Assessing the infrastructure management by applying Geographical Information System in Sekhukhune District Municipality

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SUMMARY

Assessing the infrastructure management by applying the Geographical Information System in Sekhukhune District Municipality. South African community relies on its public infrastructure systems—roads, water systems, waste systems. for the effective running of the country. These large, complex systems are owned and operated by municipalities and other infrastructure agencies. Failure in the supply of water and services delivery to communities and businesses by water utilities such as water boards, water service providers and municipalities, is commonly caused by a lack of both proper maintenance plans and geographic information about assets such as conditions, locations, historical data and performances.

GIS technology is a central tool which is used to develop fully descriptive Geo-database information, to manage up-dated information about assets and maintain them, such as the current condition of the assets and their operational status. Government and municipalities utilize such technology to plan, maintain and manage their data. GIS databases assist in the integration of many types of data; specifically, geographic data that are available in different types, formats, locations, sizes, etcetera.

The primary objective of this study was to understand the status of geographic information system (GIS) in Sekhukhune District Municipality and how effectively the municipality has utilised the GIS tools to implement and monitor free basic service delivery. Sekhukhune District Municipality has endeavoured to offer various and avenues to freely access information. The Sekhukhune District Municipality moderately utilises the geographical information system (GIS) and does not frequently update its departmental databases as well as offer updated and better-quality geo-information. The Sekhukhune District Municipality has endeavoured to use geographical information system (GIS) to offer the residents and other stakeholders a high quality and updates national and municipality information.

The secondary objective of this study was to provide an overview of geographical information system (GIS) can provide solution infrastructure management within

Sekhukhune District Municipality. To establish and analyse how GIS can contribute to improve efficiency in service delivery at local municipality to curb backlogs, financials loss, in-efficiencies, data loss and integrity etc.

A literature review and empirical research were undertaken to assess the problem statement. The literature study mainly focuses on the infrastructure assets management, GIS technology usage – applications in infrastructure management in local government, utilities in South Africa and around the globe.

The empirical research obtained from the participants within Sekhukhune District Municipality from different departments/unit such as Finance, Planning and Economic Development, Infrastructure and Water Services, Community Services and Municipal Manager' office department are the operate within the local government context.

The study showed that the municipality is moderately utilizing the Geographical Information System (GIS) for infrastructure management. The results from empirical research also showed that the Sekhukhune District Municipality did not implement GIS fully and it does not update its geo-data information regularly and this result in data integrity deteriorating e.g. billing statement for the services rendered by the district might be sent or addressed to wrong consumer. The empirical study also showed that the geographical information system (GIS) can provide solution in Sekhukhune District Municipality particularly infrastructure Water services department in operation and maintenance of water infrastructure to reduce in-efficiencies. This has been echoed by various scholars that utilize GIS in the form of updated registers of assets and layouts of infrastructure to identify high-risk regions and address the issues of infrastructure-maintenance backlogs. In order for municipalities to identify the serious issues affecting service delivery, there must be consolidation and use of information integration approaches from several systems of management into layered representations of infrastructure service delivery. Such a process assists municipalities in the prioritization of high-risk areas for maintenance planning.

Recommendations were made on how GIS can improve the infrastructure management within Sekhukhune District Municipality and other local municipalities to deal with poor services delivery and prevent the communities' service delivery protests.

Key Words

Geographic Information Systems

Sekhukhune District Municipality

Asset management

Infrastructure Management

Infrastructure assessment

Infrastructure Plans

Operation and Maintenance

Service Delivery

Information Integration and management

Local Government

Municipal infrastructure Framework

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ABBREVIATIONS:

AM	Asset Management
ANN	Artificial Neural Network
BIMS	Billing Information Management System
DM	District Municipality
DMIS	Disaster Management Information System
DRDLR	Department of Rural Development and Land Reform
DWS	Department of Water and Sanitation
DWA	Department of Water Affairs
FA	Fixed Assets
FAMS	Fixed Asset Management System
GIS	Geographic Information Systems
GPS	Global Positioning System
HHs	Households
ICTs	Information and Communications Technologies
IDP	Integrated Development Plan
IIMS	Integrated Infrastructure Management System
IM	Infrastructure Management
LIMS	Land Information Management System
LM	Local Municipalities
NDP	National Development Plan
PSPs	Professional Service Providers
RSA	Republic of South Africa
SDF	Spatial Development Framework
SDM	Sekhukhune District Municipality
SG	Survey General
STATS SA	Statistics South Africa
WSA	Water Services Authority
WSDP	Water Services Development Plan
WSMP	Water Services Master Plan

CHAPTER 1

ORIENTATION, INTRODUCTION AND MOTIVATION OF THE STUDY

1.1 INTRODUCTION

South African community relies on its public infrastructure systems—roads, water systems, waste systems. for the effective running of the country. These large, complex systems are owned and operated by municipalities and other infrastructure agencies. This study focuses on infrastructure management's deployment of geographic information systems (GIS) and how these systems influence the operation and maintenance of this infrastructure, together with how GIS can improve the delivery of basic services by improving efficiency in the asset management of infrastructure components such as water and roads. Infrastructure management, which is sometimes referred to as asset management in financial terms, is the process of keeping a record of assets, tracking their condition and deciding how to allocate capital for their maintenance and refurbishment. According to Lemer (n.d.) the importance of asset management is making decisions about the maintenance, repair, development, use and replacement of the infrastructure assets. The main purpose of the infrastructure management is to attain maximum return on the capital investment and is referred as 'efficient' in economic jargon.

