation.

In summary, a constraint-oriented instrument for determination of SDI progression in the context of on-going improvement is derived from the above components and designed into

table 7.10. The measurable quantities are harvested across Chapter 5, 6 and parts of Chapter 7 as reflected in the various contexts of the SDIs of SACU countries. A measuring scale similar to that used in Mwange *et al* (2016) is adopted for this instrument, which is to be used for the purposes of harvesting perspective views to support on-going SDI improvement roadmaps within countries and SACU as a region.

Table 7.10: SDI constraints and variables for SDI On-Going Improvement Framework

SDI Constraints Indicators	**Constraints variables**	***Extremely low = 1***	***Very low = 2***	***Low = 3***	***Medium = 4***	***High = 5***	***Very high = 6***	***Extremely high = 7***
Macro-Environment	1. Corporate/Government/Regional body awareness 2. Political influence 3. Priorities of stakeholder organisations							
Organisation	1. SDI Mandate 2. Autonomy of SDI Office 3. Leadership and SDI Strategy							
Legal	1. Act 2. Policy 3. Regulations and guidelines							
Marketing	1. Stakeholder organisations 2. Societal awareness 3. Societal participation and access							
Informational	1. Technical Data 2. Met Data 3. Data sharing and exchange							
Management	1. Prevailing requisite skills 2. Capacity building program 3. Requisite Skills projections							
Technology	1. Technological data capture 2. Information communication infrastructure 3. Prevailing geospatial Information systems							
Financial	1. Central SDI Funding 2. Cost Saving 3. Revenue generation							

This instrument is considered feasible because it is anchored on existing well-known SDI assessment approaches and data obtained from studying SDI in SACU countries (Makanga and Smit, 2010; Mwange *et al*, 2016). From table 7.10, it follows that SDI implementation and progression, should be subjected to assessment by these components, to establish constraints or weak indicators and seek solutions for them. The involved indicators are treated as constraints which needs to be structurally exploited following the theory of constraints as a means to SDI On-Going Improvement (SDIOGI) advanced in Chapter 3. They are built into what is referred to as, SDI On-Going Improvement Framework (SDIOGIF) in figure 7.5. The

SDIOGIF is meant to aid SDI stakeholders at various levels to improve their practices and prospects. For instance, institution/province/country/region involved with the SDI concept, can use this framework to audit, develop knowledge and understanding of its SDI various constraints.

SDIOGIF seeks to sensitise stakeholders about the stack of SDI constraints and their cumulative nature, which if not well understood can act as serious bottlenecks and/or blockages to SDI development and progression. This instrument can be adopted at any level of SDI development and customised as roadmap focusing purpose. Among the studied SACU countries SDI, the South African SDI is seeking to evolve to a more complex structure based on the hierarchies; corporate, local (municipality), district, province and national. Therefore, in a bottom-up approach, these constraints need to be understood and hierarchically solved to avoid transcending them from one level to the other. Namibia and Botswana approach, have corporate and national as fundamental hierarchies which's constraints need to be studied and understood. The SDI constraints of the SACU members will adversely affect efforts towards regional infrastructure. Therefore, SDIOGIF is proposed for adoption as a key in a SACU Regional SDI roadmap. Its purpose is to address the various nodes, such as; organisations, local authorities, provincial governments, national governments, in the SACU Regional SDI development endeavour.

To further understand the cumulative nature of constraints as suggested in the above framework, it must be understood that a local authority within governance structure such as that of South Africa, can have 'n' number of corporates involved with SDI. An audit for constraints is done for each corporate SDI stakeholder and the information is aggregated to inform the status of the local authority. In the next level, there are 'n' local authorities and their SDIs are now responsible for feeding the provincial SDI. What has to be understood is that the aggregated SDI constraints of the local authorities, will become weak links of the SDI of the Province. This reasoning is adopted in a bottom-up approach to all SDI hierarchies. The upper structure, in adopting the lower level SDI constraints, should also carry out measurements of their own, so as to fill in any gaps which are beyond the limits of the lower structures. In a top-down reasoning, weak links at the top of the structure will also have an adverse effect on those at the lower level.

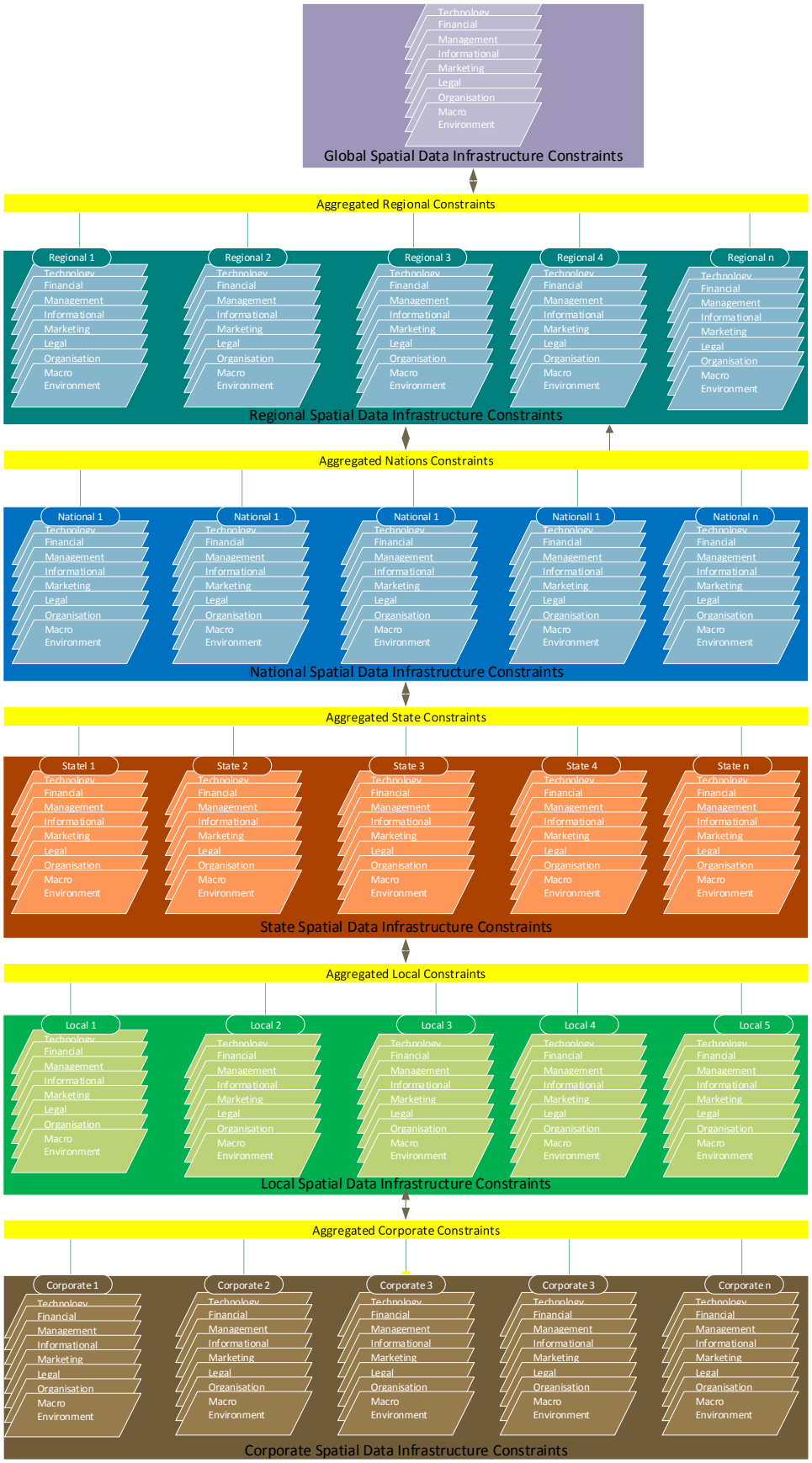

Figure 7.5: SDI On-Going Improvement Framework (SDIOGIF)

7.3 SACU-SDI Framework for Development

From the proceedings of section 7.2, SACU-SDI framework is articulated for possible development. This framework is intuitive but innovative bearing in view of the fact that, SDI has never been advanced as an intervention for SACU regionally. The proposition is considered to be innovative because it will promote the economic mandate and function of SACU with environmental management. In addition, it will raise the profile of SACU as a trade block in terms of concerted geospatial information management for the good of the inhabitants. The framework will promote a regional integration by promoting benchmarking, policy formulation and harmonisation and sustainable environmental management. The framework is envisaged to cover; Central Organisation, Funding, Assessment, Policy Formulation, Fundamental Data Sets, Metadata, Technologies and Research as described below:

