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The Assessment of the Current Geographical Information System (GIS) Initiatives in the Public Enterprises of Swaziland

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by

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A research report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science (Environmental Science).

8 November 2022

Johannesburg, South Africa

I, Malungisa Blessing Khumalo, declare that this research report is my own unaided work. It is being submitted in partial fulfilment of the requirements for the degree of Master of Science in Environmental Science and Geographic Information Systems to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other university.



Signature of candidate

8 November 2022 in Johannesburg

Abstract

There is a growing use of geographic information systems (GIS) within the public sector in many countries. GIS require considerable financial resources and investment in information and communication technology (ICT) and human resources, which are primarily financed by public funds. The growth in adoption is partly influenced by the promising potential of GIS that has been widely discussed in the literature on GIS. The usefulness and application of GIS in aiding decision making and in public policy formulation and implementation have also been widely discussed in the literature on GIS. To examine the effectiveness of GIS in public policy, one has to develop a mechanism for measuring the success achieved by the implementation of GIS in decision making. However, the methodologies for the evaluation of the use of GIS in the public sector are mainly lacking.

The aims of this research were to evaluate the effective use of GIS in the public sector in Swaziland. Three organisations were selected, namely the Swaziland Posts and Telecommunications (SPTC), Swaziland Water Services Corporation (SWSC) and Swaziland National Housing Board (SNHB). Like in most developing countries, the lack of GIS evaluation to improve implementation is a challenge for these organisations. The current GIS applications at SPTC, SWSC and SNHB were evaluated using maturity, value and GIS product assessments. Four methods of analysis were used for data analysis: GIS maturity calculation; relative frequency of maturity calculation; gap analysis; and GIS value assessment. The results found that the SPTC, SWSC and SNHB were all in the exploitation stage of maturity. The overall relative frequency of maturity in the dimensions is the following: 35% of indicators are in the exploration stage; 56% are in the exploitation stage; and 9% are in the enterprise stage. The gap analysis shows that the organisations are in the exploitation stage of maturity. Cost prevention, coordination, employee satisfaction, better data management, time saving and better quality of information were regarded as the main ways in which GIS add value to organisations. The GIS product assessment results show that the overall compliance rate with the cartographic standards is 57.09%.

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Abbreviations

ESRI	Environmental Systems Research Institute
GIS	Geographic Information Systems
USDHS	United States Department of Homeland Security
AFDGB	African Development Bank Group
SPTC	Swaziland Posts and Telecommunication
SNHB	Swaziland National Housing Board
SWSC	Swaziland Water Services Corporation
SSA	Shared Situational analysis
CBA	Cost Benefit Analysis
RF	Relative Frequency

CHAPTER ONE
GENERAL INTRODUCTION

1.1 Background

"Now, more than ever, it is important for citizen scientists, the academic community, GIS professionals, and app developers alike to have access to authoritative sources of information for their work," said Jack Dangermond, founder and president of the Environmental Systems Research Institute (ESRI) (Pruchniewski, 2021).

A GIS can be described as a system that aids the digital capture of location data (Huisman & De By, 2009). Information is obtained through analysis and management techniques all under a common storage medium (Huisman & De By, 2009). GIS use the power of the visual digital map to enhance trend identification through the analysis of location-based information (Singh, 2011; Reinhardt, 2000).

An example of advanced GIS application is its use in America for predictive policing in crime prevention, which combines policing expert knowledge with the powerful analytical capabilities of GIS to predict future crime hotspots (USDHS, 2013). Communities vulnerable to burglary are identified by combining crime data with infrastructure data to better protect these areas (USDHS, 2013). Such techniques are not used in developing countries. Only a few of these countries, such as South Africa, are taking steps towards incorporating GIS in crime prevention by establishing policies to ensure that every police station has a GI system; however, the utilisation of the systems needs evaluation (Breetzke, 2006).

The effective use of GIS by organisations requires the evaluation of their state of GIS application or maturity using maturity models (Alrwais et al., 2015). Exceptional maturity can enhance service delivery (Makela et al., 2010). A maturity model is a framework of qualities required in implementing and using geospatial technology (Gudes et al., 2014).

Maturity models provide frameworks for the assessment of GIS use. Organisations get a picture of where they are in terms of GIS use, which provides opportunities for filling all the gaps that have been identified (Makela, 2013). They also provide a visual path towards the enterprise stage

and enable the assessment of the health of a GIS (Giroux, 2015). Typically, these assessments reveal lacking dimensions that need to be addressed in the implementation of GIS such as the lack of a GIS strategic plan, awareness, proper training and sufficient funding (Gudes et al., 2014).

Fundamentally, there is a need to understand how GIS are implemented, the value that organisations derive from their use and the surrounding setting of their use (Alrwais et al., 2015). Studies that seek to do this and track GIS use after its introduction are rare in developing countries, yet they are important in guiding the direction GIS use needs to follow (Alrwais et al., 2015). Such knowledge, once obtained, gives an understanding of GIS use and function within and across organisations and is an opportunity for improvement (Kurwakumire, 2014).

1.2 Problem Statement

The cornerstone for advanced GIS use in developed countries is to regularly conduct maturity assessments by evaluating the development of a GIS using growth indicators (Makela, 2013), by conducting value assessments to measure the benefits associated with GIS implementation at organisational level (Alrwais et al., 2015), and by conducting GIS product assessments to map products based on the most appropriate cartographic rules and guidelines (Vansteenvoort & De Maeyer, 2005). These assessments contribute to understanding the impact of GIS – they reveal whether the GIS are achieving their objectives and measure the performance of the GIS (Kurwakumire, 2014).

Swaziland, a country rich in natural resources (arable land, forests, rivers and minerals), has some organisations that use GIS for managing natural resources. Like in most developing countries, the organisations are challenged by the lack of GIS evaluation (Kiprop, 2019). The SPTC, SNHB and SWSC are public enterprises that were established to manage the land and water resources in Swaziland. These organisations separately deliver water and housing projects for the Swazi nation, using in-house GIS as an information management tool. Due to a lack of GIS evaluation, the level and extent of GIS application within the SPTC, SWSC and SNHB are not known. The GIS setup and information owned by each organisation are not easily accessible to other organisations, which hinders information sharing (Makela, 2013). The extent and quality of GIS implementation within the SPTC, SWSC and SNHB must be understood to improve spatial

collaboration initiatives among the organisations, which will result in proper service delivery (Kurwakumire, 2014). Understanding will be achieved by evaluating the current state of GIS application at the SPTC, SWSC and SNHB using maturity, value and GIS product assessments.

1.3 Aim

The aim of this study is to assess GIS initiatives in Swazi public enterprises.

The specific objectives are:

- To evaluate the GIS maturity of public enterprises;
- To assess the value associated with GIS application in public enterprises; and
- To conduct a GIS product assessment in public enterprises.

1.4 Structure of the Report

This report is divided into six chapters, namely the introduction, literature review, methodology, results, discussion, conclusion and recommendations.

Chapter one covers the general introduction, which includes the background, research problem statement, and research aim and objectives. This chapter introduces the concepts of GIS use and maturity assessments, and value and map quality assessments.

Chapter two is a literature review of GIS maturity models, value assessments and GIS product assessments. The chapter presents previous research on GIS use, GIS maturity, GIS value assessment and GIS product assessment. The frameworks that will be used to conduct this research are discussed.

Chapter three explains the methodology that provides the background for the study area and the population study. It further outlines the data collection methods and methods of analysis that this research used to assess GIS maturity, GIS value and GIS products.

Chapter four presents the results of the study that were obtained from evaluating the GIS initiatives at the SWSC, SPTC and SNHB. Results from the GIS maturity, GIS value and GIS product assessments are presented in tables and graphs.

Chapter five discusses the findings of this research by comparing them to previous research findings on the same subject matter. This chapter also highlights the limitations of this study.

Chapter six presents the conclusions drawn and the recommendations made.

Disclaimer: In April 2018, Swaziland officially changed its name to the Kingdom of Eswatini.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The literature review is based on an organisational assessment of GIS maturity, GIS value and GIS product assessment. This chapter highlights the types of methods used in previous research. The literature was gathered from studies conducted between 1991 and 2021 using Google Scholar. The criterion used was to select articles that support the research frameworks that will be used for conducting this research. The frameworks are the system usage maturity model framework, GIS value taxonomy and GIS product assessment frameworks.

2.2 GIS Application and Maturity Assessment

GIS maturity can be defined as the state of completeness of a GIS and the level of implementation of the GIS by an organisation (Alrwais et al., 2015). GIS maturity studies differ in the dimensions indicating level of maturity (Alrwais et al., 2015). The literature highlights the approaches to maturity assessment. These approaches involve evaluating the presence and absence of model indicators in an organisation, and then assigning numbers to qualitative responses to obtain GIS maturity as a number. A questionnaire and survey are used to determine GIS maturity. The literature highlighting the indicators and stages of maturity will be outlined below.

2.2.1 GIS application in public enterprises

GIS application in public enterprises was facilitated by the advancements in information technology. In the early 1990s, public entities in America were already making substantial investments in GIS and had started conducting assessments on the use of the technology (Brudney & Brown, 1992). Currently, developed countries use their GIS capabilities models to evaluate their public sector agencies (Green et al., 2017).

Literature on the use of GIS in Africa emerged in the early 2000s, and highlighted the challenges faced by African countries in their implementation of GIS (Eria, 2012). These challenges were

stipulated as the poor maintenance of computer technology and inconsistency in the public sector GIS data available (Eria, 2012).

GIS use in African public enterprises has gained traction only in the last decade, from 2010 to 2020. The current trend in African countries such as Nigeria and South Africa is that several government (public) enterprises are establishing GIS departments in their organisations (Asiyanbola, 2018). The types of systems used are web-based systems, field applications, desktop applications, and paper maps printed on demand for conducting field exercises (Kurwakumire, 2014). The assessment of GIS is also in its infancy. Studies in Uganda found that only 37% of organisations are evaluating their geographic information systems while 63% are not (Kurwakumire, 2014).

2.2.2 Maturity models

Onsrud and Pinto (1993) conducted a survey and used a questionnaire to determine factors that influence the establishment of GIS in local authorities, and then performed factor analysis to summarise the responses they received. Grimshaw (1996), in developing a taxonomy to describe GIS, used seven dimensions as indicators. They were used to describe the five stages of the growth of GIS that build on one another.

The model used by Chan and Williamson (2000) has three stages. The stages are the development of a GIS project using a business process to raise awareness; the securement of organisational resources and the development of a centralised GIS; and the development of GIS modules for business functions based on set standard practices.

Tomaselli (2004) used a five-stage model to describe the stages an organisation goes through when using GIS.

Van Loenen and Van Rij (2008) proposed a GIS maturity model with four stages, namely initiation, standardisation, intermediary and network. They used six organisational dimensions for each maturity stage, namely financial sustainability, awareness, vision, leadership, communication, and self-organising ability.

Kurwakumire (2014) proposed a benefits-based approach that is set over four stages of growth – the grassroots, intermediate, mature and integrated stages.

2.2.3 GIS Maturity Assessment

From the literature that follows, it becomes clear that quantitative and qualitative methods were used to determine the maturity of GIS in organisations. Marr and Benwell (1996) used a survey to evaluate a GIS maturity model based on Gibson and Nolan's (1974) model for IT assimilation. This model has four maturity stages, namely paper-based systems, the move towards GIS, the fully integrated stage and the integration of corporate data resources. They used SPSS software, the chi-squared test and the Cramér's V statistic to analyse survey responses.

Makela (2012) identified three dimensions and five levels or stages of maturity. Makela (2012) used the dimensions and maturity levels to assess the maturity of three companies. GIS maturity was calculated by assigning numbers from one to five to responses based on dimension indicators. The numbers were averaged per organisation to determine the level of GIS maturity. The organisations were found to be in the middle stage of maturity, which is stage three in a five-stage maturity model.

Likewise, Babinski (2013) outlines a GIS maturity capability model that has five maturity stages. This GIS maturity capability model, by Babinski (2013), uses a questionnaire with forty-five questions about GIS infrastructure and resources. Closed-ended questions were used in the survey with values ranging from 0.0 to 1.0 being assigned to the responses. The response values were added and averaged by the number of questions to obtain the maturity value (Babinski, 2013). The results of the assessment highlighted the need for a GIS strategy, and better data and project management.

Alrwais et al. (2015) used a three-stage maturity model of GIS usage, which is also the model this research used. This three-stage model categorises maturity as either exploration, exploitation, or enterprise. These stages build on one another, starting with exploration and with enterprise as the final stage. This model was used to determine the usage of GIS and to calculate the GIS

maturity in this study. This study found the local authorities that were assessed to be in the exploitation stage of maturity.

2.3 GIS Usage Maturity Model

Alrwais et al. (2015) proposed a GIS usage maturity model to determine the degree to which GIS systems are used and integrated into organisational processes. Alrwais et al. (2015) defined maturity as the extent of GIS usage and absorption within an organisation.

2.3.1 GIS Usage Maturity Model Stages

Alrwais et al. (2015) proposed a three-stage and five-dimension model for maturity assessment (Table 1). The stages are exploration, exploitation and enterprise (Alrwais et al., 2015).

Exploration: This is the first stage, which represents the infancy of the GIS. This stage is identified by little to no use of GIS, the use of paper, no spatial data sharing, outsourced GIS functions and the use of GIS only for record-keeping (Alrwais et al., 2015). **Exploitation:** This is the second stage, characterised by the realisation of the need for GIS, routine use of GIS, a GIS department, the integration into some business processes, a GIS management style that is service centre-based and the presence of a GIS specialist (Alrwais et al., 2015). **Enterprise:** This is the final stage where GIS are extensively used to give an organisation a competitive edge. In this final stage, there is continuous process reengineering, there are multiple departments using GIS, there is executive usage of GIS for decision making, there is a centralised geospatial platform accessible to all departments and the interorganisational sharing of spatial data is enabled (Alrwais et al., 2015).