Service improvements and optimised investment are key outputs of good asset management practice. Customer focused asset-intensive industries, such as those often found in the utilities sector, face increasing customer expectations, together with challenging quality and efficiency targets. Successful achievement of these targets requires a solid understanding of the business and global environment, together with the linkages between asset deterioration and service performance. There is a clear need to understand the interactions between the needs and capabilities of a municipality, both now and in the future, and how these might be affected by external events (Heather & Bridgeman, 2007).

The study of assessing the infrastructure management by applying GIS in Sekhukhune District Municipality. Sekhukhune District Municipality is a Water Services Authority (WSA) in terms of National Water Act No.108 of 1997, and, as such, is expected to perform water services authority functions/duties as follows:

- Á Provide access to water services
- Á Prepare draft water services development plan
- Á Formulate the contents of draft water services development plan
- Á Draft water services development plan
- Á Arrange adoption of development plan
- Á Prepare a new development plan
- Á Propose and authorize deviations from development plan
- Á Report on implementation of development plan
- Á Arrange contracts and joint ventures with water services providers
- Á Act as water services provider
- Á Adhere to relevant Bylaws

(Auerbach & Michael, 2018) define Geographic Information System as integrated devices used to map natural events, trends and conditions. GIS employs several different and separate hardware and software tools, such as satellite and aerial sensors and cameras, along with specialized computer databases and other systems. GIS software employs a geographic reference, such as a digitized map, to study a given region. Depending on the type and complexity of the scientific pursuit, the GIS then creates one or more layers such as pipeline, roads network, municipal boundaries etc, before applying the compiled data to that map. The resulting image (or 'rendering') provides a composite of the area being studied according to the respective scientist's research.

The following are the reasons why GIS tools can be applicable in a municipal environment to improve operational efficiency and maintenance of water infrastructure or assets in the Sekhukhune District Municipality.

GIS technology is a central tool which is used to develop fully descriptive Geo-database information, to manage up-dated information about assets and maintain them, such as the current condition of the assets and their operational status (Baird, 2012).

The aim of this study is to dissect the GIS integrated model's technology in order to ascertain how it can benefit municipalities by helping them to operate and maintain the water infrastructure.

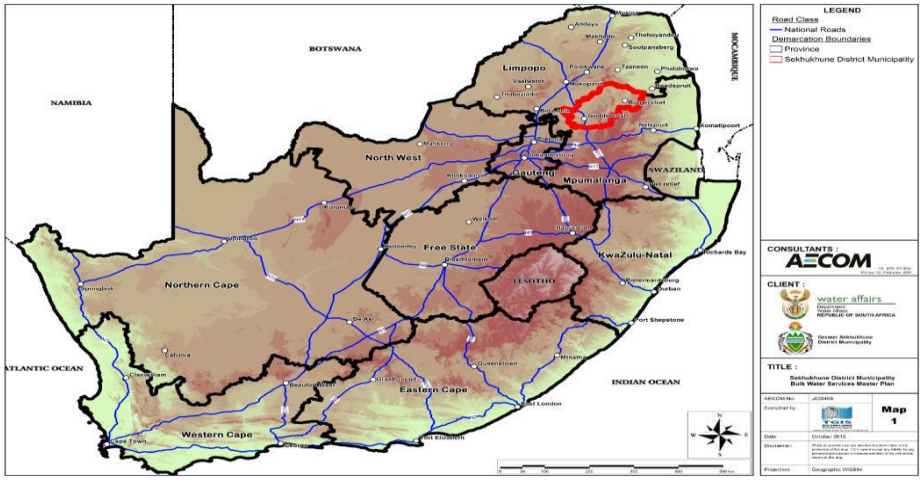
The study, therefore, entails assessment of the GIS technology and how it can improve the management (operation and maintenance) of the municipal infrastructure lifespan.

1.2 BACKGROUND OF THE STUDY

Sekhukhune District Municipality is found in the Limpopo Province, situated in the northern-most part of South Africa. It covers an area of approximately 13 264 square-metres - most of which are rural – and it lies in the southern part of Limpopo to the north west of Mpumalanga.

Sekhukhune is located outside major towns such as Pretoria which is approximately 200km to the South, Nelspruit at about 150km to the East and Polokwane about 180km to the North. It is estimated that only 5% of the Sekhukhune population live in urban areas. The main urban centres are Groblersdal, Marble Hall, Burgersfort, Jane Furse, Ohrigstad, Steelpoort and Driekop. Outside these major towns, one finds almost 605 villages which are generally sparsely populated and dispersed throughout the district. The area's town and villages are serviced by its major rivers - the Olifants River, the Tubatse River and the Elands River, all of which supply water to a number of large dams. The Sekhukhune economy is driven largely by agriculture, mining and tourism activities.

Figure 2.1: Location of Sekhukhune District Municipality in the Limpopo Province of South Africa