(1) **Central Organisation**: The SACU Secretariat is advanced as an appropriate organisation for the SACU Regional SDI because it is the administrative wing responsible to members states with well entrenched partnerships. The SACU Secretariat should become the central platform where, member countries SDI Coordinating organisations meet to advance the regional SDI. Political-will to establish SDI need to be established at the highest echelons of SACU, whereby, an additional Technical Liaison Committee on Regional SDI could be established in close collaboration and technical expertise of the identified organisations in member countries involved with SDI, being the following:

- Botswana: Ministry of Land Management, Water and Sanitation (Department of Surveys and Mapping)
- Lesotho: Though SDI activities are not that clear, either Ministry of Finance or Ministry of Environment
- Namibia: Ministry of Finance and the Director General of Economic Planning (National Statistics Agency)
- South Africa: Department of Rural Development and Land Reform (Directorate of National Spatial Information Framework)
- eSwatini: Ministry of Natural Resources and Energy (Surveyor General)

(2) **Funding**: To kick-start SDI, funding is very important. In case of the studied SACU countries, funding has been shown to be a major concern. A two-tier approach is

considered feasible where (a) The Secretariat finances fundamental administrative activities and policy formulation activities and (b) the member countries continue to finance their internal SDI activities with the objective to align them to SACU requirements as per policy that is developed.

(3) **Assessment**: This study has emphasised the importance of assessing SDI, identifying its constraints and exploiting them to aid its advancement. SACU countries have already been studied to determine their constraints which are discussed in 7.2.5 above and designed into an SDI assessment system. This instrument should be used to undertake a purposive SDIOGI for the member countries by the SACU Secretariat. SDI assessment can partly be deduced from this study and other studies similar to it to build and prioritise how to proceed based on the resultant SDI statuses e.g. the Disparities found in the SDI Legal Frameworks as discussed in Chapter 5 and 6.

(4) **Policy Formulation**: Regional SDI Policy should be formulated by the Secretariat for SACU by deriving guidance from the Assessment results performed in (c) above. The policy should be informed by the objective of bringing improvements to SACU economic mandate and environmental management in respect of traded commodities as articulated under 7.2.4. In addition, the policy must be benchmarked within SACU and against best practice from partner regions such as the INSPIRE, which is the European Union version of Regional SDI. The Policy should address the context of SACU in terms of its constraints, economic and environmental management requirements.

(5) **Fundamental Data Sets**: Once the policy is formulated, founding fundamental spatial data sets have to be identified to kick start the informational program. The SACU Secretariat has Technical Liaison Committees which focus on trade and industry; agriculture; customs; and transport. Another committee will have to be established to deal with SDI Coordinating Organisations, for formation of SACU Regional SDI with the objective to manage entrenched economic activities and environmental management concerns. The SACU Regional SDI is therefore proposed based on six primary base data set following the South African SDI example. This proposal is put forward with a stated Regional SACU SDI purpose, base data sets, custodians and recognition of its status as constrained. The proposed base data sets as summarised in table 7.11 are; Administrative Boundaries, Transport, Trade Statistics, Environmental, Hydrology and Geodesy.

a) **Administrative Boundaries**: Boundaries define the extent and various lower divisions of SACU as an economic block and forms the basis of reporting for the traded commodities. They have to be integrated with the help of SDI system and be aligned to the execution of the SACU mandate. Boundaries are important in such a proposal because, they define the hierarchical structure of SDI into local, national and regional. They also form fundamental residential lattices, whereupon the populations who are beneficiaries of the SACU economic activities are found.

b) **Transport**: Transport routes, in particular roads, are primary themes which are mapped by National Mapping Agencies. National Mapping Agencies have been shown to be central to SDI development of their countries. Transport is a major concern in SACU as witnessed by its Technical Liaison Committee. Emphasis in this structure is that, its regional mapping should be done in SDI format, with appropriate attributes to support improved decisions in line with regional economic activities and environmental concerns.

c) **Trade Statistics**: The trade statistics will take into account the human distributions and settlements as beneficiary nodes to the SACU economic activities. Trade Statistics must be closely associated with the cadastre as the underlying referencing framework. The trade statistics maps are meant to map and depict the actual benefit that is accruing to communities in respect of the SACU agreement.

d) **Environmental**: These data sets should emphasize land use and the environment. As already alluded, agricultural and manufacturing products form a great bulk of traded commodities. This implies as an example that, SACU in facilitating imports/exports/re-exports of live animals and trees, they have to objectively align those with appropriate land use and environmental status (vegetation, soil erosion, deforestation etc) of member countries.

e) **Hydrology**: These are shared resources and international boundary frameworks for the SACU countries. The objective is to harmonise them under one accessible environment as fundamental resources that supports commodities traded through SACU.

f) **Geodesy**: Most SACU countries do emphasise geospatial data quality as a necessity to their SDI. Therefore, a geodesy base data set is regarded as

assurance to this and as a movement towards enhancing a unified regional reference framework and development of a geoid model.

Table 7.11: Proposed SACU Initial SDI Base Data Sets and diagnosed Main Constraint

SDI Purpose	**SDI for Southern African Customs Union (SACU) based on the objective of promoting regional economic mandate along sustainable environmental concerns**					
Primary Theme	Administrative Boundaries	Transport	**Trade statistics (SACU)**	Environmental	Hydrology	Geodesy
Elements	1. National Boundaries 2. Provinces Boundaries 3. District Boundaries	1. National roads 2. Main roads 3. Secondary roads 4. Other roads 5. Streets 6. Boarder Posts 7. Airports	***1. Live animals*** ***2. Live trees and other plants*** ***3. Minerals Products*** ***4. Manufactured Products*** ***5. Energy Products*** **6. Cadastre**	1. Environment 2. Soils for Plants and crop production 3. Settlements and human populations 4. Industrial facilities 5. Weather 6. Mining	1. Water courses, streams and rivers 2. Drainage networks catchments 3. Water bodies (eg dams, lakes) 4. Water resources: boreholes 5. groundwater	1. Trigonometrical Beacons 2. Continuous Operating GNSS Base station networks 3. SACU Geoid Model
Base Data Set Custodian	National Mapping Agencies	National Roads and Transport institutions	***National Statistics Organisations, SACU Secretariat and National Mapping Agencies (Surveyor General)***	National Environmental and Mining Organisations	National Water and Sanitation Organisations	National Mapping Agencies (Surveyor General)
Constraints	SDI AWARENESS at SACU: 1. Lack of understanding of the usefulness of geospatial information on SACU mandate and activities 2. Lack of skilled map power 3. Lack of policy					

The development of the above data sets into a SACU Regional SDI poses a mammoth task, in that more studies and geodatabase development models will need to be considered. A geodatabase approach has not been instituted as it will lead to a major deviation from the topic of this study, but it is a study opportunity for the future in the context of SACU Regional SDI concept. Comprehensive specifications of these fundamental data sets are quite wide and they require intra-national working groups between SACU countries for harmonisation and interoperability in terms of standards and metadata. In addition, the Regional SDI road map is already constrained in terms of lack of understanding, awareness and legal frameworks. As reported in chapter 5 and 6, countries like Botswana and Lesotho don't have a legal framework nor a distinctive functional SDI effort.

(6) **Metadata:** Namibia and South Africa have already developed metadata following the ISO Technical Committee on GIS and Geomatics products. As a starting point, the

Namibian metadata must be adapted for SACU Regional SDI because of its simplicity. The Namibian SDI Metadata can be viewed in http://geofind.nsa.org.na/.

(7) **Technology**: In terms of establishing a geoportal, the Namibian example is once more recommended. The technology supporting the Namibia SDI geoportal https://digitalnamibia.nsa.org.na/ is an open source one and it has proved to be resourceful. Therefore, it must be benchmarked and adapted to support implementation of SACU Regional SDI.

(8) **Research and development**: SACU Regional SDI must be supported by a robust research and development program within the existing Policy and Research Directorate. Standards, network accesses, data sharing, product and service development are considered to be central to this activity. This activity and its processes can be benchmarked from the INSPIRE model. Universities within the SACU countries can be used as fundamental resource bases for collaboration from the on-set and as the concept matures, a localised SDI research program can be established. There are a number of universities which can be useful in this endeavour e.g. University of Cape Town, University of Pretoria, University of Botswana and University of Namibia, just to mention a few. Another useful research institute in this endeavour is the Council for Scientific and Industrial Research (CSIR) in South Africa.