2.3.2 GIS Usage Maturity Model Dimensions

Alrwais et al. (2015) identified five dimensions that can be used to measure GIS maturity over the three stages: system; user; task; organisation; and GIS department (Table 1). A questionnaire was used to assess the extent to which the organisations have fulfilled each of the five dimensions.

2.3.2.1 System Dimension

The system dimension refers to the features, customisation and quality of the GIS in use and uses three subcategories as indicators: GIS function; GIS products; and GIS customisation (Alrwais et

al., 2015). Function refers to what the system can do in terms of design, database management, data processing, geoprocessing, decision support and modelling (Alrwais et al., 2015). Products refer to the software used by an organisation (Alrwais et al., 2015). Customisation refers to the degree to which GIS products and functions are manipulated to render solutions (Alrwais et al., 2015).

2.3.2.2 Task Dimension

The task dimension refers to actions performed by GIS users to achieve certain goals, and tasks can either be complex or simple in terms of difficulty (Alrwais et al., 2015). There are four indicators of the task dimension in this model, namely core business processes, support processes, task complexity and process reengineering (Alrwais et al., 2015).

2.3.2.3 User Dimension

The user dimension refers to the person operating the GIS to perform a task and the people who use the geospatial information products (Alrwais et al., 2015).

2.3.2.4 Organisation Dimension

The organisation dimension refers to the presence of qualitative organisational variables that affect GIS adoption. The indicators for this dimension are strategy, vision, training, awareness, and cooperation (Alrwais et al., 2015).

2.3.2.5 GIS Department Dimension

The GIS department dimension refers to the characteristics of the GIS implementing division. The establishment of a GIS department is vital to increase the impact on the number of departments that use the GIS. GIS department indicators are organisational structure, role of the department and the number of GIS employees (Alrwais et al., 2015). The characteristics of each dimension indicator for every maturity stage are shown in (Table 1) below.

Table 1: Maturity Usage Model Dimensions and Maturity Stages (Alrwais et al., 2015)

Dimensions	Stage 1: Exploration	Stage 2: Exploitation	Stage 3: Enterprise
System **1) GIS functions used** **2) GIS products utilized** **3) GIS customization**	1) Mapping (overlay, visualization), basic measurement and spatial database	1) + Spatial and statistical analysis 2) + Online GIS 3) Minimal	1) + 3D, decision modeling, forecasting and monitoring 2) + Mobile GIS
	2) Desktop GIS 3) Vendor driven		3) Extensive and ongoing
Tasks **1) Core process** **2) Support process** **3) Complexity of the task** **4) Workflow reengineering after GIS**	1) Only in certain established process 2) Minimal 3) Simple (location, structured) 4) Digitize manual process	1) ≈ 40% of core process supported by GIS 2) ≈ 40% of support process supported by GIS 3) Moderate (trends, semi-structured) 4) Moderate changes to take advantage of GIS	1) ≈ 60% of core process supported by GIS 2) ≈ 60% of support process supported by GIS 3) Complex (what if modeling, unstructured) 4) Radical changes as GIS enables new and existing workflows
Users **1) Percentage of internal users over all employees** **2) Percentage of departments using GIS over all departments** **3) Extent to which GIS is used at the operational, tactical and strategic level of management** **4) Number of GIS connections (usage agreements) with outside agencies**	1) <20% 2) <20% 3) Operational: Moderate Tactical: Minimal Strategic: None 4) None	1) 20-40% 2) 20-40% 3) Operational: Moderate Tactical: Moderate Strategic: Minimal 4) <3	1) 41% or more 2) 41% or more 3) Operational: High Tactical: High Strategic: Moderate 4) 3 or more
Organization **1) GIS vision** **2) GIS strategic plan** **3) Purpose of use** **4) Pattern of use** **5) GIS awareness** **6) Training** **7) Cooperation/ coordination between departments as a result of GIS**	1) To manage spatial data 2) Doesn't exist 3) Inventory 4) Specialized 5) Low 6) For designated employees only 7) Rare	1) To improve efficiency 2) Researching GIS strategic plans 3) + Analysis 4) Routine (embedded in business process) 5) Moderate 6) During implementation mostly 7) Moderate	1) To enhance decision making 2) Formal document exists 3) + Policy making 4) Innovative 5) High (GIS day exists) 6) Ongoing in house and outside 7) High (team work spirit)
GIS Department **1) Structure** **2) Role** **3) Number of staff** **4) Skill set** **5) Management style** **6) Use of consultants**	1) Doesn't exist 2) Not clear 3) <3 4) Cartography and engineering 5) Traditional (order taking help desk approach) 6) To justify initial investments	1) A team within a department 2) Provide basic GIS functionalities 3) 3-7 4) + Web programming 5) Service oriented 6) During implementation	1) Stand alone department 2) Support organization 3) 7 or more 4) + Mobile programming + Business knowledge 5) Customer oriented (on demand solutions) 6) Ongoing and considered important

A maturity matrix was developed by Alrwais et al. (2015) to calculate the maturity of an organisation using the usage model. Firstly, the indicators for the dimensions were coded 1 for exploration, 2 for exploitation and 3 for enterprise based on responses to a questionnaire per

organisation (Alrwais et al., 2015). The scores were tabulated and used to calculate GIS maturity (Alrwais et al., 2015).

2.4 GIS Value Assessment

GIS value assessment is the evaluation of the benefits gained from the use of GIS. Previous researchused surveys and several questionnaires as tools to obtain responses to determine the benefits that organisations receive from using GIS. The benefits of GIS are categorised differently by different authors, yet recurring themes can be seen, such as technological benefits, business process and service delivery improvement, time and cost savings, and societal benefits.

2.4.1 Value Assessment Approaches

Worrall (1994) stated that cost benefit analysis (CBA) is a method that is used to assess the economic benefits of a business investment. It has also been used to assess GIS implementation initiatives. Nedovic-Budic (1999) noted that CBA is difficult to use in public sectors as they are not profit-driven like private entities. A better method for the evaluation of public sector organisations is required – a method that will assess the abstract and social effects of GIS.

Clapp et al. (1989), in their assessment of developed land information systems, highlighted a four-stage benefits model. These stages are the operational efficiency, operational effectiveness, programme effectiveness and well-being stages.

Also, Calkins and Obermeyer (1991) highlighted the importance of understanding the value gained from using GIS to enable further development of the system. Calkins and Obermeyer (1991), in their development of a value assessment taxonomy, identified time savings, avoidance of costs, reduced risk, new GIS innovations, and productivity as key areas for assessing the value of GIS. Calkins and Obermeyer (1991) used a questionnaire consisting of twenty-four questions grouped into six categories.

Worrall (1994) also identified efficiency, effectiveness and intangible benefits by performing a CBA of GIS.

Brown (1996) assessed GIS value based on the seven goals that GIS aim to achieve: improved decision making; better project management; improved public services; improved productivity; better long-term planning; improved information sharing; and better inter-departmental coordination. Brown (1996) obtained this information by administering a survey that used a scale of one to five to rate each goal.

Nedovic-Budic (1999) conducted a literature review of GIS benefits, and identified efficiency and effectiveness gains in organisational business processes. They also highlighted the importance of determining the social effects of GIS use. Likewise, Tulloch and Epstein (2002) identified four stages of GIS value gained: development; record keeping; analysis; and democratisation. Joffe (2003) placed value on the rendering of GIS services to other stakeholders and customers. GIS benefits are attained through revenue-generating activities such as subscriptions, usage fees and the external sale of GIS capabilities.

Pick and Shin (2008) surveyed company executives over a two-year period to assess their perceived GIS value. They used a process-based approach to develop a model to assess the process level benefits of GIS (Pick & Shin, 2008).

Eldrandley et al. (2015) identified broad benefit levels from the use of GIS: individual (time saving and increased awareness); organisational (cost savings and increased productivity); and social benefits (better service delivery and public participation). Eldrandley et al. (2015) stated that the attainment of GIS benefits depends on the success of the implementation of GIS, and used a questionnaire to evaluate eleven hypotheses.

Lastly, Akingbade et al. (2009) developed a GIS value taxonomy from the review of literature on the impact of GIS between 1998 and 2008, by categorising value gains as effectiveness, efficiency, and societal well-being (Table 2). Effectiveness refers to how GIS fulfils information requirements; efficiency refers to the way in which GIS improves data handling and acquisition, and the way in which GIS improves business processes with minimum waste; and societal well-being refers to the way in which GIS improves an organisation's interaction with society (Akingbade et al., 2009). The current research will use this taxonomy to determine the value that organisations associate with the use of GIS.

Table 2: Taxonomy of GIS Impact (Akingbade et al., 2009)

Category	Definition	Indicators
Efficiency	The degree to which GIS operates with minimum (waste, duplication and expenditure of resources) or with the same level of inputs but provides greater output (productivity).	1. Better allocation of resources (labor, space, material and capital) 2. Cost (savings or avoidance) 3. Increased productivity (automation and simplicity which translates into grater output with less or the same resources) 4. Better spatial data management capability (acquisition, storage, retrieval, coverage, completeness, accuracy, availability, access and dissemination) 5. Time-saving
Effectiveness	The extent to which GIS has contributed to the satisfaction of information needs, in adequate quantity and quality of data and decision-making process. GIS enhances performance as well as enabling many business processes that are not possible without GIS.	1.Adequacy of service relative to the need (satisfies information needs with expected quality) 2.Improved planning, coordination and cooperation 3.Improved products and services 4.Increased job satisfaction (internal users satisfied with the technology and decisions made based on it) 5.Better conflict resolution (as a result of information) 6.Support for more explicit articulation of decisions (improved decision making, better decisions than without GIS) 7. More responsive to the needs of citizens
Societal well-being	The degree to which GIS helps in the realization of collective goals of a society or impact of GIS on broad societal objectives such as "individual integrity, social justice, distribution of wealth and fulfillment of human aspirations."	1.Citizen-public sector interactions (Public participation and citizen empowerment) 2.Economic benefits (increased revenue for example accurate taxation or fraud detection) 3.Enhancement of principles of a democratic society, for example, freedom from constraints such as corruption (better transparency) 4.Improved standard of health and safety 5.Protection of legal rights, such as privacy (surveillance and confidentiality) 6.Social justice: fair treatment and a just share of benefits, for example equal availability of information to citizens when needed and equal ease of access (equity)

2.5 GIS Products Assessment

The review of various approaches to GIS product assessment highlights the importance of using a list of standards to determine map quality. According to Gartner (1998), the quality of a map product is a measure of how well it meets the standard requirements for presentation and visualisation. Gartner (1998) highlighted the importance of understanding map quality in the quest for making better maps. Vansteenvoort and De Maeyer (2005) proposed two approaches to GIS product assessment. The first approach is communicative map quality, which determines how much information is transferred through the communication process. The second approach is the total map quality approach, which uses a cartographic reference to determine map quality (Vansteenvoort & De Maeyer, 2005). The total map quality approach is of interest to this study.

This is an analytical method that involves specifying a quality reference that has a list of map specifications defining the quality of a map (Vansteenvoort & De Maeyer, 2005). These specifications form a reference product that can be used to determine the extent to which a particular product matches the reference (Vansteenvoort & De Maeyer, 2005). Liashenko et al. (2021) identified three approaches to map quality assessment: the production approach; the consumer approach; and the value approach. The production approach is a technical method of evaluating the elements of maps, GIS and GIS services. Liashenko et al. (2021) stated that the production approach is concerned with map accuracy and production issues, whilst the consumer approach is concerned with needs, expectations and usability.

Medeiros (2016) evaluated map figures against a list of cartography standards, scoring +1 for standard applied, and 0 for standard not applied. The better the similarities to the map requirements, the better the look and feel of the final products, which in turn translate to a better map quality (Vansteenvoort & De Maeyer, 2005).

Medeiros (2016) used the universal cartographic design standards approach in assessing the quality of map products after reviewing a wide range of literature. Medeiros (2016) produced twenty-nine standards (Table 3). The Medeiros (2016) approach will be used in this study.

Table 3: Cartographic Design Concepts (Medeiros, 2016)

Topic	Description (desired result)	Impact on map goals
N Arrow	N arrow not included on maps where orientation to N changes (e.g. conic projections). N arrow is not required on maps of very large and familiar areas.	0 if variation can't be determined, 1 if left off non uniform maps, -1 if left.
Scale Bar	Scale bar uses whole number divisions. Scale bar should not be included on map projections where distance is not preserved (esp. very large areas).	0 if variation can't be determined, 1 if left off non uniform maps, -1 if left.
Visual Hierarchy		
Figure - Ground	Map elements arranged visually from background to foreground (or from figure to ground). Clear seperation between background and map data.	Maps with no VH appear flat and make it difficult to determine what features are more important than others.
Intellectual Hirearchy	The VH suggests feature importance and aligns with the maps purpose.	The VH, or visual depth in a map should refelct the intellectual hiareacrchy, or feature importance to the map. A VH that does not match the maps purpose can be misleading.
Clutter	Map dispenses with elements that are not part of the IH or do not support the purpose of the map.	An effective VH does away with features or elements are not supportive or important to the maps purpose. Too many un ralted features or layers in the VH make map reading difficult.
Color		
Color use	Judicious use of bright colors. Map avoids using heavy, bright, or fully saturated colors over large areas. NA for greyscale.	Broad use of brigth or fully saturated colors can be disracting.
Logical associations	Conventional colors used for familiar features (e.g. blue for water; green for veg). Bright or saturated colors suggest high values, light or faint colors suggest low values. White suggests no data. NA if greyscale.	Ignoring logical or expected color associations can be disorienting to the map reader.
Diverging color classes	Diverging color ramps used with diverging data. Critical value is indicated for diverging data. NA if greyscale or not classified.	Ramps that change away from a central neutral color suggest diverging values with a critical value. Applying this sceme to normal, linear data suggests a critical value that is not present.