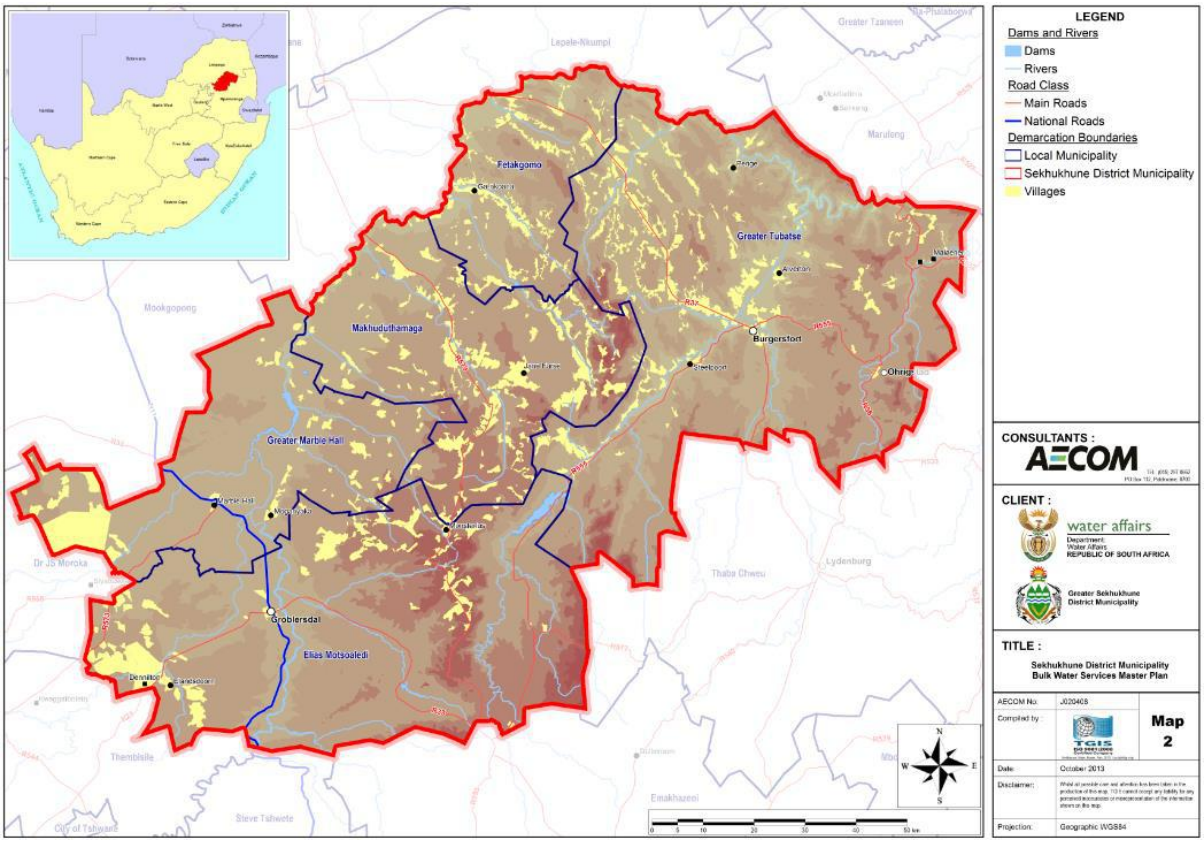


Source: (AECOM Pty Ltd, 2014).

There are four local municipalities (LM) within the Sekhukhune District Municipality namely:

- Elias Motsoaledi LM
- Fetakgomo – Tubatse LM.
- Ephraim Mogale LM (formerly Greater Marble Hall).
- Makhuduthamaga LM

Figure 2.2: Locality Map showing the Sekhukhune District Municipality Topography and local municipalities.



Source: (AECOM Pty Ltd, 2014).

The local municipalities are responsible for adopting and implementing relevant plans to ensure optimal functioning of their geographical areas, the DM functions as an overarching tier which enables regional, district-wide cooperation and coordination of planning and development initiatives in an integrated manner across the district. As such, the LMs in this district are the implementing agents at local level, dealing to a

large extent with operational matters, while the DM provides guidance and regional planning tools (AECOM Pty Ltd, 2014).
The Sekhukhune District Municipality was formally appointed as the Water Services Authority (WSA) in terms of the Water Services Act (Act 108 of 1997) for its entire area and, therefore, is directly responsible for water services delivery in its entire area of jurisdiction (AECOM Pty Ltd, 2014).

This bulk Water Services Master Plan (WSMP) is, therefore, a tool for water management across the Sekhukhune District Municipality, with specific details included in the plan, such as demographic and socio-economic analyses, the Water Services Development Plans (WSDP) and associated geodata-base and related information, to assist in water services and resource management not only at local level, but also at provincial level and, thus, enables incorporation of information at the national sphere (AECOM Pty Ltd, 2014).
Sekhukhune District Municipality is a rural area, comprising some 2500 of small villages and townships. According to Statistics South Africa, Census 2011 (cited in Municipal Demarcation Board, 2007), the total population of the DM in this region is 1 million.

This study entails the assessment of how infrastructure management by engineers, managers, technicians, artisans and general labour can improve water services, operation management, maintenance and budgeting for maintenance of water infrastructure, in the municipality.

The water utilities are facing infrastructure management, rehabilitation and routine maintenance. The lack of the prediction of the failure of water infrastructure components such as pipes, has triggered studies to develop technology or models which can create susceptibility of pipe failure or prediction of infrastructure component failure. Such models as EPR software have been developed to predict pipe failure and can be built within the GIS model (Farmani, et.al. 2017).

The implementation of GIS technology in the operation and maintenance of water supply infrastructure assists with data understanding, analyzing data and querying possible problems during planning.

The GIS integration model can be used as follows:

- Á Viewing water infrastructure systems.
- Á Editing or altering information.
- Á Updating Geo-database information.
- Á Scheduling maintenance plans for water infrastructure.
- Á Managing personnel responsible for operating the water supply.

The purpose of the study is to assess the *status quo* or the existing mechanism used in managing the infrastructure in Sekhukhune District Municipality, to determine its effectiveness and efficiency and how can it be integrated with GIS.

Also, to investigate the current deficiencies in the application of the GIS model in the operation and maintenance of water infrastructures.

1.3 PROBLEM STATEMENT

Failure in the supply of water and services delivery to communities and businesses by water utilities such as water boards, water service providers and municipalities, is commonly caused by a lack of both proper maintenance plans and geographic information about assets such as **conditions**, **locations**, **historical data** and **performances**.