In summary, a structure similar to that proposed by Bartha & Kocsis (2011) as displayed in figure 7.6, is recommended for adaptation as a graphical impression of the proposed SACU Regional SDI.

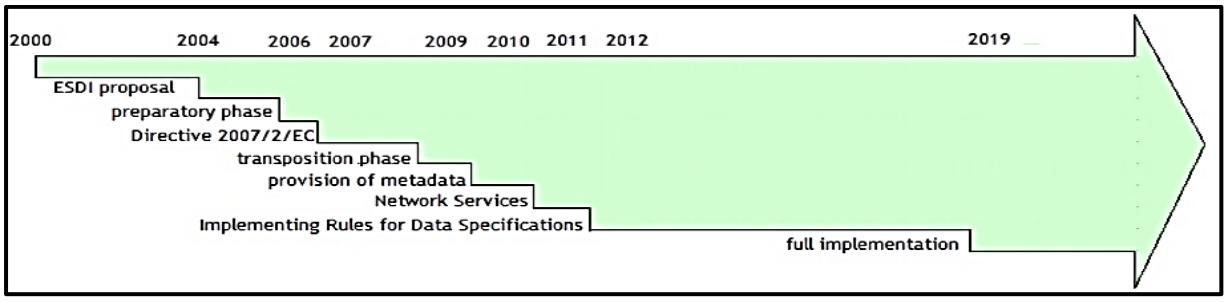

Figure 7.6: Roadmap of INSPIRE. (Source: Bartha & Kocsis, 2011)

The structure on figure 7.6 refers to the European Union version of Regional SDI and is a very simplistic graphic impression, which can be designed by adapting the fundamental constructs

advanced for SACU Regional SDI onto it. Time is important in the implementation of the structure; hence it will be necessary to scope the activities to emphasise their execution and completion timelines. If ever implemented, The SACU Regional SDI should also emphasise full implementation and continued improvement into the future.

7.4 Critical Discussion of the Regional SACU SDI Proposal

The critical question to ask is – how can geospatial information be introduced at SACU level? The above proposal has acceded that it is not an easy thing to do when considering that, there is lack of awareness at SACU coupled with varied constraints relating to member states. Nevertheless, Regional SACU SDI has been put forward as a new suggestion in academic and practice discourses of geospatial information. This framework as suggested, is focussed at taking advantage of SACU as a durable economic platform and developing its SDI with the future in mind. As nations develop, geospatial information has continued to come to the forefront as the viable integrative framework upon which various economic, environmental, social and political activities are based. Examples supporting this assertion have been comprehensively discussed in this thesis and they range from individual countries to regional and global levels, for instance: USA (National SDI), European Union (INSPIRE), Australia (Australian SDI), Asia-Pacific SDI, South American Regional SDIs, South Africa (South SDI) and Namibia (Namibia SDI).

The Regional SACU SDI suggested in this chapter has concentrated on establishing relationship between economics and environment as witnessed in the alignment of SDI with SACU economic objectives in Section 7.2. It has to be noted that, understanding the relationship between economics and environment are key to issues of sustainable development. This point is related with that of Scott and Rajabifard (2017) emphasising the Canadian work led by Tomlinson in the early 1960s. According to Scott and Rajabifard (2017, p. 62), Tomlinson: *"introduced the use of electronic computers in the storage, compilation and assessment of natural and economic map and statistical data for the evaluation of marginal agricultural lands in Canada"*. From the preceding reference, *"natural map"*, is conceptually regarded as any geospatial information typology that refers to the agricultural lands e.g. the hydrological system map, while *"economic map"* refers to the agricultural produce by value e.g. U$20,000 per hectare for maize and *"statistical data"* refers to agricultural product

quantities e.g. 200 tons of corn per hectare. In the current scenario, SACU countries do have *'natural and economic map and statistical data'* within their various departments (table 7.2) which largely exists in silo format, and the modern technologies, in particular SDI provide an opportunity for them to be integrated to widen their perspectives and decision-making scope within SACU as an economic system. The Regional SACU SDI if implemented will be the integrative platform which allows for *"natural and economic map and statistical data"* to be viewed through a single microscope and to respond to several requirements such as UN Sustainable Development Goals (SDGs). Scott and Rajabifard (2017, p. 62), acknowledging the recent policies relating to UN Agenda 2030, have posited that *"adoption of the 2030 Agenda provides the global policy mandate to exploit the contribution to be made by geospatial information to support the SDGs"*. SACU countries as members of the UN have a duty to view Agenda 2030 as a welcome development and adoption of its requirements as a way to addressing national and regional sustainable development through SDI.

SDI as an enabling platform possess potentials to foster regional integration and help in SACU development agenda and policy formulations especially where statistics and the environment are concerned. This point has been elaborated in Scott and Rajabifard (2017) in appreciation of the position taken by the UN Secretary General in 2012 on geospatial information and 2013 Australian report to United Nations regarding a statistical-geospatial framework. The positions adopted at the UN are high-level and their success is seen through pragmatic implementations in nations and regions. Therefore, SACU as an economic platform for five nations, can play an unequivocal political role for the implementation of the high-level UN pronouncements on geospatial information following SDI concept within its member states. This could be done by integrating geospatial information into its policies focused in the following: Industrial, Agricultural and Competition (SACU, 2009). As an example of SDI usefulness, development and monitoring of SACU Industrial Policy could be considered. The emphasis on the realisation of the SACU Industrial Policy, should not only be realised through establishing several industries with the intention to deriving maximum economic benefit for member states without their comprehensive focus on the environmental impacts nationally and regionally.

SDI is an evolutionary phenomenon (Rajabifard *et al*, 2007). For Regional SACU SDI to emerge and evolve a purposive transformation and collaborative agenda focussed on its

development will be required. SACU through its structure as discussed in Section 7.2.2 will have to make calculated decisions on integration of spatial data with statistical data especially in view of its data discussed in Section 7.2.3. Ways towards similar agendas have been set out by the UN through its UN-GGIM Committee of Experts and some of their reports such as UN-GGIM (2013, 2015a, 2015b, 2016) and United Nations (2011, 2012, 2013a, 2013b, 2015a, 2015b, 2016, 2017) are useful insights and guideline frameworks to use in SACU Regional SDI endeavour. The Regional SACU SDI should draw from the following message by United Nations (2017, p. 1):

> *"Several organizations are working on issues related to geospatial information, but the growing number of global issues, including cross-border problems such as climate change, natural disasters, peace and security in the world, and the quality of the environment, which no nation or region can solve in isolation, calls for global coordination between member States and international organizations."*

Regionally, SDI understanding within SACU remains a challenge. But dim as it looks, SDI has to be promoted through research and regional endeavours that seeks to appraise leaders of the positive impact it can bring to issues of governance, economic development and environmental management. This chapter was an attempt to set a foundation for that to happen within SACU. There are no ready answers for the exact outlook of such SDI, but a generic framework for Regional SACU SDI has been set out in Section 7.3. If SDI is embraced at SACU level this framework could be used alongside the guiding principles by the UN mentioned above to kick-start the concept.

7.5 Conclusion

In Chapter 2, comprehensive review of the basic constructs of SDI such as; legislative frameworks, standards, access networks, technical frameworks, Partnerships, technologies e.g geoportals were done. Their consideration in case of SDI development in the SACU region have been concluded to be constrained in Chapter 3, 5, and 6. With that in mind, instigation for a SACU Regional SDI, has been done by initially identifying SDI awareness within the SACU executive wing, The Secretariat. SDI Awareness was found to be none-existent, but a conceptualisation for SACU Regional SDI was done following five school of thoughts.

Firstly, SACU Regional SDI concept is advanced with the objective to harmonise economic pursuits with environmental management by, juxtaposing SACU organisational mandate with well-known SDI objectives. Secondly, SACU organisational structure was reviewed and propositions made regarding how it can be aligned with SDI, especially in relation to issues of organisational set-up and policy development. Thirdly, SACU traded commodities data was evaluated and possibilities of linkage with geospatial data in SDI format was advanced. Fourthly, comparison of country SDIs were done based on RM-ODP and the organisational operational framework to appreciate the challenges and successes associated with them as fundamental inputs to SACU Regional SDI. Fifthly, a proposition of SDI On-Going Improvement (SDIOGI) is advanced in recognition of prevailing SACU country constraints, and is based on indicators of SDI Readiness Index, State of Play and a management philosophy called Due Diligence. The constraint-oriented SDI approach is anchored on analytical exploitation and focussing of the following; Macro-environment, Organisation, Informational, Legal, Marketing, Financial, Technology and Management as Composite Constraints associated with results of SDIs of the SACU countries. Finally, A structure is put forward as guidance to how the SACU Regional SDI should be framed. This structure recognises political will of member states as paramount to the actual implementation of Regional SDI. Emphasis to such endeavour have been anchored on; Central Organisation, Funding, Assessment, Policy Formulation, Fundamental Data Sets, Metadata, Technologies and Research as necessary SDI constructs to associate with its implementation.