Topic	Description (desired result)	Impact on map goals
Multi or single color ramps	Single color ramps for linear data. When multiple colors are used for linear data, ramp transition through neutral to non-neutral color for increasing values (yellow to dark blue vs. red to green). NA for greyscale.	Two colors, neutral to non neutral suggests a linear value change. Transitioning through to non neutral colors suggests a divergence in values or a change from "acceptable" to "unacceptable" as with green to red color scemes.
Symbology		
Visual variables	Data symbology is varied by the appropriate visual variable for qualitative or quantitative data. NA for non data driven maps.	Hue & shape for qualitative, value & size for quntitative.
Legibility	Symbols and labels are readable and distinguishable at published map scale.	
Classifications	No more than 6 unique color classifications by value. Applies to quanititatvie data only.	Humans generally can't reliably distinguish between around 6 different shades of the same color. Extra classes ok when using different shades of the same hue for class groups (e.g. dark green forest, light green grass).
Data scale	Data resolution is appropriate to the map scale and extent. Map avoids using very detailed data at small scales or overly simplified data and large scales, or mixing overly detailed and generalized data.	
Projections		
Distortion	Map uses a projection that fits the map scale and extent and avoids strong visible distortion. 0 in casses where projection is undectable.	
Rotation	Projection for main map and any insets are rotated individually.	
Context	Map avoids "island effect" by including some background data outside of immediate area of interest. Background detail matches map subject (e.g. a map of well locations may dispense with detailed minor roads but leave on local river networks).	Readers can have a hard time interpreting the maps geography when all base map details are clipped to the study area extent.
Labels		
Style	Type is styled uniformly by feature class. Label appearance compliments its meaning.	Labels are symbols, and their appearnce can enhance their meaning. Uniformity of style by feature helps reinforce the VH. Haphazzard styling may cinfuse the reader.

Topic	Description (desired result)	Impact on map goals
Placement	Labels are placed with their features whenever possible. Labels are placed to avoid crowding, breaking lines, and overlapping other features. Labels are aligned to their features. Area labels are letter spaced to help indicate area. Line feature labels for large areas are curved to follow feature. Labels are placed right side up (or "feet falling").	
Fonts	No more than 2 font families on the map. No decorative fonts in the body of the map.	Excess font use, or non conplimentaty fonts creates a distracting map. The eception might be maps for posters or contests.

2.6 Existing Gaps in Knowledge

The literature reveals that the application of GIS can be assessed through separate maturity, value and GIS product assessments. There is a lack of studies that consider maturity, value and GIS product assessments in one review. The use of all three approaches to assess individual organisations allows an extensive review of GIS application. Most of the studies are based on first-world contexts where GIS is considered advanced, and the assessments are conducted on a continuous basis (Green et al., 2017). The assessment of GIS application in developing countries is a one-off process normally funded by international donor organisations (Kurwakumire, 2014). Organisations in developing countries need to be capacitated to be able to conduct regular assessments. There is a lack of knowledge on how developing countries are using GIS. The various assessment approaches need to be assessed in the context of developing countries to determine which assessment approach is suited to their organisations.

CHAPTER THREE
METHODOLOGY

3.1 Study Area

3.1.1 Geographical Location, Areas and the Extension

Swaziland is a landlocked country that shares borders with South Africa for 430 kilometres to the north, south and west, and with Mozambique for 105 kilometres to the east (Brown, 2011). Swaziland is made up of four administrative regions and 59 subregions. The administrative regions are Shiselweni, Hhohho, Manzini and Lubombo (Brown, 2011). For the interest of this study, the public enterprises being assessed are in the Hhohho region. The headquarters of the SWSC are in the Lobamba subregion, the headquarters of the SPTC are in the Mbabane East subregion and the headquarters of the SNHB are in the Mbabane West subregion (Figure 1).

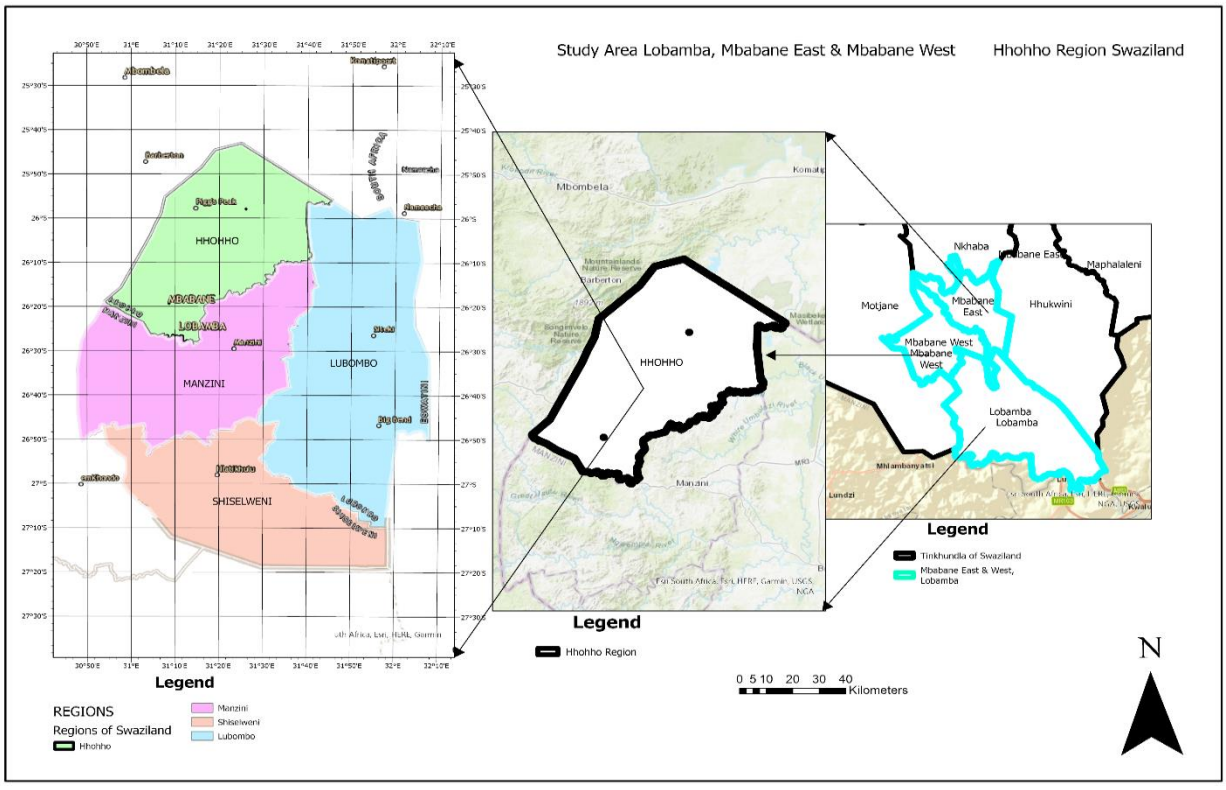


Figure 1: Location of Study Areas, Mbabane East, Mbabane West, and Lobamba (Khumalo, 2019)

3.1.2 Population

According to the most recent population census of 2019, the population of Swaziland stands at 1 093 238 people, and the population grows at a rate of seven per cent (CSO, 2019). The gender composition of the Swazi population is 51.4% female and 48.6% male (CSO, 2019). The Manzini region has the largest population, followed by Hhohho, and then Shiselweni and Lubombo (CSO, 2019).

3.1.3 The Economy

The main driver of the Swazi economy is manufacturing, which accounts for a third of the gross domestic product (GDP). Agriculture accounts for eleven per cent, while mining is on the decline (Davidson & Mavhungu, 2002). The main industries are coal mining, asbestos and agro-based industries, wood pulp and sugar (Davidson & Mavhungu, 2002). Agricultural activities are mainly subsistence farming, and sugar remains the major revenue earner from this sector (Davidson & Mavhungu, 2002).

3.1.4 Physical Environment

Swaziland has four distinct physiographic regions distinguished by elevation and relief, namely the Highveld, the Middleveld, the Lowveld and the Lubombo plateau (Brown, 2011). Mountains, hills and plains dominate the topography of the east-to-west cross-section of the country, giving rise to valleys, plateaux and basins (Brown, 2011). The Swazi climate is classified as subtropical, and characterised by hot and wet summers, and cold and dry winters. Temperatures in the country range from 0 °C in mid-winter nights to 33 °C in mid-summer (Swaziland's National Report on Climate Change, 2000). The mean annual rainfall ranges from about 1 500 mm in the Highveld to a little less than 500 mm in the Lowveld (Brown, 2011).

The hydrology of Swaziland is made up of four river basins, the Great Usuthu, Komati, Mbuluzi and Ngwavuma basins, with the first three being major contributors to sugar cane irrigation (Mathondo & Msibi, 2001). The Mbuluzi feeds into the Mnjoli Dam, which is used to irrigate more than 24 000 ha of sugar cane (Mathondo & Msibi, 2001). All the river basins flow through the Lubombo District, where sugar cane farming is concentrated (Mathondo & Msibi, 2001).

3.1.5 Administrative and Political Structures

Swaziland is governed by a constitutional monarchy with executive powers vested in the king (Mkhonta, 2007). The executive of the country is run by the prime minister who is appointed by the king. Since 2005, the government has consisted of 15 ministries and 25 state-owned enterprises, each of which functionally falls under a parent ministry (Mkhonta, 2007). The ministries of interest to this study are the Ministry of Natural Resources and Energy (MNRE), which is the parent ministry for the SWSC, the Ministry of Housing and Urban Development (MHUD), which is the parent ministry for the SNHB, and the Ministry of Information Communication Technology (ICT), which is the parent ministry for the SPTC.

3.2 Population Study

"The Eswatini Water Services Corporation (EWSC) is a body corporate duly established under the Water Services Corporation Act No.12 of 1992 as the sole provider of water services in the urban areas (water supply, and sewage treatment and disposal) and to control the abstraction of raw water from boreholes in those areas for which it is responsible. EWSC is a category 'A' Public Enterprise in terms of the Public Enterprise (Control and Monitoring) Act No.8 of 1989 and therefore it is wholly owned by Government." (SWSC, 2019)

"The objectives of the Corporation are to abstract, store, transport, purify and collect water, convey, treat and dispose (of) sewage in ***areas specified in the schedule of the Water Services Act. The Corporation is mandated to:***

- Prepare schemes for the development of water resources and for the supply of water and construct, maintain and operate such schemes.
- Keep under constant review the quality, reliability and availability of water supplies.
- Control and regulate the production, treatment, storage, transmission, distribution and use of water for public purposes.

- Design, construct, acquire, operate and maintain water works for the purpose of supplying water for public purposes and
- Inspect and advise on the management, collection, production, transmission, treatment, storage, supply and distribution of water." (SWSC, 2019)

The SWSC administrative structure comprises the Government of Swaziland, the MNRE, the SWSC Board of Directors, and the executive management heading the following departments: Strategic Services; Operations; Finance; and Technical Services. Their GIS department falls under the Technical Services Division (SWSC, 2019).

The Swaziland Posts and Telecommunications Corporation (SPTC) was established through the SPTC Act No. 11 of 1983. The Corporation's responsibilities are to establish, operate and maintain postal and telecommunications services nationally. The SPTC is wholly owned by the Government of Swaziland and plays a key role in providing basic telecommunications services and internet services (SPTC, 2019). The SPTC is a monopolist national telecommunications operator by law, dominating fixed-line service provisioning and participating in the mobile sector as a joint venture partner (ADBG, 2000).

The SPTC administrative structure comprises the Government of Swaziland, the ministry (ICT), the SPTC Board of Directors, and the executive management overseeing the following key operational areas: Finance; Information technology (IT); Swazi Post; Swazi Telecom; Corporate Strategy and Corporate Services. Their GIS division falls under the IT Department (SPTC, 2019).

"The Swaziland National Housing Board (SNHB) was established in 1988 under the National Housing Board Act No. 3 of 1988. Formerly known as the Industrial Housing Company, SNHB is a category 'A' Public Enterprise which reports to the government of Swaziland via the MHUD." (Nhlabatsi& Dlamini, 2015). "The mandate of SNHB is to provide affordable housing for the Swazi nation. SNHB acquires land from the Swazi Government and develops infrastructure and constructs houses on the land." (Nhlabatsi & Dlamini, 2015). The SNHB also provides rental units at affordable local rates within urban areas (Nhlabatsi & Dlamini, 2015).

Their administrative structure consists of the Government of Swaziland, the Ministry of Housing and Urban Development, and the executive management heading the following departments: Executive; Finance; Internal Audit; Property Development; Property Management; Human Resources; and Corporate Services. The SNHB's GIS division is found under the Executive Department (Nhlabatsi & Dlamini, 2015).

Public enterprises contribute significantly to the development of economies and the management of communities around the globe. The way public enterprises operate in terms of structure and function enhances the ability of the government to deliver services (Thynne, 2021). Water and waste water need to be managed in a well-coordinated manner (Oyebode, 2018). When the SNHB is developing township infrastructure, the SWSC is responsible for monitoring the installation of water and sewer services, whilst the SPTC is responsible for the installation of fixed-line telecommunications. Telecommunication services are now considered as important as water and electricity. Singh et al. (2000) consider telecom infrastructure an integral component of township planning and development.

The SPTC, SWSC and SNHB were tasked with the management of water and land resources by the Swazi government. They all have functioning GIS departments that produce geospatial information products with different themes. The SWSC has data on the infrastructure of water and sewer connections for Swaziland, the SPTC produces data on telephone lines and post offices, whilst the SNHB produces data on township layouts and rental units. Geospatial information cannot be easily retrieved from any of the organisations, which is a setback for public service delivery. Geospatial data is only shared if a formal request has been made and approved by the executives of the organisations concerned. This process usually takes a long time and results in delays in the delivery of projects.

3.3 Research Design

To achieve the aim of this research, a case study was combined with quantitative research methodology in the form of a survey.