According to the Water Services Development Plan (WSDP 2016), the Sekhukhune District Municipality has approximately 263 805 households (HHs), while only 11% of these Households in Sekhukhune District Municipality have authorised piped water inside their homes, compared to an average of 18.4% for the total Limpopo Province. Almost a quarter (39%) of Households in the Sekhukhune District Municipality, numbering 102 884 (2014 Free work surveys) still have no access to piped water at all (Sekhukhune District Municipality (Wayo Consulting), 2015). The 39% Households either have no access to piped water due to no water infrastructure and dilapidated infrastructure. The lack of relevant information on water infrastructure is the main reason that the DM is unable to determine accurately the extent of the water infrastructure backlog and this deficiency has led to inappropriate or inadequate budgeting and planning for water infrastructure operation and maintenance. Currently

the DM has no Operation and Maintenance plan in place and it is, thus, unable to react timeously to any breakdown or failure of operations.

According to Raftells (2011) running a water municipality/water utility would seem be pretty straight forward because it merely involves finding water treating it, and selling it to customers, but in reality water utilities are a complex organism that have many stakeholders to please and goals and objectives to attain. What at one time involved engineering and operational challenges, has evolved into an industry that must address complicated financial issues, environmental concerns, and a range of community concerns and complex regulatory level of services. In South Africa water quality provided by municipalities or water services providers must comply with the minimum standard set by the SANS 241, National Water Act and Water Services Act. The municipality must comply with municipal finance management act (MFMA) with regard to managing its finances. The community demand a certain level of services from the municipality as set out in the Water Services Act and RSA constitution.

Providing portable water around the globe is proving to be more and more difficult due to escalating operational costs arising from challenges such as water scarcity, high water losses and aging water infrastructures. Water is life and can prove to be the most important natural resource for country such as South Africa to tackle owing to the thorny issues of poverty and inequality. The sustainability of the water supply within the community is the catalyst socio-economic improvement (Bluefield Research, 2018).

The absence of effective water infrastructure assets management as a mechanism to manage the water assets can significantly increase the cost of operating the water supply, which, in turn, will negatively affect financial sufficiency and community sustainability (Raftells, 2011).

According to the STATS SA June 2016 report, the District municipal expenditure pattern indicates R289.3 billion was spent in 2015. The largest contributor was operational cost at 25.6%. The report further showed that out of the total assets disposals of R1.9 billion, infrastructure contributed the highest proportion of 47,8%, compared to other assets such as equipment, landfill, vehicles. which accounted for 27,8%, according to Statistic South Africa (2016).

Due to pressure for water utiliies to manage water infrastrucutre assets in cash strapped entities, the need for efficient systematic maintenance based on precise and well informed decision making. The cause for this pressure is the rapid urbanisation and population growth factors.

The following problems can result from a lack of effective and efficienct processes for the managing of the water assets (Boshoff, 2014):

- Á The rise in the assets disposals due to poor maintenance.
- Á Infrastructure is allowed to deteriorate and eventually fail.
- Á Regular breakdowns result in an escalation of maintenance costs.
- Á Backlogs in maintenance increases.
- Á New capital projects are implemented and old infrastructure are under budgeted.

Poor routine assets maintenance (repairs) and assets renewal reduce the life cycle of infrastructure assets and result in high maintenance costs which lead to premature assets disposals (Lemer, n.d.). As a water service provider to the community, the Sekhukhune District Municipality relies on the performance of the infrastructure components, such as pipes, pumps, valves, motors and electrical switches and have set guidelines for maintenance plans that should be followed. Failing to adhere to these maintenance plans, results in consistent operaton failures and components not functioning optimally.

1.4 OBJECTIVES

1.4.1 Primary Objective

The primary objective of the study is to assess how infrastructure management in Sekhukhune District Municipality can be enhanced or improved by encouraging engineers, managers, technicians, artisans and general labour to implementing GIS tools.

The focus of this research is to determine how effectively South African municipalities have utilised GIS tools to implement and monitor the delivery of basic services.

According to a district report (Sekhukhune District Municipality, 2019) the Sekhukhune District Municipality sees the GIS system as key to enhancing its revenue through its

integration with the financial information system. The GIS would be linked with the valuation roll or the property ownership information by aligning the stand numbers or land parcels with the property owner's details and the municipality can view properties on default or defaulter properties, the property usage or land use and also the properties not yet entered into the billing net.

All properties included in the billing net would be mapped and a report with street addresses generated and sent through to the defaulter on a monthly basis for revenue collection. Through this mapping process, all the properties that defaulted on their service payments would be highlighted in red on the map.

Water meters would be mapped and audited timeously to check faults because these contribute to loss of revenue. These water meters will be linked to a particular property and water meter numbers for billing purposes.

The GIS would assist with the location of water meters and also be used to monitor areas consuming more water comparative to areas with less consumption. It is important to have accurate street addresses to ensure that bills are delivered to the correct consumers

To achieve all the above goals the GIS system must be linked to the creation of a Spatial Property Database.

GIS USAGE

The Sekhukhune District Municipality GIS should have four layers or modules which must be integrated in order to realize its full potential and add value to the municipality namely: billing system, disaster management, fixed asset management and land information management.
The integrated GIS would be beneficial to the following stakeholders or departments;
Finance Department:

- Billing information.
- Meter reading.

- Á Revenue enhancement
- Á Assets management and assets register
- Á Impairment
- Á Property Valuation

Infrastructure Water Services department:

- Á Asset management and asset information
- Á Annual budgeting for operations and maintenance.
- Á Scheduling of maintenance plan.

Planning & Economic Development:

- Á Land information management.
- Á Land parcels' identification.
- Á Spatial planning and land zoning.
- Á Land developments and applications.
- Á Tourism attractions advertisement

Community Services:

- Á Disaster management.
- Á Municipal health system management.

Municipal Manager`s office:

- Á Management reports in a form of maps.
- Á Auditing – verification of municipal fixed assets.