Chapter 8 : Conclusions and Recommendations

8.1 Conclusion

SDI has been discussed in this study as a multi-sectoral hierarchical platform which's implementation and progression are subject to constraints within the SACU countries. These constraints are conceived as multi-sectoral in nature across local, national and regional governance structures. They are cumulative and if not properly mitigated, they will adversely affect SDI progression. What has emerged in the study is that much of the SDI implementation power and control rests with national governments. Some countries have legislated this power and control, while others have not. Those with legislations and associated instruments have exhibited better coordination, control, focus and progression in SDI implementation. In conclusion, the questions and objectives of this study are revisited for summation with the study findings, responses and propositions across Chapter 2 - 7. Recommendations on topical issues are also made in order to aid the way forward in terms of areas of research in SACU and learning from global SDI trends.

8.1.1 Answering Research Questions

A study of this nature always starts with questions which requires answers supported from empirical evidence derived from the collected data. Therefore, the questions asked at the beginning to this study are recited and given succinct answers derived from the results and analysis in Chapter 2 - 7.

Question 1: *Why are Spatial Data Infrastructure implementation slow in SACU and how could they be fast paced*? To answer this question a **context-based** study was instituted in respect of the five SACU countries being Botswana, Kingdom of eSwatini, Lesotho, Namibia and South Africa and analysing existing SDI efforts. Out of these five countries, Kingdom of eSwatini could not be accessed for comprehensive data collection and soliciting of answers in respect of this question. The other four countries were accessed and their context answers are described by possession or lack of the SDI legal framework.

Countries Lacking Legal framework

> Botswana has shown and maintained interest in SDI development since early 2000. But to date there is no SDI in the country and lack of legislative framework has been

identified as the main constraint for advancement of Botswana SDI. Botswana approach, has been to establish SDI through the use of stakeholder committees, but this has not achieved SDI as can be witnessed by lack of fundamental outputs such as sustainable geoportals, standards and metadata. SDI mandate in Botswana has remained ambiguous, since the concept was embraced. What is evident in respect to most SDI components in Botswana is that they are constrained.

Lesotho has shown interest in the SDI concept, and like Botswana, there is no SDI legal framework. SDI implementation in Lesotho has not been pursued with much vigour and at best it can be described as dormant. The SDI idea in Lesotho has never really gone further than acknowledging the concept. Lack of SDI legal framework is viewed to be responsible for lack of other fundamental SDI drivers such as organisational mandate, prioritisation and funding. SDI in Botswana and Lesotho also lacks strategic influence in terms of the appropriate political support. The strategic influence is viewed as important foundations on which a sound SDI legal framework can be constructed.

Countries with Legal framework

Countries with the legal framework are Namibia and South Africa, and from the findings they have made some noticeable progress in SDI implementation programs.

Namibia started its quest for SDI in early 2000 and it was evaluated in Makanga and Smit (2010) as very slow. Since 2011, Namibia instituted its first steps towards an SDI legal framework by infusing it within the Statistics Act. This step has produced a number of positive results such as the SDI Policy and implementation Strategic Framework in 2015. A metadata and geoportal have been established for Namibia, and are found respectively at the following websites: http://geofind.nsa.org.na/ (metadata) and https://digitalnamibia.nsa.org.na/ (geoportal). The Namibia example signify the importance of the legal framework in speeding up SDI implementation as it pronounces clear mandates and requirements. All the mentioned achievements are within a 6-year period spurning 2011 -2017.

South Africa on the other hand, established SDI Act as early as 2003 with the objective of establishing National SDI. South Africa has experienced challenges relating to coordination and cooperation despite the SDI being mandated to Department of Rural Development and Land Reform (DRDLR). Though, South Africa has established SDI website: http://www.sasdi.net/, it is not comprehensive enough to offer accessibility to geospatial data as envisaged by the SASDI Act.

In overall, underlying constraints in fundamental SDI components and processes in the SACU countries are found to be responsible for the slow pace of development. The discovered constraints as viewed through the SACU countries are elaborated under paragraph on ***Objective 3*** in section 8.2. The expositions in this work is that, the constraints need to be identified, measured and scaled for solutions, to be able to support the SDI On-Going Improvement (SDIOGI). The SDIOGI has been proposed in this work following the Theory of Constraints and will be elaborated in section 8.1.2 in conjunction with the paragraph on ***Objective 1***.

Question 2*: Why have SACU countries not successfully adapted SDI development drives from elsewhere?*

Regarding adaptation of SDI from elsewhere, it is established that European INSPIRE and United States of America NSDI approaches have influenced SDI development efforts within the SACU region. In countries where constraints are adequately addressed, such as Namibia, the SDI concept has been adapted in collaboration with other states like Norway and Sweden. In South Africa, a number of ISO technological standards on geospatial data such as the Metadata, have been embraced and adapted to aid SDI implementation. Comparatively, Botswana, which has had collaborations with Sweden, is said to have had some prototypes which collapsed after the withdrawal of the Swedish organisational and technical partnership. In overall, SACU countries have successfully measured up to SDI adaptation from elsewhere, though some countries did not make much progress. Inevitably, the countries without positive results in adaption to the SDI efforts from elsewhere, are those who lack legal frameworks.

This work proposes that regional benchmarking and adaptation of SDI need to be considered as a viable alternative. This can be done through understanding the major bottlenecks and possible blockages which a successful neighbouring country had to overcome for SDI to kick-start and make a steady progress. Namibia among the studied countries, is viewed as the most plausible prototype to the SDI adaptation concept in the SACU region and suitable for benchmarking by countries like Botswana and Lesotho.

Question 3: *In case of SACU Countries, who are the main players in the development of national and/or regional SDIs and how should they interact to ensure its realisation?*

The questionnaire responses and documents used in this study, have revealed that, existing SDI efforts in the SACU region have been largely undertaken at the national level and remain focussed in that way. In Botswana, the efforts have been driven by two different government departments at different successive times; being the Department of Information Technology (DIT) in the period 2002 to 2009 and Department of Surveys and Mapping (DSM) in the period 2009 to date. In both cases, the believe was that, SDI is better placed for execution within the stated departments. Initially it was configured under DIT and when it did not work, after that, it was moved to the erstwhile Ministry of Lands and Housing under the e-government initiative overseen by Department of Surveys and Mapping. Botswana scenario exposes that, despite the coordinating organisations managing to congregate stakeholders, their SDI effort has not been able to return any acceptable outputs. In Lesotho, SDI was considered under a government standing committee in environment named Committee on Environmental Data Management (CEDAMA) and this, has also not achieved any useful results in terms of SDI constructs such as legal frameworks, geoportals, standards, metadata and organisation.

In Namibia, through the Statistics Act of 2011, SDI has been sanctioned for implementation within the National Statics Agency with the help and direction by the Spatial Data Committee (SDC) chaired by the Surveyor General. Politically, this SDI fall within the mandate of the Minister of Finance and the Director General of Economic Planning Commission. Namibia SDI has made immense progress in the

recent times. In case of South Africa, SDI is being implemented as per the SASDI Act of 2003. Organisationally it is sanctioned for implementation under the Department of Rural Development and Land Reform (DRDLR). DRDLR utilises the National Spatial Information Framework (NSIF) together with, the Committee for Spatial Data (CSD) under National Geo Information (NGI) to propel and guide the National SDI implementation. The findings in this work reveals that NSIF is often viewed as a '*player and referee*' by other stakeholders who believe that SDI should be independent organisationally so as to solicit its own funding and other organisational remits such as policies, regulations and guidelines to implementation.

Regionally, there is no SDI to talk about within SACU, as such a conceptual proposition is articulated in Chapter 7 for consideration as a general guidance towards regional SDI and a roadmap. This proposition realises the importance of the national country SDIs, SACU mandate, organisational structure, data and assessments as the defining principles and agents towards Regional SACU SDI. A concept and framework of SACU-SDI with purposes of promoting regional economic mandate along sustainable environmental concerns is articulated. The fundamental SDI constructs to facilitate the proposed structure are: Central Organisation, Funding, Assessment, Policy Formulation, Fundamental Data Sets, Metadata, Technologies and Research.