3.3.1 Survey

The survey was compiled to assess the maturity and value of GIS in the three organisations (the SPTC, SWSC and SNHB). The study used the snowball random sampling technique to select the participants. Structured two-hour face-to-face surveys were conducted on the premises of the organisations in December 2019 and a questionnaire was used to obtain information. Responses were completed by the respondents and any unclear questions were properly explained. The surveys were completed on the premises to avoid low response rates, and this provided an opportunity to clarify any aspects of the questionnaire that were unclear (Beiske, 2002).

Two people were surveyed per organisation. These were the GIS manager and a member of the management team. The GIS managers were chosen because they are on the Swaziland GIS committee and they had recently been guest presenters at a GIS users conference to demonstrate their application of GIS. The members of the management team were chosen because they are at executive level, and they head departments that use GIS daily. At the SWSC, the GIS manager and the head of Technical Services were surveyed. At the SNHB, the GIS manager and the head of Property Development were surveyed. At the SPTC, the GIS manager and the head of Information Technology were surveyed. The administering of the questionnaire was scheduled with the three organisations via telephone. Once appointments had been made, the three organisations of interest were visited.

3.3.2 Sampling

Three organisations were selected for this study and their GIS managers showed some interest in participating. The concept of information power motivated the selection of only three organisations based on the national scope of their work (Malterud et al., 2016). These organisations have a footprint that covers the whole country, which makes their contribution valuable. They have dedicated GIS managers and have the financial capacity to obtain GIS hardware and software.

3.3.3 Questionnaire

Three questionnaires were designed based on the adopted maturity usage model (Table 1) and the taxonomy of GIS impact (Table 2). The questionnaires consisted of two sections and were administered to the GIS manager and a member of the management team per organisation to collect primary data. The questions in the first section were aimed at assessing the GIS maturity with the GIS manager, and were in multiple-choice format. Each dimension indicator was framed as a question. The questions had only three possible answers (1, 2, or 3) based on the maturity stage indicators (1 for exploitation, 2 for exploration and 3 for enterprise), which respondents had to choose from. The respondents were not made aware of what the options 1, 2 and 3 represented in the maturity usage model. There were twenty-four questions in section one to assess the state of the five maturity dimensions (system, task, users, organisation, GIS department).

Questions one to three were about the system dimension and meant to assess GIS functions, GIS products used and the level of GIS customisation. Questions four to seven were on the task dimension. Questions eight to eleven were on the users. Questions twelve to eighteen were on the organisation dimension. Questions nineteen to twenty-four were on the GIS department dimension. There was an additional multiple-choice question that required respondents to tick the most suitable descriptor of their GIS system from among the three maturity stages given.

Section two, aimed at a member of the management team at the executive level, used thirteen questions to determine the value perceived by the organisation's management team members in their organisation's use of GIS, based on thirteen value indicators. The thirteen indicators are data management, cost savings, prevention of unnecessary costs, increased productivity, better resource allocation, time savings, improved information quality, interdepartmental coordination, improved organisational planning, improved service delivery, employee satisfaction, conflict resolution, and increased public engagement. The management team member was required to select one response from a four-point Likert scale (strongly agree, agree, disagree and strongly disagree) per question. Each response was used to determine the extent to which the organisations had realised each value indicator.

3.3.4 GIS Product Acquisition

Secondary data sources in the form of nine GIS products were acquired from the three organisations (the SPTC, SWSC and SNHB) for assessment to achieve the third objective. The SNHB provided three GIS products, the SWSC two GIS products and the SPTC four GIS products. The SNHB provided a map of all institutional housing construction sites (IHP Map), a map of Nkhanini township (Nkhanini) and a map of Woodlands Extension Two township (Woodlands). The SWSC provided a map showing the Matsapha water network and a map showing the Nhlangano water network. The SPTC provided a map showing post office delivery routes, a map showing the Mbabane exchange cabinet boundaries, a map showing WiMAX coverage and a map showing the location of post offices. The GIS managers were asked for map products that met their standards and best practices in production. The GIS products were selected by the organisations because they were produced within five years of conducting this research (2014 to 2019). The GIS products were produced using ArcMap 10.3 desktop. They were assessed using the cartographic design concepts (Table 3) (Medeiros, 2016).

3.4 Data Analysis

Data analysis, according to Cohen et al. (2007), involves organising, accounting for and explaining the data, which means making sense of the data in terms of the participants' definition of the situation, and by noting patterns, themes, categories and regularities.

3.4.1 GIS Maturity

To evaluate GIS maturity, Alrwais et al. (2015) established a three-stage usage model that categorises maturity as either exploration, exploitation, or enterprise (Table 1). The model dimension indicators were used to assess how GIS is implemented at the SWSC, SPTC and SNHB using a survey questionnaire (Table 1). Responses to survey questions based on the indicators were then summarised (Table 4) and coded using the three maturity stages, as follows: 1 – exploration; 2 – exploitation; and 3 – enterprise. The coded values were used to calculate the average GIS maturity on the maturity indicators for each of the three organisations (Table 4), and the figure was rounded off to the nearest significant figure among 1 – exploration, 2 – exploitation and 3 – enterprise (Makela, 2012).

Equation 1 was applied throughout (Table 4) to calculate GIS maturity. The equation averages the variable scores per dimension and adds the averages, then divides the number by five, which is the total number of dimensions. Equation 1 is the following:

$$GIS\ Maturity = [(\sum(a))/3 + (\sum(b))/4 + (\sum(c))/3 + (\sum(d))/7 + (\sum(e))/3]/5 \quad (1)$$

Where:

$a = \text{System}$

$b = \text{Tasks}$

$c = \text{Users}$

$d = \text{Organisation}$

$e = \text{GIS Department}$

The maturity figure that was obtained from the GIS maturity calculation was rounded off to the nearest decimal place, which was either 1, 2 or 3. The final rounded-off figure was used to classify the maturity stage as follows: 1 – exploration; 2 – exploitation; or 3 – enterprise. A bar graph summarising the maturity scores for each organisation was produced in Microsoft Excel (Figure 2).

3.4.2 Relative Frequency (RF)

The relative frequency of each maturity level per dimension category was calculated by using Equation 2:

Relative Frequency = (f/n) 100 (2)

Where:

- f = the number of times the maturity stage occurred in the dimension
- n = total frequencies in the dimension

The relative frequency numbers were used to produce a graph (Figure 3).

3.4.3 Gap Analysis

A gap analysis of the level of maturity per maturity indicator category and dimension indicator category was conducted using radar charts (Figures 4 and 5). The radar charts were produced using the relative frequencies for maturity dimensions and dimension indicators per organisation.

3.4.4 GIS Value Assessment

This research categorises GIS benefits as efficiency, effectiveness and societal well-being (Alrwais et al., 2015) (Table 2). Efficiency relates to cost savings experienced from the use of GIS. Effectiveness relates to an improvement in organisational performance and societal well-being refers to how GIS has improved the ability to solve societal problems (Alrwais et al., 2015). A summary of the GIS values used and their indicators can be found in Table 2. The value gained from the use of GIS was assessed using a four-point Likert scale (strongly disagree, disagree, agree, strongly agree) (Alrwais et al., 2015). "Respondents were asked to indicate whether they agree or disagree with each value indicator, which had no middle point neutral; this strategy was chosen to force respondents to think deeply if the indicator under question had been achieved or not." (Alrwais et al., 2015). The responses were coded in SPSS as follows: 1 – disagree; 2 – disagree; 3 – agree; 4 – strongly agree. The statistics (mean and standard deviation) of the values were computed in SPSS for the different value indicators. Average mean and standard deviation values were calculated in Microsoft Excel using the average function. The individual value indicator means and standard deviation figures were evaluated against the average mean and standard deviation. The computed means were also rated using a Likert scale interval of Strongly Disagree (1.00 – 1.50), Disagree (1.51 – 2.50), Agree (2.51 – 3.50) and Strongly Agree (3.51 – 4.00).

3.4.5 GIS Product Assessment

Standards and best practices exist in map making to minimise design errors and improve the quality of map outputs (Medeiros, 2016).

This study identified the eight main categories of design, layout, visual hierarchy, colour, symbology, data scale, projections, context and labels, and the 29 cartographic standards demonstrated in Table 3. Each map figure was evaluated in turn against the check list of cartographic design standards and scored as +1 for standard applied or zero for standard not applied (Medeiros, 2016). The scores per cartographic standard were totalled for each map and converted to percentages to determine the rate of use per category for the SPTC, SWSC and SNHB.

The rate of cartography standards used per map product was calculated by adding all the cartographic standard scores and converting them to percentages by means of the following equation (Equation 3):

$$The\ rate\ of\ cartography\ standard\ use\ = ((\sum x)/y) \times\ 100 \quad (3)$$

Where: $x = \text{Score per map product}$

$y = \text{Total number of cartography standards}$

3.5 Methodological Reflections

The GIS usage model and the GIS maturity formula were used for GIS maturity evaluation. This method worked well, since it was easy to use the formula to calculate GIS maturity once the responses were coded. The usage model uses all the factors required for successful GIS implementation as dimensions. The value taxonomy and SPSS method were useful. The SPSS software enabled effective data analysis. The total map quality approach was suitable for conducting GIS product assessments. The total map quality approach is an analytical method that involves specifying a quality reference that has a list of map specifications defining the quality of a map. Microsoft Excel enabled the capturing of map scores and enabled the simple calculation of the rate of cartography standards used. Calculating the relative frequency enabled comparison among all maturity dimensions. The radar charts were a good method for analysing data graphically to compare maturity dimensions by looking at a single diagram.

CHAPTER FOUR

RESULTS

4.1 GIS Maturity Assessment

4.1.1 Average GIS Maturity

The results from coding and averaging the dimension indicators for the three organisations are illustrated in Table 4. The average indicator scores are 1.8 for the SWSC, 1.9 for the SPTC and 1.6 for the SNHB. When rounded up to the nearest significant figure, they become 2 for each organisation. The results showed that dimension indicators are on level 2 of maturity, which is the exploitation stage.

Table 4: A Coded Summary of Responses per Dimension Indicator with Average Maturity Score per Organisation (Khumalo,2022)

Dimension Indicator	SWSC	SPTC	SNHB
GIS functions used	2	2	1
GIS products utilised	2	2	3
GIS customisation	2	2	2
Core processes supported	2	2	1
Support processes supported	2	2	1
Complexity of task	2	2	2
Workflow reengineering after GIS	2	3	2
Percentage of internal users over all employees	1	1	1
Percentage of departments using GIS over all departments	2	2	1
Extent to which GIS is used at technical, operational and strategic levels	2	2	1
Number of GIS usage agreements with outside agencies	1	1	3
GIS vision	1	1	1
GIS strategic plan	1	1	1
Purpose of use	2	2	1
Pattern of use	2	2	2
GIS awareness	2	2	2
Training	1	1	1
Cooperation among departments as a result of GIS	2	2	1
Structure of GIS Department	2	2	2
Role of GIS Department	2	2	2
Number of staff in GIS Department	1	3	1
GIS skills	1	1	2
Use of consultants	3	2	1
Management style	3	3	3
Average	**1.8**	**1.9**	**1.6**

4.1.2 Calculating GIS Maturity

The results of the GIS maturity that was calculated using equation 1 are shown in Figure 2. The results showed that the SNHB had a maturity rating of 2.1, the SPTC had a maturity rating of 2.3 and the SWSC had a maturity rating of 2.4. When rounded off to the nearest significant figure these maturity ratings become 2, which represents the exploitation stage (level 2) of maturity.

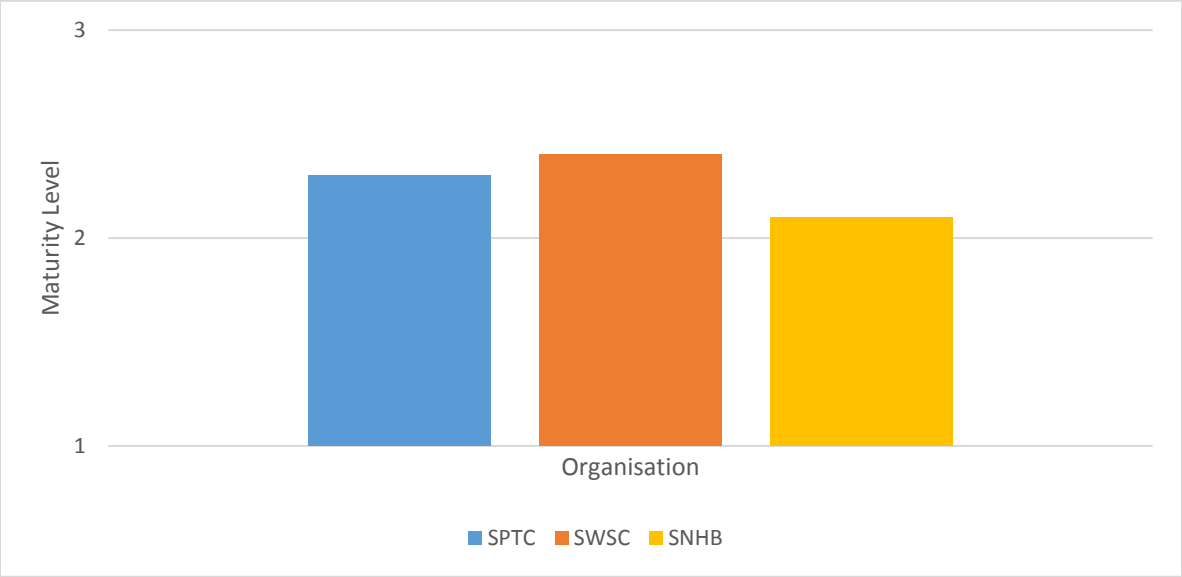


Figure 2: A Summary of Final GIS Maturity Scores that were Obtained from Using Equation 1 (Khumalo,2022)

4.1.3 Maturity Level Relative Frequency in Dimensions

The results obtained from calculating the relative frequency of maturity levels in each dimension indicator are shown in Figure 3. The system dimension's relative frequency (RF) of maturity stages is 11% exploration, 78% exploitation and 11% enterprise. The task dimension shows a RF of 9% exploration, 82% exploitation and 9% enterprise. The user dimension shows a RF of 67% exploration and 33% exploitation. The organisation dimension shows a RF of 47% exploration, and 52% exploitation. Lastly, the department dimension shows a RF of 28% exploration, 44% exploitation and 28% enterprise. The overall relative frequency of maturity stages in the dimensions is 35% of the indicators in the exploration stage, 56% of the indicators in the

exploitation stage and 9% of the indicators in the enterprise stage. The results show that four of the dimensions (system, task, organisation and department) have a higher percentage in the exploitation stage of maturity. Only the user dimension has a high percentage in the exploration stage.