According to a report (Sekhukhune District Municipality, 2019) presented by the department of Planning and Local Economic Development, the GIS is a system or a tool used in spatial decision making processes that is designed to capture, store, manipulate, analyze, manage and present all types of geographic data. This system is mostly used in a municipal environment to map spatial projects or indicate where properties are and for the distribution of spatial information. The following legislation governs GIS: Spatial Data Infrastructure Act 54, (54 of 2003), Statistics Act 6 (6 of 1999), Promotion of Access to Information Act 2 (2 of 2000)

The primary objectives of GIS in the Sekhukhune District Municipality are:

- Á To coordinate sharing of GIS resources (personnel, hardware, software and data) to support decision making.
- Á To facilitate acquisition of hardware and software.

- Á To promote effective maintenance (updating) and integration of district wide GIS layers for strategic planning.
- Á To improve service delivery and management efficiencies.
- Á To collaborative efforts within all the municipal strategic business units.
- Á To decrease redundancy.
- Á To visualize data to create new information.
- Á To support daily work flows throughout the municipality.

1.4.2 Secondary objectives

The study seeks to demonstrate that the GIS has the following beneficial elements in the operation and maintenance of water assets:

- Á Ensures credibility of the information to help operation managers to make an informed decisions.
- Á Maintains the desired infrastructure lifecycle level of services.
- Á Provides the assessment of capital budget required for water infrastrcutures.
- Á Improves the communication and coordination with other departments within an organisation.
- Á Aligns water infrastrucuture geodata base collection with their condition status and up-dates such information.
- Á Helps to justify the capital spending and maintenance programmes.
- Á Improves service delivery of water supplies by reducing water interruption and curbing common water services interruptions.

1.5 SCOPE OF THE STUDY

The study intends to explore the extent of studies around improving line managers' ability to manager water infrastructures in Sekhukhune District Municipality and other municipalities. The set of questionnaires will be distributed to selected group of peoples through email or hand delivery.

1.6 RESEARCH METHODOLOGY

1.6.1 Literature study

Raju (2013) defines the literature study as a “critical analysis of a segment of a published body of knowledge through summary, classification, and comparison of prior research studies, reviews of literature, and theoretical studies. There are three types of literature review according to the University (Raju, 2013) namely:

- Evaluation review.
- Exploration review.
- Instrumental review.

The following literature study sources were visited to ensure a broad and balance primary and secondary literature review: journals articles, text books, internet sources such as government websites, reports, workshops, governments plans (NDP).

The study of secondary literature will be based on peer literature reviews of published journals articles, government reports and case studies.

1.6.2 Empirical Study

This study chose a quantitative approach because it involves the quantification of the collection and analyses of the data. It employs a collection of numerical data, and regards the relationship between theory and research as deductive and prefers a natural science approach such as positivism (Bryman, et al., 2014).

The study quantifies the data collected from a sampled place which is in Sekhukhune District Municipality. The data that has been collected will be quantified and analysed in comparison to each other to indicate their linear relationship. The theory and research identified through the literature review of the application of GIS integration in the water supply services will be deducted.

Sets of questionnaires will be generated and distributed to the various employees across Sekhukhune District Municipality, who are involved in infrastructure maintenance, while those employed in the finance sections will be given a different set of questions. It was estimated that over 100 individuals will answer the questionnaires that will be distributed through email or hand delivered to various sections of the Sekhukhune District Municipality.

The study is considered to comprise a cross-sectional design. The collection of data from more than one section of the Sekhukhune District Municipality will be attained

quantitatively to demonstrate the data connection of different variables. This data will then be evaluated to determine the paradigm associations.

The sampling approach considered for this study is convenience sampling because only specific individuals will be sampled to represent the entire institution (Bryman, *et al*., 2014)

According to a report presented by the National Planning Commission (2012) due to huge water infrastructure maintenance backlog, South African water utilities will face challenges when trying to meet the demand for water and sanitation services because of the need to grow the economy in order to curb unemployment and poverty. The studies undertaken in the US at one of the water utilities, indicate the need to reinvest in water infrastructure through repair and replacement of water pipes at a very high rate because most of the infrastructure has been operational well beyond their expected life span (Baird, 2012).

Inefficiency in the operation of water infrastructure assets maintenance can be because of insufficient provision being made for renewals, lack of infrastructure monitoring systems that track the condition of assets, lack of assets-age data, deteriorations, sub-standard maintenance, absent of asset lifecycle planning practices, inadequate revenue and poor economic growth.

The main objective of this research is to assess managers' understanding they role in the operation and the maintenance of water infrastructures to improve effectiveness and efficiency. To determine the *status quo* currently in place and how the GIS assets management system can help improve this situation.

1.6.3 Data gathering

This study chose the quantitative research methodology, thus hand-delivering a set of questionnaires to participants was used as the data collection technique. The types of questions set of questionnaires used in this research consist of the following variables:

- Dichotomous variables - (yes or no types of response) and nominal variables (data hardcopy or softcopy).

- Ordinal variables – questions that require the respondent to rank their response in scale of 1 to 5 or poor, fair, good and excellent.
- Ratio variables.

The collected data was then analysed using the following:

- Frequency and Descriptive statistical analyses.
- Statistical technique – The reliability test was conducted using statistical techniques such as T-test- using Levenne p(value) method, Cronbach's Alpha and Inter-Item Correlation Coefficient (r) to assess the infrastructure management by applying GIS in the Sekhukhune District Municipality.

The researcher chooses non-probability sampling which comprises the Convenience and Snowball sampling method.