Question 4: *How can the critical success and failure factors of a spatial data infrastructure be managed?*

This study's main exposition, advances underlying constraints and their impacts in the SDI processes, as responsible for its success and failures in development within the SACU countries. As such, constraints have been carefully evaluated for the various SACU countries. These constraints are considered on the basis of a time period in the development cycle of an SDI i.e. the beginning of an SDI implementation, on-going processes and assessment periods. If certain constraints are conclusively recognised from inception, then they have to be solved to ensure they do not impede the on-going improvement and prospering of an SDI. An example to support this point is drawn from Botswana which have struggled with SDI because of lack of legal framework, which adversely affect focus in SDI implementation and apportionment of mandates to

involved stakeholders. As such, if Botswana had committed to the establishment of a legal framework (Act, policy and guidelines and regulations) relating to SDI, it would have most probably made good progress like its neighbours, South Africa and Namibia.

8.1.2 The objectives

In concluding, it is also important to look back at the objectives set out in the proposal for undertaking this study. These objectives are listed in table 8.1 with their fulfilment chapters stated.

Table 8.1: Study objectives and their fulfilment study chapters

No.	Study Objective	Fulfilment
1	To review SDI discourses and propose a constraint oriented methodological approach as a road map of advancing its development and progression	Chapter 2, 3 and 7
2	To investigate SDIs found in the five SACU countries in order to identify their state of development	Chapter 4, 5 and 6
3	To investigate and describe variables that constitute constraints that could have slowed Spatial Data Infrastructure Development in SACU countries	Chapter 2, 5, 6 and 7
4	To carry out a comparative analysis of the state of development of SACU countries SDIs to suggest possible benchmarking and propose a framework for regional SACU SDI.	Chapter 5, 6 and 7

In recognition of ***Objective 1***, Chapter 2 and 3 are tailored to look at SDI discourses in terms of origins, political influence, geospatial representation, its established components and assessments across the whole world (Coleman & McLaughlin, 1998; Rajabifard, 2002; Rajabifard *et al*; 2002; Rajabifard & Williamson, 2003; Crompvoets, 2002; Crompvoets & Bregt, 2003; Crompvoets, *et al*, 2004; Grus et al2006; Grus et al, 2007; Grus et al 2008; Grus, 2010; Makanga and Smit, 2010; Mwange *et al* 2013; Guigoz *et al*, 2017). Strong arguments are raised for the concept of constraints within the main discourses of SDI. In these arguments various components used in SDI assessments are advanced as measurables for constraints. To focus this in SACU, the results from the work of Makanga and Smit (2010) and that of Mwange *et al* (2016) are utilised to conceptualise SDI constraint-oriented approach following the Theory of Constraints (Goldratt and Cox, 1984; Goldratt and Cox, 1992; Coman and Ronen, 1994; Dettmer 1998; Rahman1998; Watson *et al*, 2007; Kim et al 2008; Şimşit, *et al*; 2014). This approach is referred to as SDI On-Going Improvement (SDIOGI) and it is temporal and cyclic in execution. The proposal is summarised in table 8.2.

Table 8.2: Summary of the SDI On-going Improvement Framework

Step	Spatial Data Infrastructure On-Going Improvement
1	SDI Development set up with vision and mission statements and well-articulated goals
2	SDI development agenda with clear input and output as measurables
3	Main Constraint identification: Sectoral scalable perspective views on ***macro-environment, organisation, marketing, legal, financial, informational, management and technology***
4	SDI Development processes. Solving the main Constraint
5	Other constraints subordinated to Main constraint.
6	Assessment of the constraints to verify solution status to Main Constraint (Multiview SDI Assessment)
7	Identify next Constraint for exploitation (go back to step 1 or 3).

In relation to O***bjective 2***, it is found that SACU countries' SDIs are exhibiting various statuses and each visited country's context is summarised below.

Botswana: The National SDI is not developed and it is lacking in almost all the fundamental components associated with SDI implementation. There is no legal framework, standards, metadata, geoportal, marketing approach and it remains organisationally weak as it is been organised through Ad-Hoc Committees. These Committees are usually related to on-going geospatial data related projects in the country e.g. Land Administration Procedure, Capacity and Systems (LAPCAS). The Ad-Hoc Committees are often successful in bringing sectoral stakeholders together, but have proved to be deficient in executing dedicated SDI implementation programs. Organisations participating in such committees have often experienced dissipating interest and enthusiasm due to several adverse reasons, for instance; lack of mandate, clear roles; inter-organisational cooperation, awareness, understanding and clarity on the benefits. Fading of interest by most organisations in SDI, is largely associated with Botswana's lack of commitment in establishing SDI legal framework. This country's national SDI requires a wholesale SDI idealisation audit in terms of the SDIOGI approach as proposed and advanced in objective 1.

Lesotho: SDI in Lesotho is almost none-existent and its known activity through CEDAMA is dormant. Lesotho is very much lacking on a number of fundamental SDI components. Just like Botswana, it does not have a legal framework, hence making mandate and agendas setting for SDI progression almost impossible. Strategic influence (ministerial or political influence) is regarded as the main constraint in Lesotho SDI, but then the tactical units such as organisations have almost given up on any possible ways to SDI implementation e.g. A champion organisation which advances SDI through various functions of government and private sector. Most SDI stakeholder organisations in Lesotho have very few skill-sets in terms of geospatial

information management officers, because all the organisations visited rarely have over five (5) such skilled personnel in their employ.

Namibia: Since 2011, this National SDI has done exceptionally well in most components as it has; a legal framework which is responsible for setting mandates and direction; informational geoportals, robust marketing, timed strategy with clear goals and management program. The first phase of Namibia SDI has focussed on the product aspect of the SDI and the next phase of its development is to expand the SDI into a process-based one where producers and users interact to ensure achievement of what is viewed as a '*spatially-conscious nation*'. The configuration of the Namibian SDI is very suitable for the SDIOGI approach advanced in objective 1 above. This SDI is very much on course so much that, its strategic framework, was actually adapted into a context-based SDIOGI anchored on its main goals being; governance structure, access, capacity and duplication.

South Africa: The early movers in terms of establishing a legal framework in the SACU region. The SASDI, as structurally mandated through the Act can be termed 'complex". The expectation of SASDI Act of 2003, did not stipulate a hierarchical system, but the current proposals are for an infrastructure capable of diligently serving the Local/Municipal, Provincial and the National structures of government. To date, no central geoportal has been achieved in terms of the original spirit SASDI Act of 2003 and the movement towards a hierarchical infrastructure are still at their early stages. A website has been established for the SASDI activities and some components are being realised such as standards e.g. Electronic Metadata Catalogue (EMC) which is being implemented in collaboration with SAEON. South Africa, decries organisational positioning of SDI coupled with coordination issues as major constraints to its implementation. Hierarchical implementation of the SDIOGI approach is regarded as the most feasible approach to SASDI because it will expose the gaps between the various hierarchies. That is, SDIOGI need to be carried out within institutions, municipalities, districts, provinces and the national requirements for geospatial information. This will help the SASDI Office to critically recognise and appreciate the constraints that the various governance structures are facing in SDI implementation.

Interestingly, it can be concluded from the foregoing four paragraphs referring to Botswana, Lesotho, Namibia and South Africa that the Legal Framework is fundamental in apportioning mandates and setting agenda for SDI progression. Those countries with legal framework have fared quite better in implementation compared to those without it, despite the period of embracing the SDI concept being relatively similar (early 2000).

Regarding O***bjective 3***, a number of components and associated variables were discovered. SDI Constraints within SACU countries were found to be revolving around 24 primary variables; These variables are the following;

> (a) Grounded awareness of SDI development across the various levels of SACU countries' governance/organisational structures (b) Strategic or political influence (c) National and Sectoral priority settings, (d) SDI Mandate (e) Autonomy of SDI Office (f) Leadership and SDI strategy focus (g) Act availability (h) Policies availability (i) Regulations and Guidelines (j) Stakeholder organisations (k) Societal awareness (l) Societal participation and access (m) Technical data (n) Metadata (o) Data sharing, exchange and duplication (p) Prevailing requisite skills sets (q) Capacity building programs (p) Requisite Skills projections (s) Technological data capture (t) Information communication infrastructure (u) Prevailing Geospatial Information Systems (v) Central SDI Funding (w) Cost Saving (x) Revenue generation. These constraints were further classified into eight fundamental Composite SDI Constraints being the following; (1) Macro-environment; (2) Organisation (3) Legal framework (4) Marketing, (5) Informational (6) Management (7) Technology and (8) Financial. Each Composite Constraint is related to three variables in a respective fashion i.e. Macro-Environment related to a, b and c, Organisation to c, d and f, and so forth. These composite constraints and variables are discussed in detail in Chapter 7, where a measuring instrument named SDI On-Going Improvement (SDIOGI) and hierarchical framework named SDIOGI Framework (SDIOGIF) are proposed.