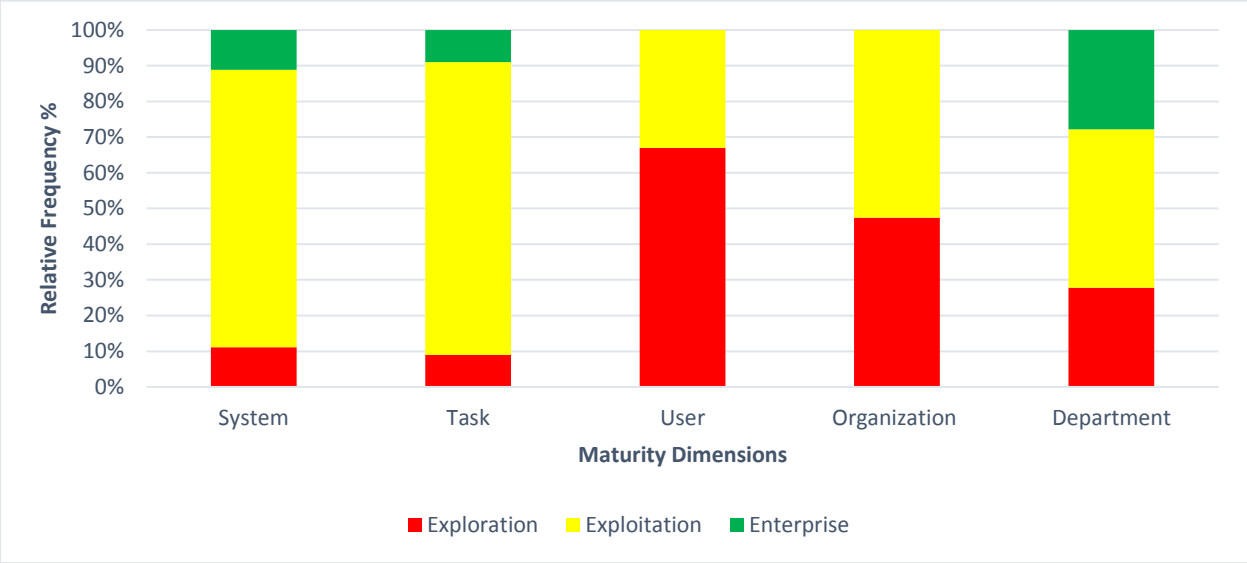


Figure 3: A Summary of the Level of Maturity per Dimension Indicator (Khumalo, 2022)

4.1.4 Gap Analysis of Maturity Dimensions

The results from the gap analysis of the maturity dimensions are illustrated in Figure 4. They show that none of the three organisations met the target maturity of level 3. However, the SPTC and the SWSC have reached a maturity level of 2 across all dimensions. The SNHB reached level 2 for the system, task and department dimensions with the organisation and user dimensions on level 1 of maturity.

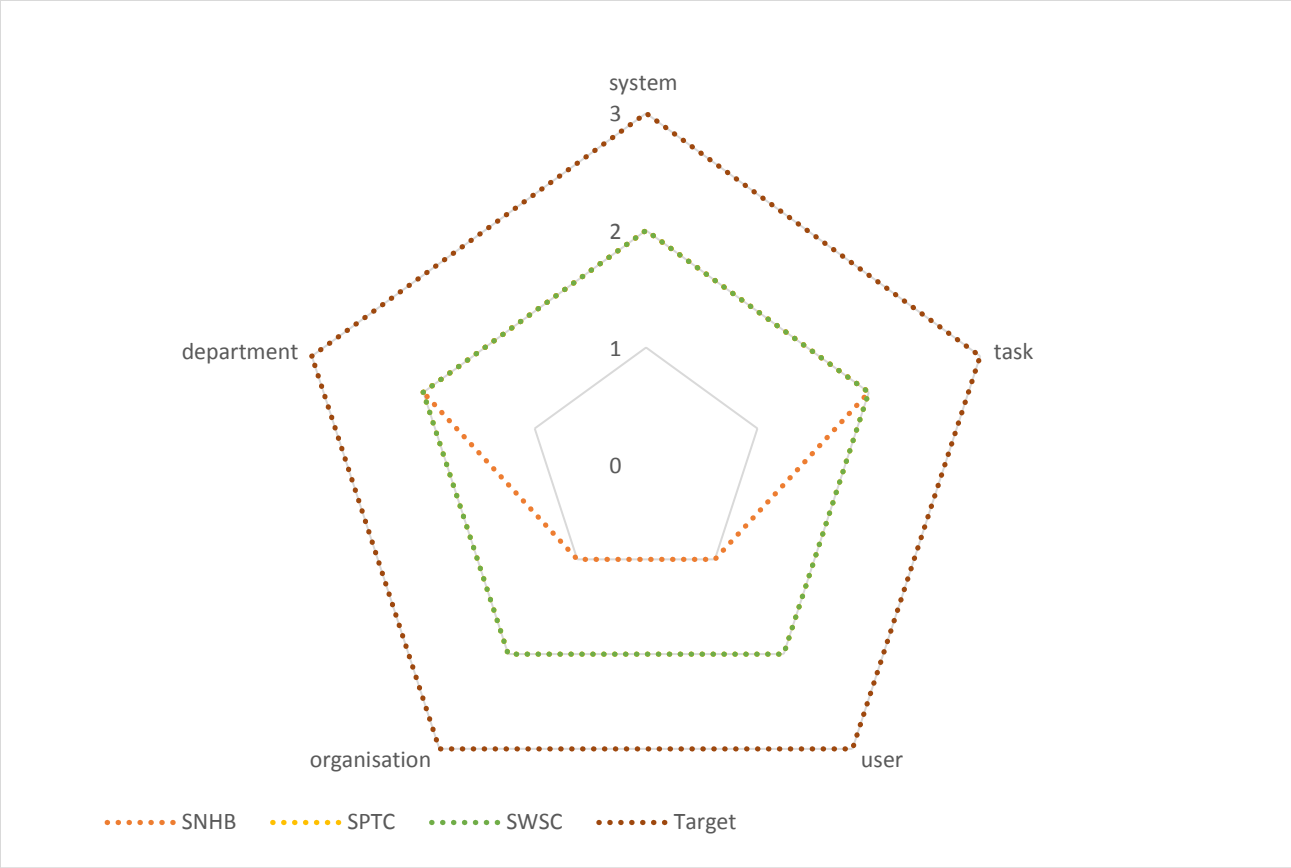


Figure 4: Gap Analysis of Maturity Dimensions (Khumalo, 2022)

4.1.5 Gap Analysis of Maturity Dimension Indicators

The results from the gap analysis of the maturity dimension indicators are shown in Figure 5. They show that the organisations met the level 3 maturity target in five of the dimension indicators. The SWSC achieved level 3 on the management style indicator and the use of consultants. The percentage of internal GIS users, number of usage agreements, GIS vision, training, and number of staff in the GIS department indicators were on level 1. The SPTC achieved level 3 on the management style, workflow reengineering and number of GIS staff indicators. The percentage of internal GIS users, number of usage agreements, GIS vision, GIS strategic plan, training and GIS skills were on level 1. The SNHB achieved level 3 on the management style and the GIS products indicator. The GIS functions, core processes supported, percentage of internal

GIS users and departments, GIS vision, GIS strategic plan, training, use of consultants, role of GIS department and cooperation among departments were on level 1.

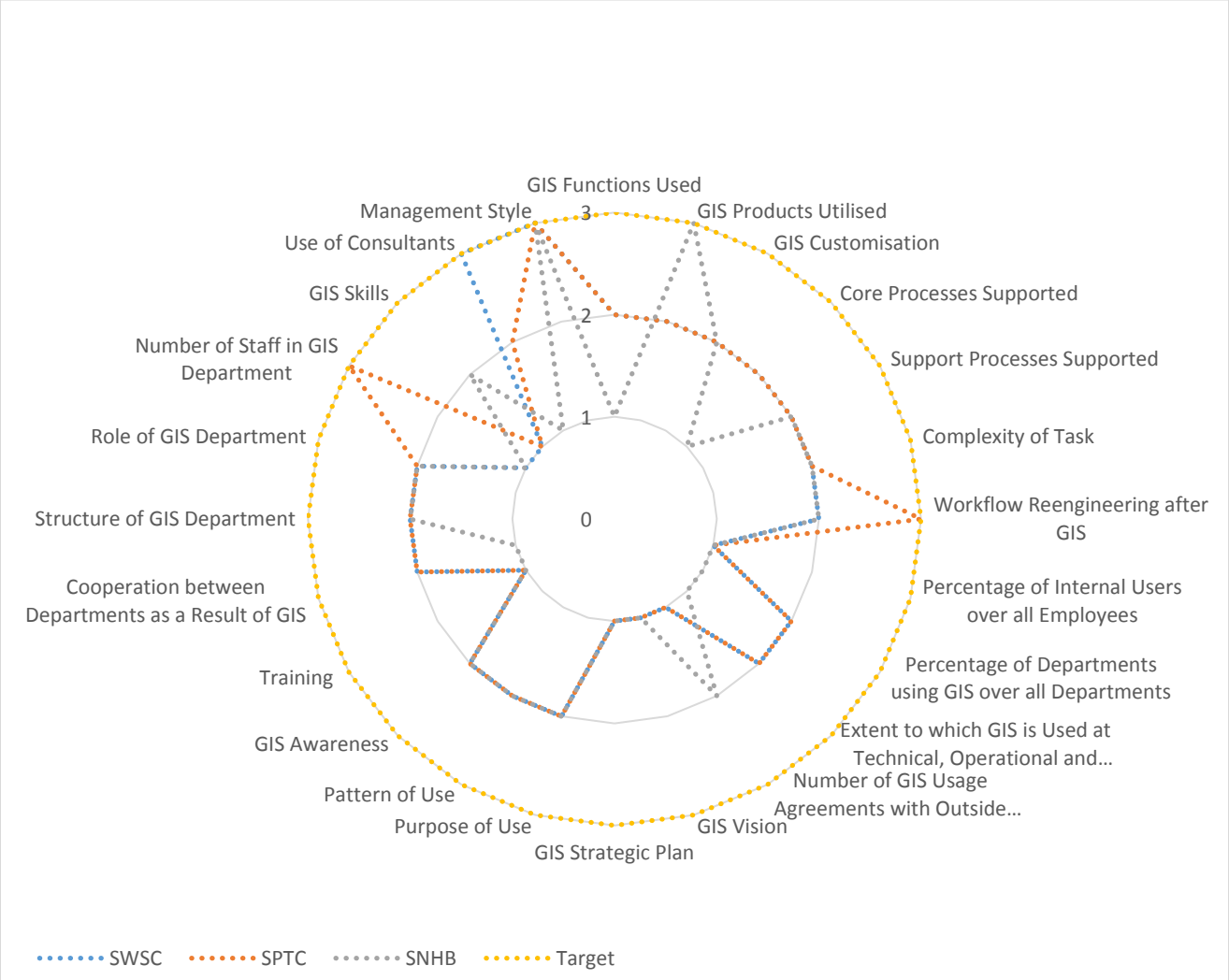


Figure 5: Gap Analysis of Maturity Dimensions Indicators (Khumalo, 2022)

4.1.6 Perceived Maturity vs Actual Maturity

The results obtained from comparing perceived vs actual maturity are shown below (Table 5). The usage maturity model stages were carefully explained to the organisations' GIS managers, and they were asked at which stage of maturity they categorise their organisation. The SWSC and the SPTC categorised their organisation in the enterprise stage whilst the SNHB categorised their organisation in the exploitation stage (Table 5).

Table 5: Comparison of Perceived Maturity to the Actual Calculated Maturity (Khumalo, 2022)

Organisation	Perceived Maturity	Actual Maturity
SWSC	Enterprise	Exploitation
SPTC	Enterprise	Exploitation
SNHB	Exploitation	Exploitation

4.2 GIS Value Assessment

The results from the statistical analysis of value indicators are shown below (Table 6). The mean values for the GIS value reveal that public enterprises agree that the GIS has enabled twelve out of thirteen value indicators as shown by the mean values ranging from 2.67 to 3.33 with an average mean of 2.8. Cost prevention, coordination, employee satisfaction, better data management, time savings and better information quality are above the average mean of 2.8 with a range of 3.00 to 3.33. The standard deviation ranges from 0.577 to 1.155 with an average of 0.7, which means that the data is within one standard deviation of the mean. Responses for coordination, planning, satisfaction, time saving and information quality had a wide gap between responses as indicated by the standard deviation of 1.00 to 1.55. Those indicators with a standard deviation of 0.577 indicate an insignificant difference in the responses.