1.7 LIMITITATION OF STUDY

1.7.1 Delimitations (Scope)

The study concentrated solely on infrastructure management by applying Geographical Information System (GIS) in Sekhukhune District Municipality. It is not the subject of the research study, however, the bases of the study involve the user of GIS. As such, the findings of the study cannot be presumed to be the true representation of all municipalities in South Africa. However, the study results allow the generalization of the findings. The social landscape at Sekhukhune District Municipality is strewed with suspicion, trust and confidentiality mainly in areas concerning public declarations. Some of the study respondents had the feeling that their data is covered by the confidentiality clause in their employment contracts. Nonetheless, this research remained focused on the study declarations to respect the study respondents. The study treated with the uppermost confidentiality, respect and professionalism levels the respondents' private information. The other study limitation is that the findings of this study may not be suitable for use in other regions or nations. As such, the sample unit of this research is not a correct depiction of every South African municipality. The responses collected do not give the statistics or information necessary for a conclusive and definitive outcome. The study can therefore not offer assurance of true depiction of South Africa since this study remains restricted by the presence of respondent bias and irresponsiveness.

1.8 CONTRIBUTION OF STUDY

The study is to demonstrate that the GIS technology has the following beneficial elements in the operation and maintenance of water assets:

- Credibility of the information to help operation managers make an informed decision.
- Maintenance of the desired infrastructure lifecycle level of services.
- Assessment of capital budget required for water infrastructures.
- Improvements in the communication and coordination between departments within an organisation.
- Provision of up-to-date data relating to water infrastructures Geo-data base collection in terms of their condition status.
- Justification of the capital spending and maintenance programs.

The research entails the study of the application GIS integration technology in the operation and maintenance of water infrastructure by water utilities institutions in South Africa. The study seeks to discover improvements of operation through greater efficiency of water distributing assets and resources being applied during operation as a result of introducing GIS technology in the assets management tools.

The operation of water assets entails the resources (such as labour, plant and equipment) applied daily in water utilities institutions to produce, supply and distribute water to communities and businesses.

Maintenance entails knowing how GIS technology can be used for water infrastructure assets repairs, replacements and renewals.

1.9 CHAPTER OUTLINE

This chapter provides a broad overview of the study. It covers the area of study such as the scope of study, the overview of the study, the area in which the study will be conducted, the problem statement, the objective of the study, the empirical study (the study design), and a broad review of literature pertaining to infrastructure management.

1.10 **CONCLUSION**

Chapter One outlined the topic of the research, objective of the research together with the background of the study. The design research methodology chosen to attain the objectives of the study requires a quantitative approach and the tools used to gather the information, together with population to be sampled, have been described. The literature studies consulted will be outlined in Chapter Two.

2 CHAPTER 2

2.1 LITERATURE REVIEW

2.1.1 Introduction

This chapter presents a review of prevailing works on infrastructure management by applying a Geographical Information System (GIS). In its review of published works on ways of enhancing or improving infrastructure management in South Africa's DMs through the implementation of GIS systems by engineers, managers, technician, artisans and general labour, this chapter focuses on two case studies, one which was conducted at the Noncore LM in the Eastern Cape Province and the other in the Buffalo City Municipality, The chapter also analyses contemporary literature on how effectively South African municipalities have utilised GIS tools to implement and monitor free basic service delivery, in order to demonstrate the benefit of a GIS system in the operation and maintenance of water assets and the consequent improvement in service delivery of water supply, by reducing water interruption and curbing common water services interruptions. This chapter also covers the background and the status of the employment of GIS technology by the Sekhukhune District Municipality

2.1.2 Nature and definition of GIS Technology

Á 2.1.2.1 Definition of Geographical Information System (GIS)

Chirikure *et al*. (2017:513) define the GIS as the arrangement designed to store, capture, manipulate, manage, present, and analyse all geographical information. Liu, Lin, Wang, Peng & Hong (2016:768) state that a GIS is the framework for managing, analysing, and gathering data. Entrenched in the geography science, the GIS integrates several data types, analysing spatial locations, organizing information layers into needed visualizations by way of 3D scenes and maps (Mayunga,2018:1). With unique capabilities, a GIS discloses deeper insight into information, including patterns, situations and relationships, that help the users make smarter and better decisions. According to Mathey (2018:164), GIS are software programs that capture geographic information by manipulating, analysing and viewing the user's needs or desires with the intent of analysing geographic or spatial information for both a possible and a given purpose.

The National Geographic (2019) defines GIS as the computer arrangement intended to capture, check, and display and store data linked to the earth's surface positions. GIS technologies are applicable to the science of geography with its collaboration and understanding apparatuses. A GIS is a computer-based tool which allows the capturing, storing, editing, displaying, analysing and printing of geographically-referenced data. A GIS helps individuals and institutions reach a mutual goal, that is, to attain actionable intelligences from the entire data types. Boyda, Holzman, Berman, Grabowski and Chang (2019:2) maintain that GIS technologies integrate with financial and Enterprise Resource Planning (ERP) systems, project management software, the leading computer programs on work-order management and maintenance to improve productivity, as well as assist in solving complex organizational or municipal complications.