The composite constraints are regarded as significant because they have been derived and compared with other existing well-known and accepted SDI assessment approaches such as Status of Play (SoP) and Readiness Index (RI) discussed throughout this thesis. The SDIOGI

and associated SDOGIF are advanced for consideration as a roadmap to SDI development and regular assessment for the various identified hierarchies in SACU and its member countries.

Objective 4 was achieved through a reflective and intensive analysis of results obtained in chapter 5 and 6 as summarised below.

> The conspicuous comparative instrument of the results, has been found to be the SDI legal framework of countries. As already alluded, South Africa and Namibia are the only countries with a legal framework. Therefore, the disparities in possession of SDI legal framework on its own renders the SACU Regional SDI proposition a challenge in terms of; ease of harmonisation of Policies, Standards, Geospatial Data, Metadata and overall governance. Despite the envisaged challenges, a proposition for SACU SDI has been made following five fundamental routes being; (1) SACU versus SDI mandate as interventions for economic advancement for the region; (2) SACU organisational structure and function versus the countries' SDI stakeholder organisations; (3) SACU traded data versus the member countries' SDI most common requisite spatial data sets as fundamental organs in Regional SDI setup; (4) A comparative and bench-marking framework based on the reasonings of SDI Reference Model for Open Distributed Processing (RM-ODP), where Namibia efforts are ultimately embraced as a SACU country of choice for bench-marking by other member countries, especially, Botswana, eSwatini and Lesotho; (5) Advancement of SDI On-Going Improvement Framework (SDIOGIF) as a method that can be followed to audit and focus the SDI activities in the member countries for the benefit of what is proposed as SACU Regional SDI.

At the SACU Regional level, the SDI is highly constrained due to lack awareness within the structures of SACU and lack of interest towards it by the member states. The member states currently do not have clear-cut collaborations and partnerships in the spheres of geospatial information collection, processing, distribution, exchange and sharing processes. Therefore, the SACU Regional SDI proposition is at best described as, an intuitive approach that is grounded on the above reasoning. But if embraced, it is considered as an innovative undertaking capable of opening the region to intensive geospatial information integration, inter-operability and research collaborations which are useful to economical pursuits and environmental management.

8.1.3 Contribution to knowledge

The contribution of this study is fulfilled by the following:

1) **SDI Constraints**: As point of departure from the traditional SDI assessment and indicators considerations, this study has advanced that, they are resourceful when treated as constraints as opposed to being measured only to gauge status of achievement or readiness. Constraints allows for a comprehensive analysis and improvement in design processes of an SDI. If constraints are understood through the geospatial data governance hierarchies, it becomes conducive to solve them sectorally, locally, nationally, regionally and globally as per interest. To elaborate, the National SDIs of the SACU countries as discussed in Chapter 5 and 6 have shown that constraints does exist. This can take an inclusive form such as possession or lack of a legal framework to more discrete ones which can be specific to organisations' lack of grounded awareness of geospatial data and SDI. A conglomeration of these constraints causes varying bottlenecks and blockages in SDI implementation and progression. For instance, considering Republic of South Africa, SDI can be said to be facing a number of bottlenecks due to organisation and coordination. While in Lesotho SDI is facing a blockage in implementation due to lack of several components necessary in its implementation.
2) **The fundamentals of SDI Legal Framework**: The fundamentals of this SDI component in implementation has been fulfilled through the discussion in Chapter 5 and 6. SACU countries with legal framework being Namibia and South Africa have fared better in SDI implementation. Botswana and Lesotho have not fared very well as countries who desire to implement SDI without a legal framework. These points, considered alongside European INSPIRE and USA NSDI efforts, aid a conclusion for SDI legal frameworks to be established as pre-requisites to implementation in all the SACU countries. The legal framework constraint is found to be useful in giving SDI development; purpose, authority, focus, mandate and better facilitation of inter-organisational partnerships.
3) **A proposition for SACU Regional SDI**: A proposition is suggested with the emphasis of aligning SDI of the member countries with the mandate of SACU by instituting a Regional SACU SDI. This should be established with the objective; "***To promote SACU economic mandate along sustainable environmental concerns***". This proposition takes into consideration the geospatial information management drives of

member countries into cognisance as fundamental inputs to SACU Regional SDI. The constraints of the SACU member countries, will translate into an aggregated condition and ultimately inhibit the regional effort. Hence the need for hierarchical solutions and harmonisation of the constraints for instance, legal frameworks, standards, geospatial data collection and metadata.

4) **SDI On-Going Improvement (SDIOGI)**: This is a temporal methodology that is proposed to support SDI development by resourcefully solving for constraints following the Theory of Constraints. In this method, a comprehensive evaluation of the perspectives of SDI stakeholders based on the following constraints components is advanced: Macro-environment, Organisation, Legal framework, Marketing, Informational, Management, Technology and Financial. Perspective views derived following this method are then ordered on the basis of their associated quantities and prioritised for solution as per objectives and requirement of the SDI and the main constraint is determined and its solutions sought. The SDI implementation should, be having a set period for evaluation e.g. 5 years as per Namibian case, in which the same components are gauged to see if the perceived main constraint was solved. The validity of the suggested method was grounded on the works of SDI assessments by Makanga and Smit (2010) and that of Mwange et al (2016) which covered the SACU countries. It is articulated based on these SDI assessments, which both exposed legal framework as a constraint in Botswana efforts, as such, had this approach been followed, by 2016, it would have possibly been solved. At the compiling of this thesis Botswana is still constrained in regard to the SDI legal framework.
5) **SDI On-Going Improvement Framework (SDIOGIF)**: The SDIOGI is built into a framework in recognition of the following hierarchies; corporate, local, nation, region and global SDI implementations. The framework recognises the inter-dependencies between SDIs within the various levels and across them. Therefore, it is proposed to cater for their aggregation and improve SDI design, analysis, implementation and assessment.

8.1.4 Limitations

The proposed SDIOGIF has not been administered to the SACU countries due to study timelines and resource limitations. The framework is a theoretical and roadmap proposition based on the findings and responses emanating from the case study countries. SDIOGIF is

considered as valid, because it is based on the information which was harvested across the SDI discourses of the case study countries and analysed within well-known methods of SDI (State of Play and Readiness) and management philosophies of Theory of Constraints (TOC) and the Due Diligence concept.

Another limitation to this research is the actual implementation of the SCU Regional SDI. The Regional SDI, is only put forward in in this study as a theoretical proposition based on findings and the constraints-based approach SDIOGIF. For this system to be implemented there is need for awareness, buy-in, funding and a SACU legal instrument (e.g. policy) as a means towards setting agendas, harmonising and apportioning responsibilities for the effort.

8.2 Recommendations

The recommendations are considered along the lines of specific constraints, possible future studies to associate with the current topic of study and the general trends in SDI discourses across the world. It is considered here that, a study such as this one should facilitate specific interventions, research and development for the benefit of the communities upon which it was carried out, hence it must generate topics for future studies. It is also considered that in continuum, a study such as this one should be able to refer to the trends on the pedestals of regional, continental and international discourses. The interest being; to align with the prevailing practices and approaches to SDI development and debates by the international community. But first the specific and future studies recommendations, as viewed within the major contributions of this study.

8.2.2 Future Studies

There are a number of intertwined specific interventions and future studies which can be carried out in SDI within the SACU region and they are listed as the following;

- Actualising the SDIOGIF as defined in table 8.2 through each country at corporate level to gauge perspective views of those involved with SDI based on quantitative approaches.
- Development of SACU SDI by further disaggregating its data to lower levels of geographic spaces within countries and developing a suitable geodatabase

- Development of a collaboration/partnership model for SACU countries in geospatial information processes to support and advance regional SDI.
- Namibia SDI assessment in the year 2020 following table 6.6 which was adapted from its strategic plan and the proposed SDIOGIF as articulated in chapter 7.
- Understanding the complexities associated with the SASDI.
- Development of the South African geospatial portal.
- Implementation of Botswana/Lesotho/eSwatini SDIs following the proposed SDIOGIF.
- A move towards SDI Legal Frameworks in Botswana and/or Lesotho.