Table 6: Mean and Standard Deviation by Value Indicator (Khumalo, 2022)

Indicators	N	Mean	Std. Deviation
Cost Savings	3	2.67	.577
Cost Prevention	3	3.00	.000
Coordination	3	3.00	1.000
Planning	3	2.67	1.155
Delivery	3	2.67	.577
Satisfaction	3	3.00	1.000
Conflict Resolution	3	2.67	.577
Public Engagement	3	2.33	.577
Data Management	3	3.33	.577
Productivity	3	2.67	.577
Resource Allocation	3	2.67	.577

Time Saving	3	3.33	1.155
Information Quality	3	3.00	1.000

4.3 GIS Product Assessment

There were nine GIS products in total from the three organisations that were evaluated based on twenty-nine cartographic standards (Table 7). The results show that the overall compliance rate with the cartographic standards is 57.09%. Standards that have to do with map layout, especially those concerning the legend and source of data and author have the lowest scores (0-33%) (Table 7); whereas those that have to do with basic map elements that do not need user configuration, such as the north arrow, had the highest percentage value (78-100%) (Table 7). The results from the GIS product assessment are illustrated in Figure 6 and Table 7.

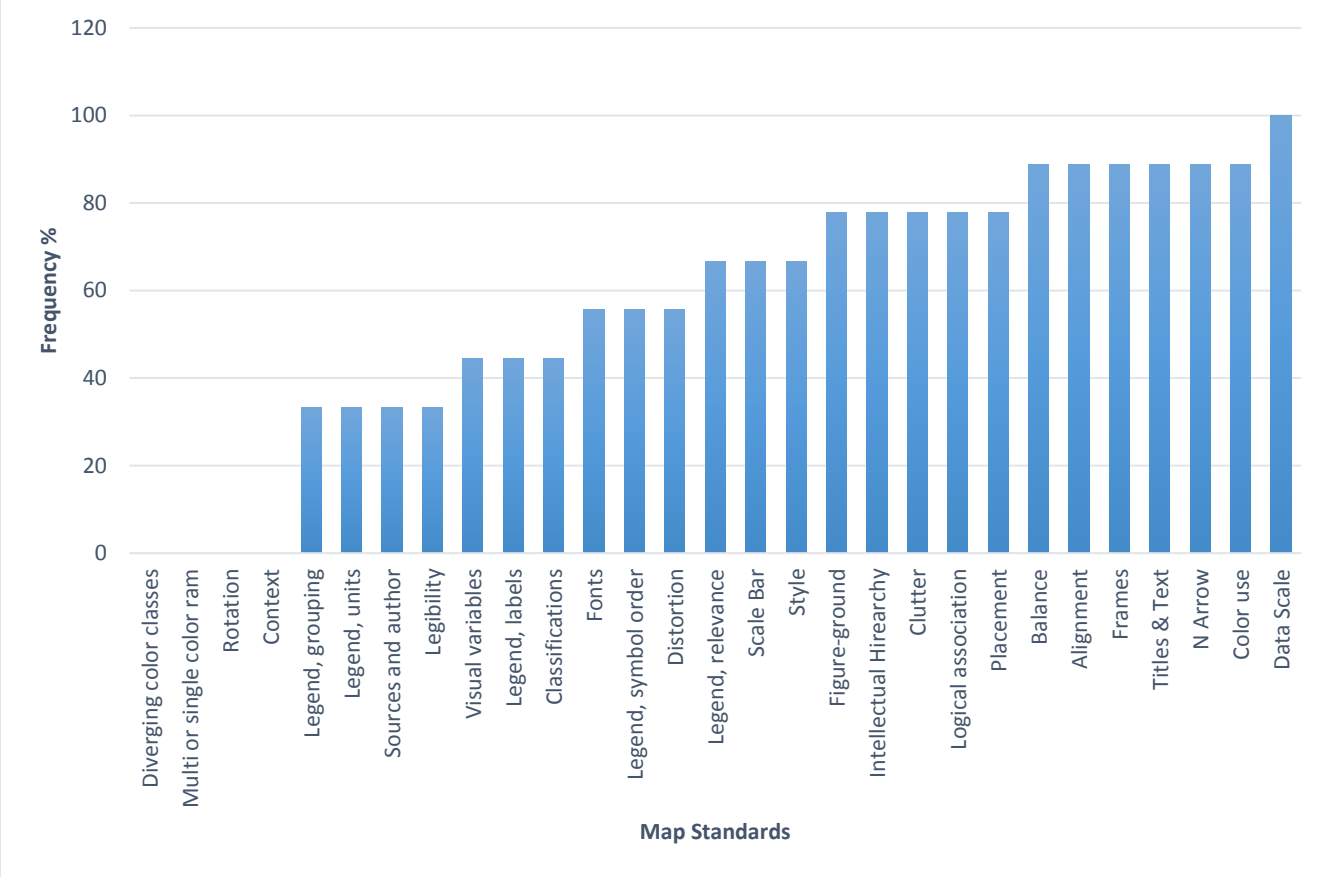


Figure 6: A Graph Showing the Frequency of Map Standards in the Nine GIS Products (Khumalo, 2022)

Table 7: Evaluation of Nine (9) GIS Products for Cartographic Standards (Khumalo, 2022)

	IHP Map	Nkhanini	Woodland	Matsapha Water Network	Nhlangano	Delivery Routes Map	Mbabane Exchange CB	Post Offices Map	WiMAX	Average for Standard %
Map Standard										
Diverging colour classes	0	0	0	0	0	0	0	0	0	0
Multi or single colour ram	0	0	0	0	0	0	0	0	0	0
Rotation	0	0	0	0	0	0	0	0	0	0
Context	0	0	0	0	0	0	0	0	0	0
Legend, grouping	0	0	1	0	0	0	0	1	1	33
Legend, units	0	0	1	0	0	0	0	1	1	33
Sources and author	0	0	0	0	0	1	0	1	1	33
Legibility	1	0	1	0	0	1	0	0	0	33
Visual variables	1	0	0	0	0	1	0	1	1	44
Legend, labels	1	1	1	0	1	0	0	0	0	44
Classifications	1	1	1	0	0	1	0	0	0	44
Fonts	1	0	1	0	0	1	0	1	1	56
Legend, symbol order	1	1	1	0	0	0	0	1	1	56
Distortion	0	1	1	1	1	1	0	0	0	56
Legend, relevance	1	1	1	1	0	0	0	1	1	67
Scale Bar	1	1	0	1	0	1	0	1	1	67
Style	0	1	1	0	1	1	0	1	1	67
Figure-ground	1	1	1	0	0	1	1	1	1	78
Intellectual hierarchy	1	1	1	0	0	1	1	1	1	78
Clutter	1	1	1	0	0	1	1	1	1	78
Logical association	1	1	1	0	1	1	0	1	1	78
Placement	1	1	1	0	1	1	0	1	1	78
Balance	1	1	1	1	0	1	1	1	1	89
Alignment	1	1	1	1	0	1	1	1	1	89
Frames	1	1	1	1	0	1	1	1	1	89
Titles and text	1	1	1	1	0	1	1	1	1	89
N Arrow	1	1	1	1	1	1	0	1	1	89
Colour use	1	1	1	0	1	1	1	1	1	89
Data scale	1	1	1	1	1	1	1	1	1	100
Percentage of standards met	68.97	65.52	75.86	31.03	27.59	68.97	31.03	72.41	72.41	**57.09**

CHAPTER FIVE

DISCUSSION

5.1 GIS Maturity Assessment

The first objective was to assess the GIS maturity of the SWSC, SPTC and SNHB. It was evident from the results of the study that the three organisations have an average maturity of level of 2.3, which translated to the exploitation stage of maturity. Organisations typically fall in the middle maturity stage when assessed, where GIS supports more than one operational area, there is cooperation on spatial data issues and management understands the use of the GIS. Comparable results were obtained by Makela (2012) and Alrwais et al. (2015) who found that organisations typically rank in the exploitation stage of maturity once the GIS has been set up and are being used.

Furthermore, the results show that the total relative frequency of maturity stages in all the dimensions is distributed as 35% in the exploration stage, 56% in the exploitation stage and 9% in the enterprise stage. The system and task dimensions are contributing to the high exploitation stage figure with 78% and 82% in the exploitation stage, respectively. These two dimensions tend to develop faster in public enterprises' GIS due to the availability of funds to procure the GIS and to hire a specialist to implement the GIS. Similar results were obtained by Babinski (2016) and (Makela, 2012), where organisations were doing well on the system and task dimensions but lacked on critical dimension indicators such as a strategic plan and GIS policy. The presence of a strategic plan and its implementation indicate an advanced use of GIS and this has been a differentiating factor between an organisation in the exploitation stage and one in the enterprise stage of maturity in this research. Makela (2012) and Babinski (2016) emphasised that the development of a strategic plan is a priority for development.

Throughout, the radar chart analysis shows that the organisations did not meet the target for level three enterprise maturity. Management style, workflow reengineering, number of GIS staff

indicators, the use of consultants and the GIS products indicators were at stage three across all the organisations. Comparable results were obtained by Alrwais et al. (2015), who found that most organisations were focused on activities classifying them in the first two stages of maturity; i.e. exploration and exploitation. Alrwais et al. (2015) realised that overcoming the one-sided implementation requires organisations to focus on those indicators that are still at level one, namely the strategic plan, vision, training, support of processes, percentage of internal users and GIS skills.

The results show that two of the three organisations overestimated their maturity as enterprises, because they have the ArcGIS software installed. A similar result was found by Alrwais et al. (2015), who found that most organisations that have bought enterprise-level software associate that with reaching the enterprise stage of maturity. Alrwais et al. (2015) stated that most organisations either overestimated or underestimated their status of GIS maturity. The results of the perceived vs calculated maturity highlight the importance of evaluating GIS maturity using a model.

5.2 GIS Value Assessment

Based on the results of the study, GIS use enhanced spatial data production and the availability of geospatial information. Similarly, Babinski (2012) found that GIS technology use resulted in the improved usefulness of GIS data and geospatial presentation abilities. The results are also similar to those of Kurwakumire (2014), who found that the benefits of GIS use are the improved availability of data where data goes from framework data, sector data and application data to geospatial products and services. As GIS mature within an organisation, the type of tools used to portray geospatial information and collect this information improves across all operational areas.

Furthermore, the results also indicate that cost prevention, coordination within departments, employee satisfaction, and time savings are above the average mean of 2.8. This mirrors studies by Eldrandley et al. (2015), who found that the benefits of using GIS are time saving, accurate and quicker decision making and increased awareness, better quality of services, and better information. The results further showed a low average standard deviation of 0.7, which indicates

that public enterprises derive similar value from using GIS. This could be attributed to the fact that these organisations work in similar spheres and are afforded the same type of resources.

The study found that the Swazi enterprises also agreed that increased productivity and cost savings were benefits achieved from GIS use. This is comparable to Worrall (1994), who focused on listing different costs and benefits associated with GIS. Efficiency benefits were listed as cost saving and avoidance of losses, productivity gains, better services, and increased income.

5.3 GIS Product Assessment

The results show that the map scaling was the highest-scoring concept at 100% and the lowest-scoring concepts were diverging colour classes and multi or single-colour ram rotation at 0%. The results of this study are comparable with what Medeiros (2016) found in his study, which shows that standards that have to do with map layout, especially those concerning the legend and source of data and author, have the lowest scores. In comparison, those standards that have to do with basic map elements such as the north arrow have the highest percentage value since they do not need any user configuration.

Analysis of the map outputs from the participating organisations outlined the need to establish common GIS standards, especially in the production of public data. This finding is the same as that made by Medeiros (2016), who identified a training and awareness gap in mapping standards. The gap needs to be filled if GIS users are to end up producing outputs of a similar standard. Synchronising GIS product standards will guarantee that information-sharing workflows are seamless, doing away with the need to first understand the information layout before being able to use it.

5.4 Limitations

All objectives were completed as per the proposal and satisfactory results were obtained. However, some hindrances limited the attainment of better results. These were some of the limitations: Swaziland has few organisations that have the financial capacity to establish proper GIS, which, therefore, reduced the sample size to three organisations.

Placement in a lower maturity stage does not mean an organisation does not have some qualities of a higher stage. Confidentiality in respect of the type of GIS products organisations could provide, resulted in a reduced sample size for map quality analysis.

The benefits and losses of using GIS were not quantified monetarily, which limits the assessment of the GIS value.

CHAPTER SIX
CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

In conclusion, this research has successfully achieved its objectives by assessing the GIS maturity of the public enterprises in Swaziland and has identified key areas of improvement in the use of the GIS in Swaziland. The value gained from using the GIS was determined and the GIS products were successfully evaluated.

In summary, the key steps that the public enterprises can follow to reach the enterprise level of maturity, are to craft a GIS strategy and policy, and further define objectives to identify gaps or even initiate the use of the GIS. This will enable organisations to monitor the GIS implementation and contribute to continual improvement. The use of the maturity assessment tools to measure the level of implementation would benefit the organisations in addressing the missing indicators, which will ensure the GIS benefits. Planned trainings for the GIS users will also be of added value to continual improvement, as will collaborating and consultations with more advanced world companies that have experience of the high benefits of advanced GIS.

There is room for extended benefits from using the GIS to achieve societal benefits that had not been realised by the three organisations.

The evaluation of the GIS products against standards should be made a standard procedure by the organisations to deliver high-quality GIS products.

6.2 Recommendations

- Future research should focus on a bigger sample size, covering more GIS users in Swaziland, in order to have a clear picture of the GIS usage.
- The maturity assessment results should then be used to set up data-sharing platforms or spatial data infrastructure (SDI) for organisations in Swaziland.
- Future research should also assess the use of maturity usage assessments in establishing SDI.

- Future research should further explore the link between societal well-being and the use of GIS.
- Future research should also focus on comparing maturity assessments between developing and developed countries.