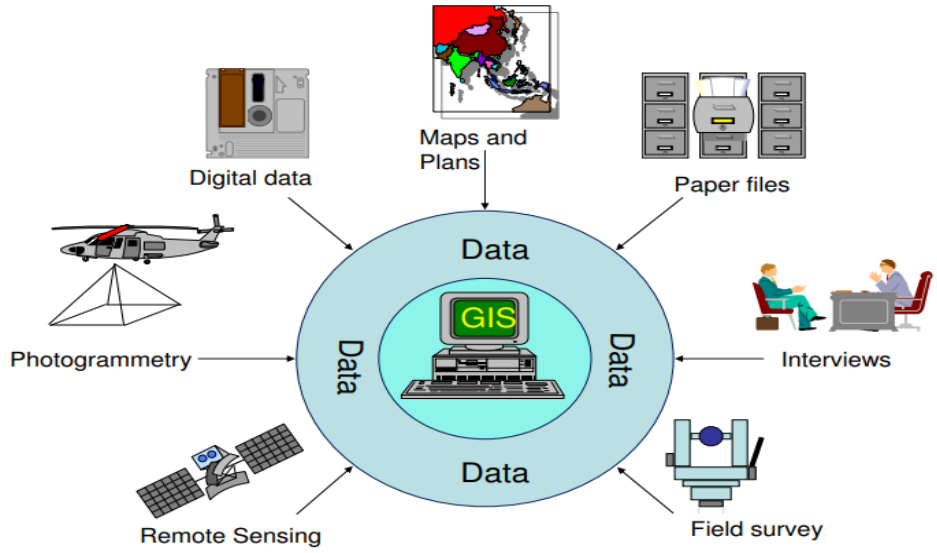


Figure 2.1: A typical Geographic Information System concept

Source: (HRSC, 2019).

2.1.3 The history of GIS

As a system, GIS began in 1960 with the emergence of early computational and quantitative geography concepts and computers (Esri, 2019). Early works on GIS comprised significant studies by academic communities. As such, Goodchild Michael led the National Centre for Geographic Information and Analysis to make formal all the studies on vital geographic data science topics such as spatial visualization and analysis. Such efforts laid the foundation for GIS and resulted in a quantitative revolution in the geographic science world (Chang, 2016:9).

Esri (2019) enhanced software tools due to his computing developments. His efforts on projects solving real-world complications resulted in Esri (2019) innovating and developing robust GIS approaches and tools that could be used broadly. The works of Esri (2019) gained acknowledgement from academic communities and, in particular, his new approaches to spatial planning and analysis. Knowles (2016:750) states that Esri developed the ARC/INFO as its leading commercial GIS invention in an attempt to effectively analyse the increasing projects. It was in the year 1981 that Esri released the ARC/INFO technology; a program that began GIS and established Esri as a software business (Aghajani, Farnia & Velayati, 2017:94).

2.1.4 Significance of Geographic Information System

Mentis *et al.* (2017:15)'s study indicates that GIS are used for identifying problems and illuminating issues that geography driven. A GIS helps in developing geographic patterns when there is well-mapped data. A study by Liu, Wang, Wright, Cheng, Li and Liu (2017:53) maintains that GIS is capable of monitoring infrastructure changes and revealing the extent to which the infrastructures retreat in a particular region or municipality. The authors indicate that GIS is useful when responding, managing and delivering actual situational awareness. GIS reveals the potential impact of hurricanes and cyclones on businesses and people, tracks storms as well as the surge of the storm. For example, in South Africa, the city of Cape Town uses GIS in its information system (IT) infrastructure.

A study by Hegazy and Kaloop (2015:124) concluded that GIS help in forecasting traffic, highlight the possible challenges at intersections where traffic might worsen due to changes in land use. GIS help in setting infrastructure priorities, based on the spatial examination of an area. In analysing infrastructure patterns, the municipality officials in charge of public safety can detect target potential danger zones and allocate officers to monitor them. According to the study by Baud *et al*. (2016:22), GIS help municipalities attain an awareness of data which would be unexploited in a normal spreadsheet. For instance, the City of Ekurhuleni Municipality has adopted the ArcGIS platform to identify areas with valuable resources. GIS quantify the as advantage in local competition and also measure infrastructure growth and/or deterioration in the different towns within a particular municipality. For instance, the City of Cape Town

consolidated property and electricity geodatabases into its GIS, as well as valuations and planning data.

2.1.5 The Key Geographic Information System Concepts

Loots *et al*. (2016:241) state that the concepts of GIS include: a) Mapping infrastructure regions; b) Mapping the infrastructure quantities; c) Mapping the infrastructure densities; d) Identifying everything inside the municipality infrastructure; e) Identifying everything near the infrastructure and f) Mapping all infrastructure changes. With regard to mapping the infrastructure quantities, the municipality plans the quantity of infrastructure, including the areas with the most and the least infrastructure to appreciate the relations between these areas, for instance, the location of cemeteries in Sekhukhune District Municipality. The municipal map will focus on the location of the cemeteries with colour coded dots to indicate the regions with the least and most cemeteries (Hankel *et al*., 2017:154).