These recommendations are not necessarily exhaustive, but act as guide to specific interventions and studies that are directly emanating from this thesis. For instance, the studies on implementing SDI in Botswana/Lesotho/eSwatini, harbours three comprehensive interventions and studies which can be undertaken in the context of each country. The study referring to the disaggregated SACU data, can be made more comprehensive by conceptualising and actualising a geodatabase suitable for the purpose. It also requires further understanding and structuring of the inter-country partnerships in such endeavours.

8.2.2 Trends in SDIs

This study is viewed and linked to the prevailing SDI trends in terms of hierarchical discourses and technological advancements. The higher hierarchies as could be witnessed by the European INSPIRE example, are important and can come with innovative and instructive directives capable of instigating countries towards sustainable SDI development directions. Technology on the other hand has become ubiquitous with a lot of open systems with free accessibility, hence can be utilised to kick-start and support continued SDI development.

8.2.2.1 The SDI Hierarchies

In relation to the hierarchies, African regional blocks and Africa as continent continue to talk about SDI developments to keep up with the rest of the world (United Nations, 2015; Mwange *et al*, 2016; Guigoz *et al*, 2017). The SDI trends in Africa dates far back to 2001 through the work of the United Nations Economic Commission of Africa (UNECA), with focuses on Agenda 21 and Habitat II Plan of Action. During those times the significance of SDI as a

vehicle to sustainable development was emphasised (Ryttersgaard, 2001). Despite the supporting role UNECA gave to the African continent, a number of countries continue to struggle with SDI, just as the study has shown in case of Botswana, Lesotho and eSwatini. That means, by now these countries are left behind, have a lot to grapple with in order to elevate their SDI status. The elevated status is viewed in this study, as very useful in supporting the development pursuits of the nations concerned and the regions they are affiliated with. Thus, hierarchies responsible for SDI development need to be interrogated and constraints-oriented approaches have been advanced in this study, as suitable for calibrating and understanding the complexities associated with SDIs. In the words of Rajabifard (2002, p. 153); "*there is still a need for descriptions to actually represent the discrepancies between the role and deliverables of an SDI and thus contribute to a simpler, but dynamic, understanding of the complexity of the SDI concept*". The referenced statement remains relevant today for the SACU countries in terms of them pursuing product-based and process-based SDIs at various hierarchies as depicted by Rajabifard (2002) in figure 8.1. Namibia, the only country with a fully-fledged geoportal and metadata repository, is still focussed on the development of a product-based SDI, which is explained in its strategic plan discussed in chapter 6. Further to that, Namibia is also interested in transcending into process-based SDI approaches towards what it views as a '*spatially enabled society'*.

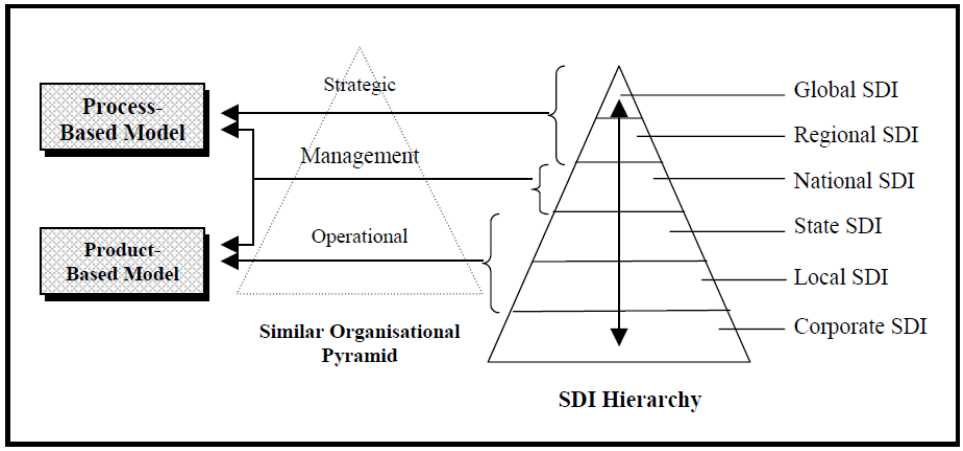

Figure 8.1: Relationships between SDI Hierarchy and different models of SDI development. (Source: Rajabifard, 2002)

SACU countries need to move up the SDI ladder with more urgency and to be responsive to the geospatial data/information challenges of their regional blocks (SACU itself as discussed in this study and the South African Development Community (SADC)), the African Continent

at large and the rest of the globe. At the global level these countries need to respond and contribute to the effort of the United Nations Global Geospatial Information Management (UNGGIM) through Africa Regional Committee (United Nations, 2015). The fundamental point raised by United Nations (2015a, p. 11) specifically relating to the African region opines that it is in pursuit of "*increasing the number of information and knowledge resources and services developed at the regional, sub-regional and national levels to improve availability and use of spatially-enabled information for development in Africa*". This study has focussed on the national and sub-regional (that is SACU) geospatial information management by advancing constraint-oriented approaches in advancing SDIs. An interesting aspect with the UN-GGIM Africa is that South Africa was drawn into the committee represented by National Geospatial Information (NGI), with responsibility of co-chairing with Ethiopia and Burkina Faso (United Nations, 2015a). In addition, South Africa was tasked as convener in fundamental data sets. This offers opportunities for SACU as a sub-regional level with representatives in higher level spatial information management efforts. In order to participate meaningfully in this forum, the SACU countries need to focus on interventions which improve the status of their geospatial information management and this study has advanced the SDIOGIF for the purpose. The SDIOGIF can be used in line with the United Nations (2013) agenda, which points towards the global body as a platform where the trends are discussed and gaps bridged. The fundamental trends are listed in table 8.3 with an indication of the place and activities involved in shaping them in 2018.

Table 8.3: Global Geospatial Information Management Trends. (Adapted from http://ggim.un.org/)

No.	*Identified Trends (United Nations, 2013)*	*Related activities in the recent times*	*Dates*	*Place*
1	*technology and the future direction of data creation, maintenance and management*	*United Nations Committee of Experts on Global Geospatial Information Management – eighth meeting*	*1 - 3 August*	*USA*
		Sub-Committee on Geodesy – second meeting	*22-23 November*	*China*
		Expert Group meeting on integration of statistical and geospatial information – 5th meeting	*22-23 November*	*China*
		International Seminar on geospatial information management to support 2030 Agenda	*5-8 December*	*Kenya*
		Workshop- Global Fundamental Geospatial Data Themes for Africa	*25-27 April*	*Ethiopia*
2	*Legal and policy developments*	*Working Group on Legal and policy frameworks*	*17-18 November*	*China*
		International Workshop - Legal and Policy Frameworks - Licensing of Geospatial Information	*10 - 13 April*	*Tonga*
3	*Skills requirements and training mechanisms*	*No activity discovered*	*None*	*None*

4	*The role of the private and non-governmental sectors*	*No activity discovered*	*None*	*None*
5	*future role of governments in geospatial data provision and management*	*A number of activities in No. 1 are also applicable for this one*	*Same dates*	*Same place*

These trends are pointers to all members of the international community involved with geospatial information management to come up with suitable systematic frameworks for the purpose. If the countries are facing constraints that inhibit the development of such systems, in particular SDI, then they are better placed to follow and utilize the SDIOGIF approach for focus and execution. Inaction from countries will leave them behind and that must be avoided as much as possible.

8.2.2.2 Technology Trends

The ubiquity in technology has led to a proliferation of all sorts of geospatial data ranging from the traditional authoritative data produced through official platforms by organisations, to passive geospatial data produced by mobile phone users. The discussions in this study have mainly focussed on the official platforms because of the prevailing legislations and working documents in relation to SDI in the SACU. But it has to be acknowledged that, the need to integrate and process well-structured and semi-structured information has become a necessity as SDIs are being developed (United Nations, 2013). Concerning SDIs, the study does show the SACU countries acceptance of technologies such as; the Global Navigation Satellite System (GNSS), Open Geospatial Consortium (OGC), International Standards Organisations (ISO), Web Map Service (WMS) and Web Feature Service (WFS). United nations (2013) has identified the trends setting technologies to be; Volunteered Geographic Information (VGI), Free and Open Source Software (FOSS), Cloud Computing, Graphical Processing Units (GPUs) Database, Parallel Processing database, NoSQL Database, Internet of Things (IoT), Big Data and Linked Data. In a continued study of SACU countries SDI, these technologies need to be considered within the contexts of the SACU countries, to gauge how they have been adopted and adapted to the prevailing SDI needs and sectoral legal requirements of SDI stakeholders. Namibian SDI geoportal does have a link with Open Street Map, which is considered to be a good way forward for that country.