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APPENDIX

Maps Used in GIS Product Assessment



Figure 7: Map of Woodlands Extension 2 (SNHB,2018)

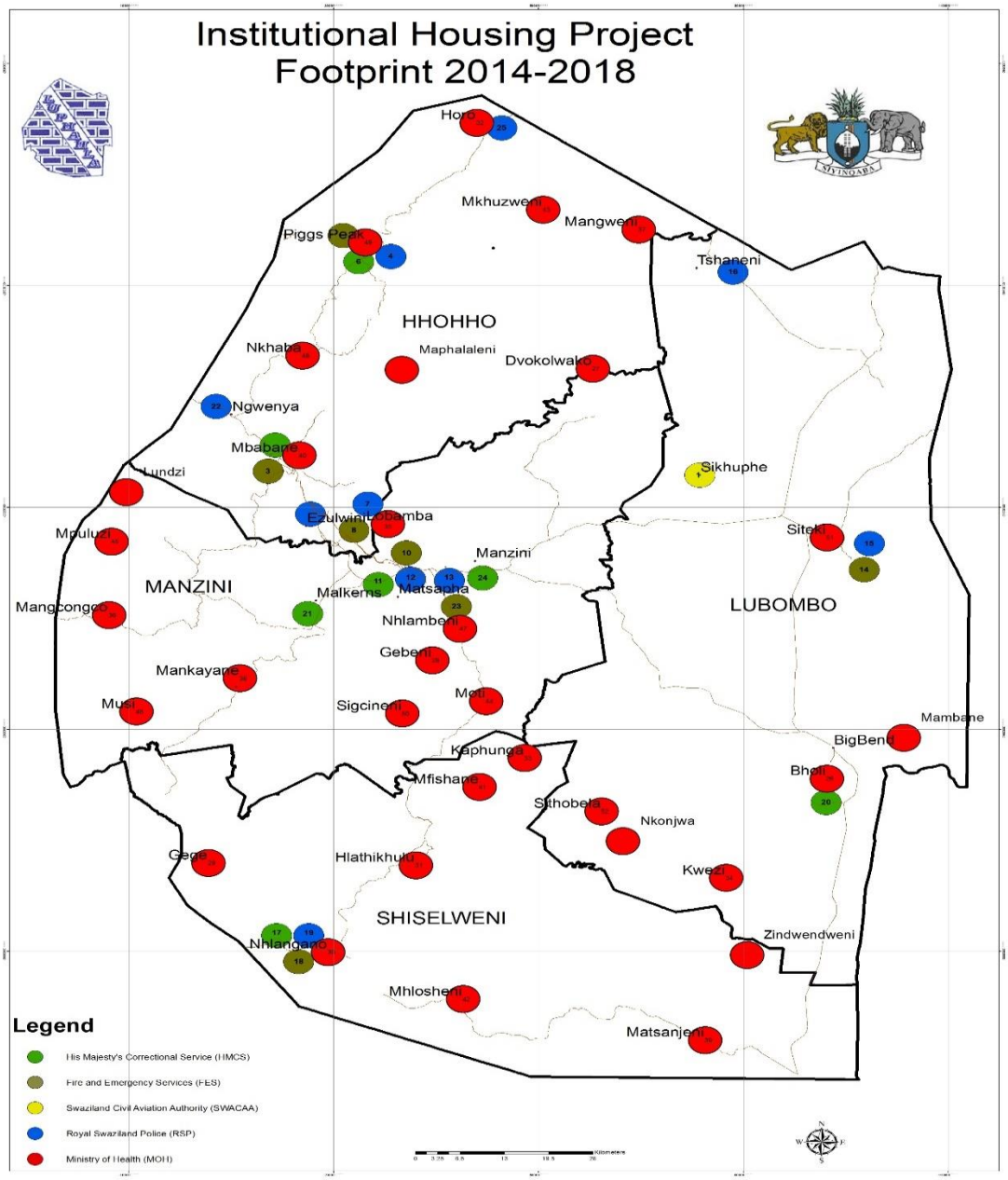


Figure 8: Map of SNHB IHP Footprint (SNHB,2018)

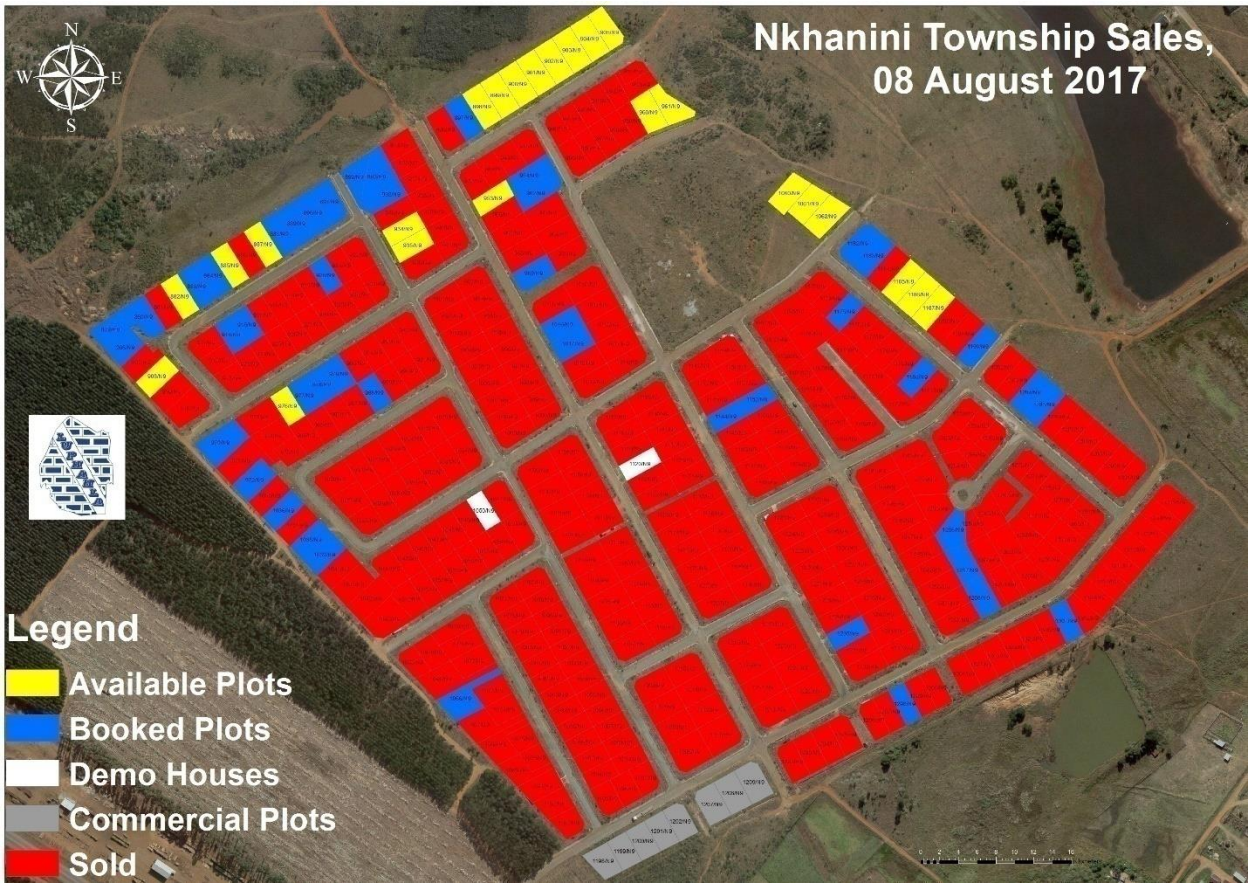


Figure 9: Map of SNHB Nkhanini Township (SNHB,2017)

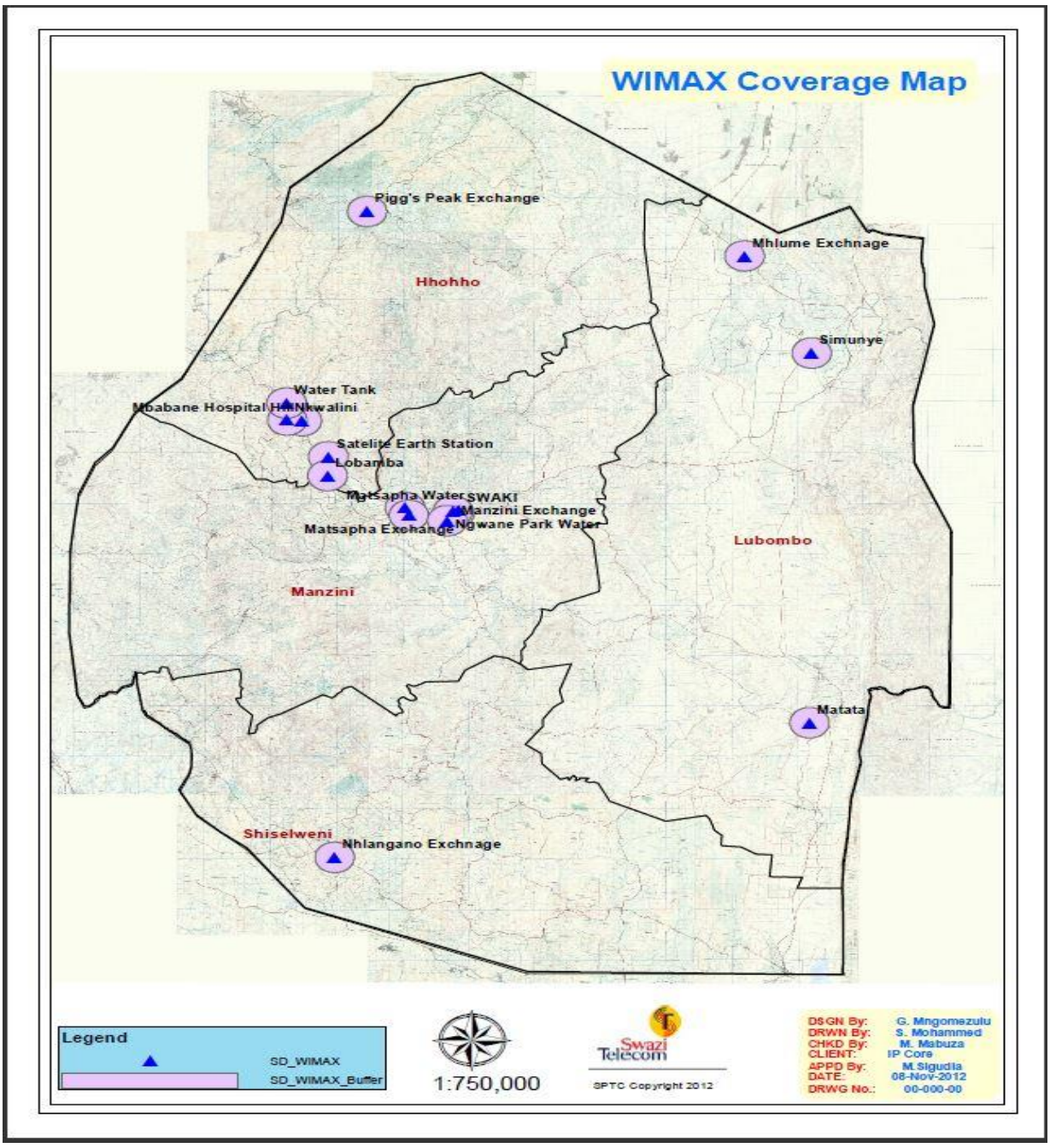


Figure 10: Map of SPTC National WiMAX Coverage (SPTC, 2012)

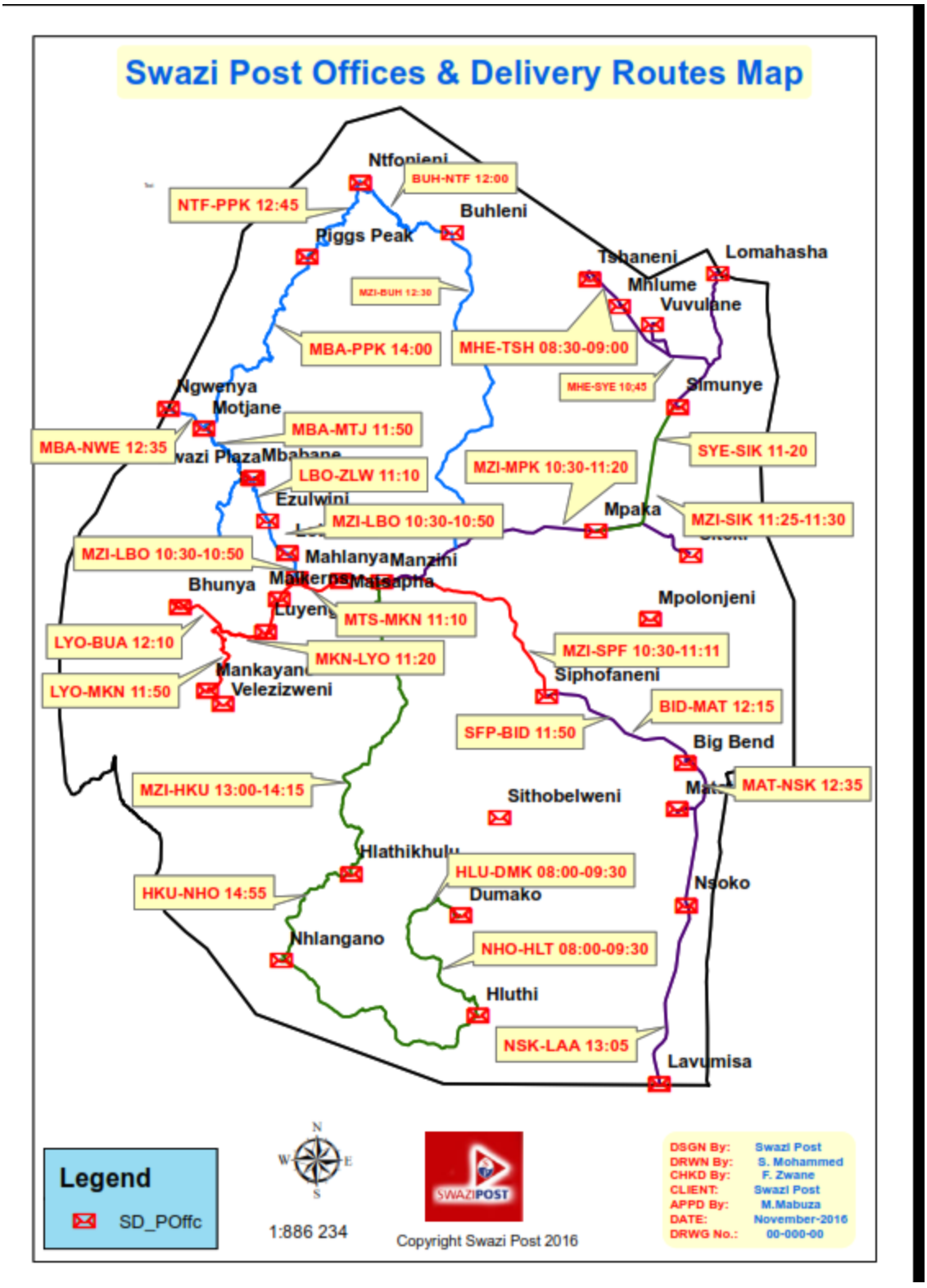


Figure 11: Map of Swazi Post Offices and Delivery Routes (SPTC, 2016)