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APPENDICES

Appendix 1: PhD Candidature Approval

DOCTORAL DEGREES BOARD
UNIVERSITY OF CAPE TOWN
Masingene Building,
Private Bag X3, Rondebosch, 7701
Tel: +27 21 650 2202
E-mail: ddb@uct.ac.za

23 February 2017

STRICTLY CONFIDENTIAL

Mr L Maphale MPHLOP001
MPHLOP001@myuct.ac.za

Dear Mr Maphale

APPLICATION FOR REGISTRATION AS A PhD CANDIDATE

I am pleased to inform you that the DOCTORAL DEGREES BOARD OFFICE has approved your admission as a candidate for the PhD under the supervision of A/Professor J Smit.

The University requires that you are registered for a minimum period of two years, provided you maintain unbroken registration and comply with the rules for the degree. If you first register for the degree after 1 May, you may not count the remainder of the year as part of the minimum prescribed period of study for the programme. Provided you have met with these requirements, the earliest date on which you will be able to graduate is therefore two years after your first registration. I would like to remind you that you must renew your registration every year, not later than the last day of February.

Senate has adopted a set of guidelines for supervision for the information and use of candidates and supervisors. A copy of this is attached and we hope it will be useful.

The rules for the PhD (copy enclosed) give the dates by which you must notify this office of your intention to submit a thesis for examination. Early notification alerts the DDB to prepare for the examination process by getting examiners nominated, approaching them and obtaining their agreement before your thesis arrives. When advising of intention to submit, include the following information - student number, full names, postal address, thesis title, department and name of supervisor/s where any supervisor is not in the same department or at another university please indicate this.

Please note that there is an upper limit of 80 000 words on the main text of your thesis. Any request to exceed this limit must be discussed with the supervisor and final approval must be obtained from the Dean.

We wish you well with your research.

Yours sincerely

Janine Isaacs (Mrs)
Doctoral Degrees Board Office
cc: A/Professor J Smit, Architecture, Planning and Geomatics
FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT
Ref: CO012017
Attachment

Appendix 2: UCT Ethics in Research Approval

Application for Approval of Ethics in Research (EiR) Projects
Faculty of Engineering and the Built Environment, University of Cape Town

APPLICATION FORM

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

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant		Lopang Maphale
Department		Architecture, Planning and Geomatics
Preferred email address of applicant:		maphalegeocon@gmail.com
If a Student	Your Degree: e.g., MSc, PhD, etc.,	PhD
	Name of Supervisor (if supervised):	Prof J. L. Smit
If this is a researchcontract, indicate the source of funding/sponsorship		Click here to enter text.
Project Title		Spatial Data Infrastructures Development and Assessment in Southern African Customs Union Countries

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

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

SIGNED BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Lopang Maphale		**18 Nov 2016**

APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	Julian Smit		**18 Nov 2016**
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section1; and for all Undergraduateresearch (including Honours).	Click here to enter text.		Click here to enter a date.
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.	G. SITHOLE Click here to enter text.		22/12/2016 Click here to enter a date.

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Appendix 3: Informed Consent Document

INFORMATION SHEET & CONSENT FORM

UCT PHD (Title of research project): SPATIAL DATA INFRASTRUCTURES DEVELOPMENT AND ASSESSMENT FOR SOUTHERN AFRICAN CUSTOMS UNION COUNTRIES

Introduction

My name is Lopang Maphale a PHD Candidate at the University of Cape Town carrying out research on the above-mentioned title.

Research Aim and objectives – The aim of this research work is to investigate, assess and understand the development of SDIs in the Southern African Customs Union countries. In that order I am interested in finding out SDI developments, achievements and challenges in the SACU region. Another objective will be to advance country specific frameworks for SDI development. In addition, I intend to propose a regional SDI framework to foster cooperation, benchmarking and collaboration in SDI work within SACU. In so doing I hope to give currency to development of regional SACU-SDIs and encourage SDI researches in the region. I would like to invite you to participate in the project by completing questionnaires and/or participating in interviews and/or participating in focussed groups such as workshops.

Participation – Please understand that you are not forced to participate, ie your participation is voluntary. The choice to participate is yours alone. If you choose not to participate, there will be no negative consequence. If you choose to participate, but wish to withdraw at any time, you will be free to do so without negative consequence. However, I would be grateful if you would assist me by participating in whatever way possible as stated in research aim and objectives.

What is Expected – The researcher is seeking to secure participation with organisations involved with SDIs where focussed groups workshops, questionnaires and interviews will be conducted. The researcher will in the cause of the work visit sites where you are as prospective informants for in depth study. In addition, questionnaire will be sent to you by email or other available communication channels to fill and send back for collating and analysis.

Benefits to participant – SDI development and assessment continues to be fundamental debates to professionals and organisations and this research is viewed to have a direct bearing in facilitating the debates and solution seeking by organisations and professionals involved with SDI especially in the SACU region.

Risk of harm to participants – No harm is envisaged in this research as all the information will be aggregated to give a general picture and inform a more generic approach to SDI development and assessment in SACU region.

Level of permission required – Please feel free to state what you will allow to be used in the research.

Anonymity and Confidentiality – The rule of thumb in this research work is to keep informants anonymous, therefore your participation will remain so. In the case of focussed groups, the interest will be to look at aggregated positions and contributions of the groups as opposed to singling out any one.

Sharing and use of data – The data collected through this research will be shared with professionals and organisations which are actively involved with development and assessment of SDIs through reports, conference presentations and journal publications.

Demographics

Country: ……. City of work: ……

Profession of Participant: …… Organisation …….

Number of years of Experience: ……. Position: ……...

Email: ……... Phone: ……. Cell: …….

Signature of Participant: ……... Date: ……

Appendix 4: SDI Coordinators Questionnaire

In order to break the ice to this research preliminary questions are put forward here to be answered by prospective informants. These questions and the answers you will give should help the researcher to frame the scenario for the in-depth study of the SDI of your country.

Instruction: (Please fill in answers by starting on new line and use Red Colour font)

1. When did the National Spatial Data Infrastructure (NSDI) concept started in your country?

_____

2. Who are the main players in the development of NSDI of your country?

_____

3. What is the current status of NSDI in your country?

_____

4. How do these organisations interact in the activities of Spatial Data Infrastructure development of your country?

_____

5. Identify constraints that can be readily associated with National Spatial Data Infrastructure of your country.

_____

6. Has your country made any meaningful effort to benchmark NSDI experiences from the member state of the South African Customs Union (SACU)?

_____

7. Please elaborate and expand your answer to 6 above.

_____

8. What are the main input considerations of your NSDI?

_____

9. What are the main output considerations of your NSDI?

_____

10. What benefits and opportunities does your NSDI create?

_____

11. How is the whole NSDI development of your country coordinated and what feedback mechanism are used in its processes?

_____

12. Does your country have a sound plan to forge ahead with SDI development?

_____

13. What are the views of your country regarding research and development activities on its NSDI activities?

14. What are the views of your country on the development of a regional SDI such as the one focussed on Southern African Customers Union (SACU)?

15. State your willingness for your country to participate this research work

Appendix 5: SDI Stakeholders Constraints Questionnaire

Your organisation has been identified to be among those who are carrying out the mandate of development of country's spatial data infrastructure. Therefore, you are requested to answer these seven (7) questions to help in the advancement of this research.

Instruction: (Please fill in answers and feel free to use additional paper if the need arises)

1. What do you consider to be the goals of your country's National Spatial Data Infrastructure development and do they relate to those of your organisational needs for spatial data?

_____
_____
_____
_____

2. What do you want as performance indicators of your country's National Spatial Data Infrastructure?

_____
_____
_____
_____

3. What would you say are the main limitations of development of National Spatial Data Infrastructure in your country (list limitations and give them short explanations)?

_____
_____

4. From the limitations which you have identified in number 3 above, which one (1) do you consider to be more limiting in terms of your organisation and why?

_____
_____
_____

5. How can the main limitation you have identified be solved to help the National Spatial Data Infrastructure in your country to progress towards desired status?

_____
_____
_____

6. Looking at the National Spatial Data Infrastructure what would you say has been achieved since the inception of SDI concept in your country?

_____
_____
_____

7. Looking at the solution(s) you have suggested for the main limitation and what has been achieved so far, what do you think needs to be done now to the National Spatial Data Infrastructure?

_____
_____
_____