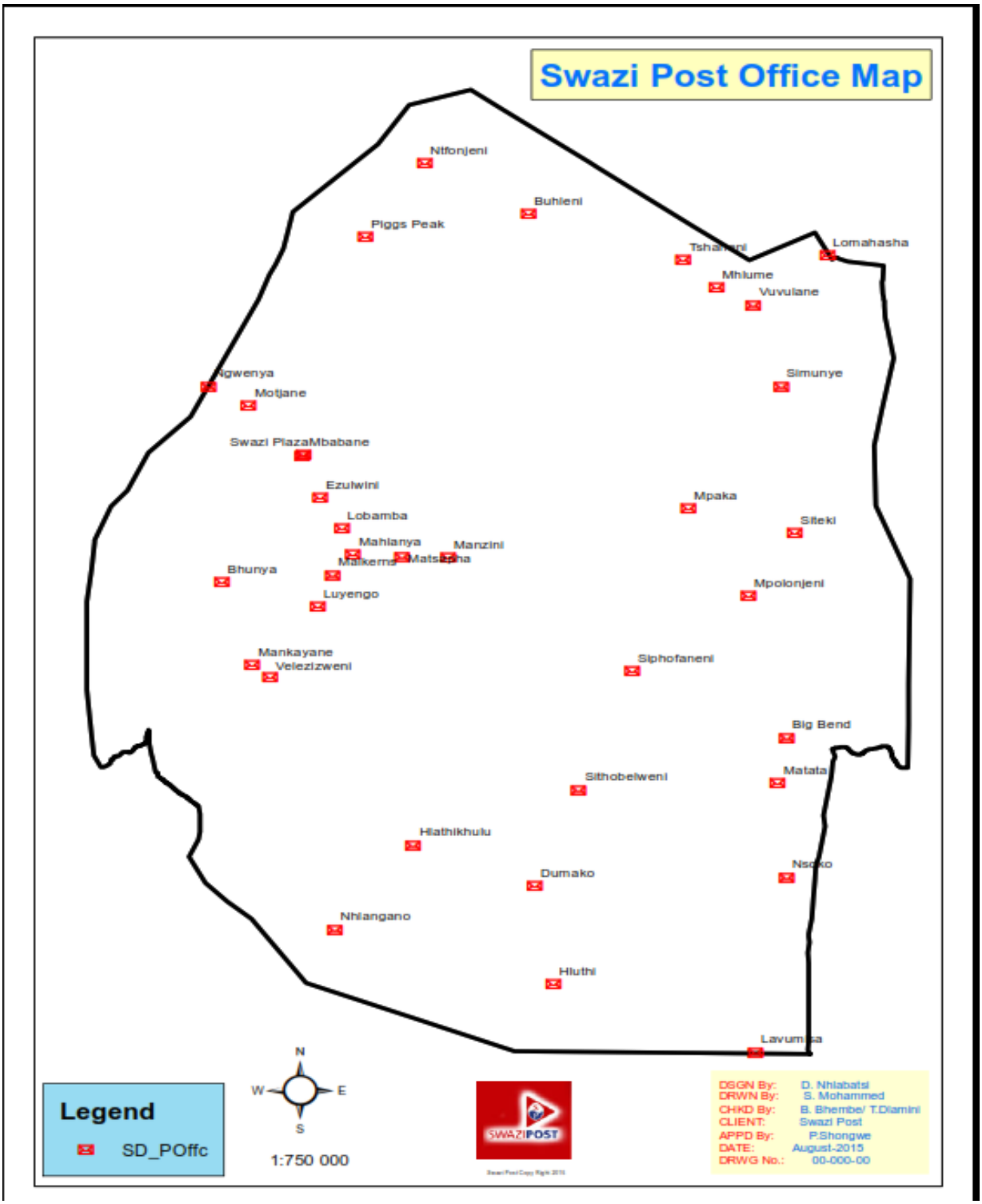


Figure 12: Map of Swazi Post Offices (SPTC, 2015)

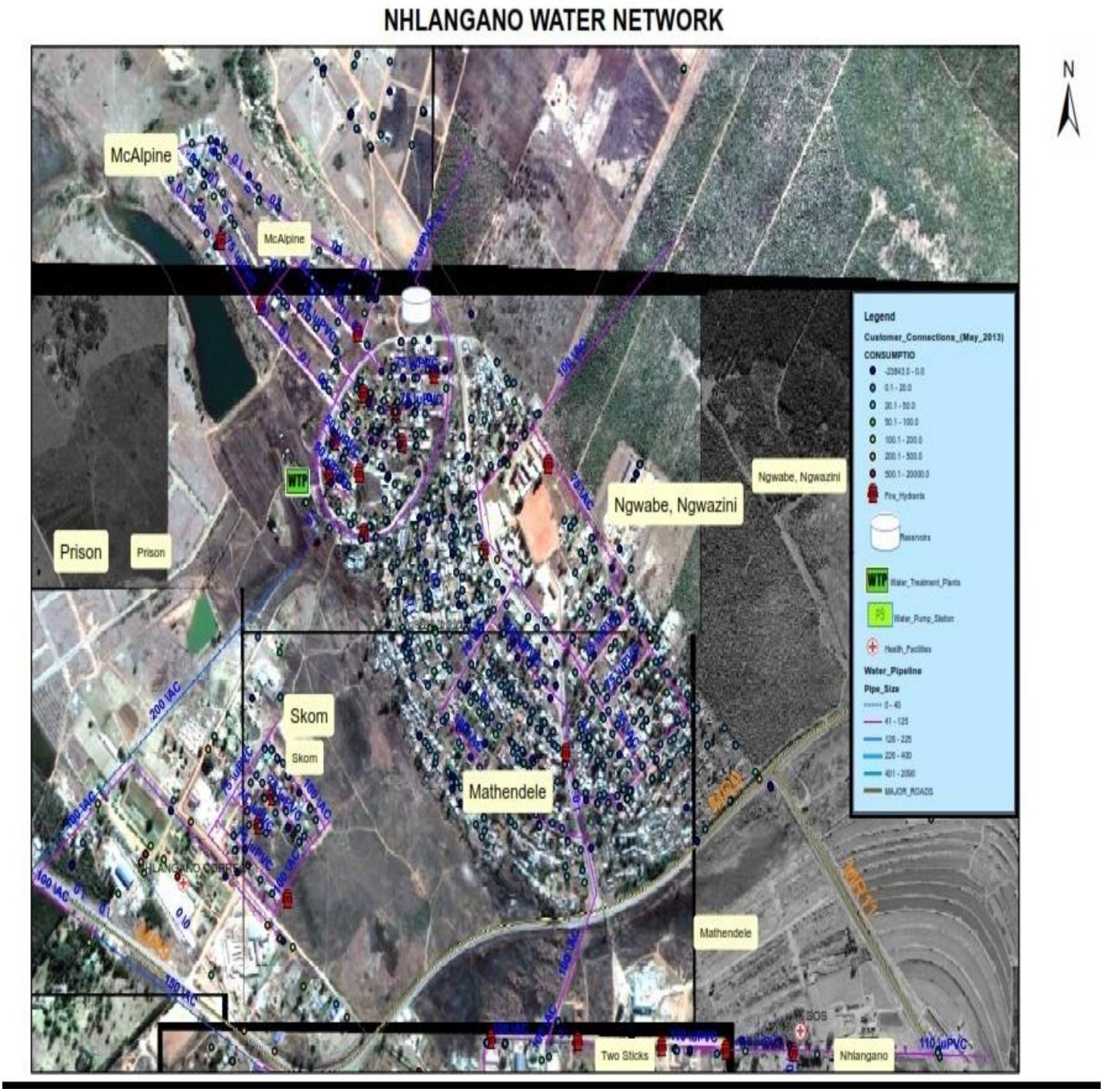


Figure 13: Map of Nhlangano Water Network (SWSC, 2013)

Questionnaire

Part One: To be answered by GIS Department Personnel

1. What GIS functions does your organisation use?
   - ☐ Mapping (overlay, visualisation)
   - ☐ Spatial and statistical analysis
   - ☐ 3D, decision modelling, forecasting and monitoring

2. What GIS products are utilised by your organisation?
   - ☐ Desktop GIS
   - ☐ Online GIS
   - ☐ Mobile GIS

3. What is the level of GIS customisation in your organisation?
   - ☐ Vendor driven
   - ☐ Minimal
   - ☐ Extensive and ongoing

4. To what extent do GIS support your organisation's core processes?
   - ☐ Only in certain established processes
   - ☐ 40% of core processes supported
   - ☐ 60% of core processes supported

5. To what extent do GIS support your organisation's support processes?
   - ☐ Minimal
   - ☐ 40% of support processes supported
   - ☐ 60% of support processes supported

6. What is the complexity of the tasks that the GIS are used for?
   - ☐ Simple (location, structured)
   - ☐ Moderate (trends, semi-structured)
   - ☐ Complex (what-if modelling, unstructured)

7. What workflow reengineering has occurred since the use of the GIS?
   - ☐ Digitise manual process
   - ☐ Moderate changes to take advantage of the GIS
   - ☐ Radical changes as the GIS enables new and existing workflows

8. What is the percentage of internal GIS users among employees overall?
   - ☐ <20%
   - ☐ 20-40%

☐ 41% or more

9. What is the percentage of departments using the GIS among departments overall?
   ☐ 20%
   ☐ 20-40%
   ☐ 41% or more

10. To what extent have the GIS been used at the operational, tactical and strategic levels of management?
    ☐ Operational: Moderate; Tactical: Minimal; Strategic: None
    ☐ Operational: Moderate; Tactical: Moderate; Strategic: Minimal
    ☐ Operational: High; Tactical: High; Strategic: Moderate

11. How many usage agreements does your organisation have with other outside agencies?
    ☐ none
    ☐ < 3
    ☐ 3 or more

12. Does the organisation have a dedicated GIS person?
    ☐ Yes
    ☐ No

13. What is your organisation's GIS vision?
    ☐ To manage spatial data
    ☐ To improve efficiency
    ☐ To enhance decision making

14. Does your organisation have a GIS strategic plan?
    ☐ Doesn't exist
    ☐ Researching GIS strategic plans
    ☐ Formal document exists

15. What is the most common purpose of GIS use in your organisation?
    ☐ Inventory
    ☐ Analysis
    ☐ Policy making

16. What is the pattern of GIS use in your organisation?
    ☐ Low
    ☐ Routines embedded in business processes
    ☐ Innovative

17. How is GIS training conducted in your organisation?

- ☐ For designated employees only
- ☐ During implementation mostly
- ☐ Ongoing in house and outside

18. How is the cooperation/coordination between departments as a result of the GIS?
- ☐ Rare
- ☐ Moderate
- ☐ High (teamwork spirit)

19. How are the GIS structured in your organisation?
- ☐ Don't exist
- ☐ A team within a department
- ☐ Stand-alone department

20. What role does the GIS department play in your organisation?

- ☐ Not clear
- ☐ Provide basic GIS functionalities
- ☐ Support organisation

21. How many people work in your GIS department?

- ☐ <3
- ☐ 3-7
- ☐ 7 or more

22. What skillsets do the GIS workers possess?
- ☐ Cartography and engineering
- ☐ +Web programming
- ☐ Mobile programming + Business knowledge

23. What is the management style of the GIS department?
- ☐ Traditional order-taking help desk approach
- ☐ Service oriented
- ☐ Customer oriented (on-demand solutions)

24. How are GIS consultants used in your organisation?

☐ To justify initial investment
☐ During implementation
☐ Ongoing and considered important

25. Please choose the maturity stage that best describes the current usage of GIS in your organisation.

☐ Exploration
☐ Exploitation
☐ Enterprise

Part Two: GIS Value

26. **Please indicate whether you agree or disagree with the following statements regarding GIS use in your organisation.**

Value Metrics	Strongly Disagree	Disagree	Agree	Strongly Agree
GIS have provided us with better data management capabilities	☐	☐	☐	☐
GIS have provided cost savings	☐	☐	☐	☐
GIS have prevented unnecessary costs	☐	☐	☐	☐
GIS have increased productivity	☐	☐	☐	☐
GIS have enabled better resource allocation	☐	☐	☐	☐
GIS have enabled time saving	☐	☐	☐	☐
GIS have improved information quality	☐	☐	☐	☐
GIS have improved interdepartmental coordination and cooperation	☐	☐	☐	☐
GIS have improved planning activities	☐	☐	☐	☐
GIS have improved our service delivery	☐	☐	☐	☐
Employee satisfaction has improved since the use of GIS	☐	☐	☐	☐
GIS help in conflict resolution	☐	☐	☐	☐
GIS have increased public engagement and interaction	☐	☐	☐	☐