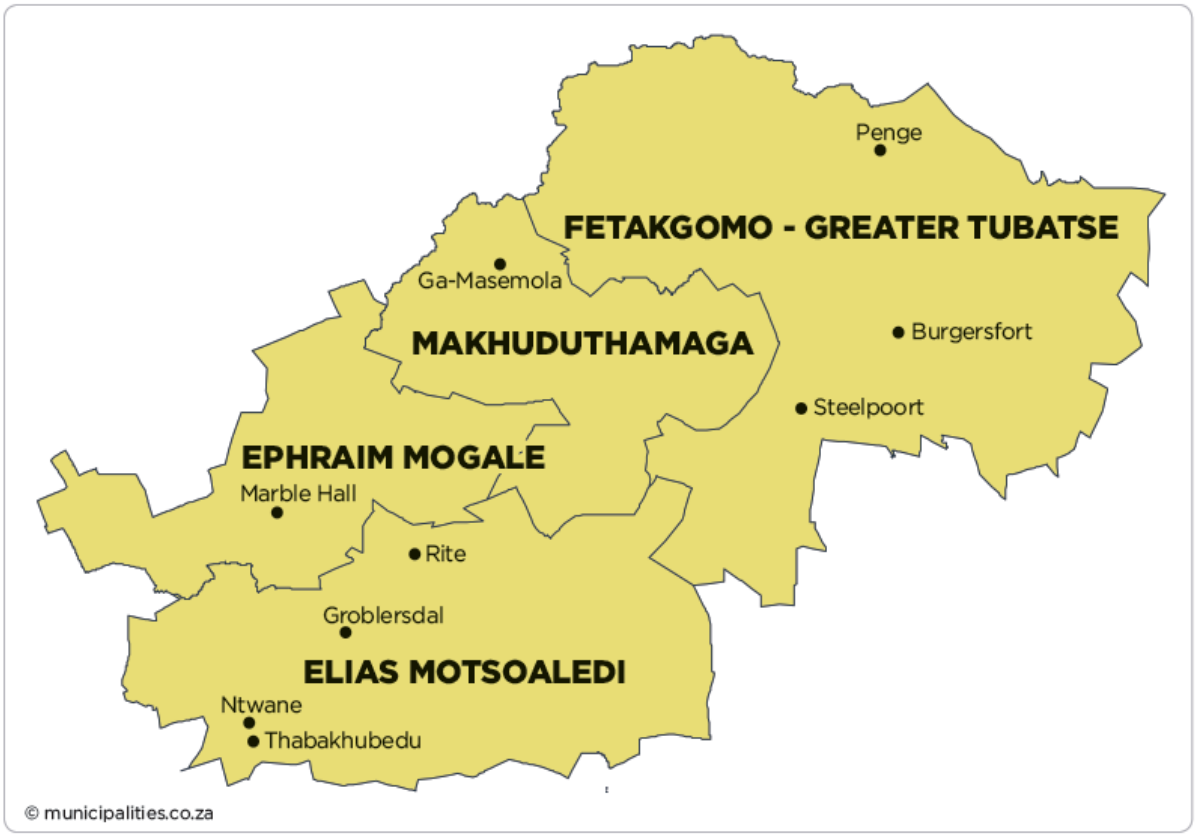
Musakwa (2018:2299) indicates that mapping the infrastructure densities entails indicating areas in the municipality with high and low infrastructure concentrations and/or total or area normalized quantities. For instance, the Sekhukhune District Municipality's population density counts as normalized by area in square miles of the census territories. Using the GIS to identify everything inside the municipality's infrastructure entails determining everything happening therein or the features situated inside a particular region or area of the municipality. Local municipal governments can ascertain the inside characteristics of their domains through the creation of specific standards for defining an area of interest (AOI), for instance, flood events and constructions (buildings) in the municipality's floodway. The local municipalities can employ GIS tools, including CLIP, to regulate which areas fall inside or outside the flood corridor. South African municipalities can employ the attributes of flood regions to ascertain potential expenses related to damage of property (Fleischmann & Van der Westhuizen, 2017:85).

Identifying everything near the infrastructures entails the local municipalities using the tools of geo-processing, including BUFFER (you need to explain this concept) and mapping to ascertain all that is occurring within a particular distance of the infrastructure or an event occurring near the infrastructure. For instance, the local

municipalities can use the time of driving from specific streets or the central administration offices of Sekhukhune District Municipality to network or even to add a criterion, including speed limits or intersection control to define the speed and distance a driver will typically use to complete a particular journey (Shaikh & Ali, 2016:889).

Mapping all infrastructure changes in a particular DM such as Sekhukhune or geographic area entails anticipating future circumstances, deciding on the suitable course of action, evaluating the policy or action's results. For example, infrastructure changes include the use of land within Sekhukhune to indicate changes in the residential developments in particular periods such as 2000 to 2017. Often dark green indicates the forests, while the bright colours indicate residential developments. Applications or mapping helps inform the municipality's policies and processes of community planning (Adeola *et al*., 2017:28).

Figure 2.2: Sekhukhune District Municipality Layout



Source: (The Local Government Handbook: South Africa, 2019)

2.1.6 Geographic Information System in South African local government.

Sieber *et al*. (2017:1262) insist that South Africa has prevailed consistently as the most progressive country in Africa in regard to its of use of Information and Communications

Technologies (ITCs). It is this trend that has partially contributed to the fast growth of GIS in South Africa. Both the South African provincial and national government departments had no knowledge of the available spatial data or the practical GIS capabilities from 1980 to 1990 (Schoeman, 2018:32). Such a lack of knowledge of the practical GIS capabilities or the available spatial data has been partially wiped-out since then, due to the creation of the mandating of state establishments such as the Chief Directorate: Surveys and Mapping, as well as South Africa's Chief Surveyor-General, in the 1990s. These two institutions were responsible for the development and growth of the GIS in South Africa. Today, these institutions play a significant role in offering an elementary geospatial structure for acquiring and storing spatial information (Johnston, Jali, Kundaeli & Adeniran, 2015:22).

Adeyemi, Markus, Gbolahan and Edeki (2018:1445) contend that the accessibility to large-scale datasets on population, and the spread of the open source systems of desktop mapping in 1990, has led to GIS becoming the fastest-growing sector in South Africa., South Africa's private sector, semi-privatised institutions, national and local governments are presently applying GIS technologies in research, business and planning. Even though South Africa is still technologically less advanced than the developed nations, it has benefitted from the development of GIS. The preliminary application of GIS technologies in South Africa was in the environmental field from where it spread to the larger municipalities and areas that finally recognised the value of using GIS for managing infrastructure and information. In South Africa, the use of GIS technologies has availed South Africa of a vital connection to the progress in global spatial mapping technologies. GIS has become the pivotal tool to decision-making in several municipal sectors such as social welfare, health and, lately, crime (Snyders & Landman, 2018:284).

The 1996 Constitution of South Africa (RSA, 1996) advocates cooperative governance. South Africa's 2000 Promotion of Access to Information Act (RSA, 2000) mandates the State to fulfil the peoples' right to access information. The 2003 Spatial Data Infrastructure Act (RSA, 2003) calls for the promotion of the effective, efficient and economical application of government resources enshrined in the 1996 Constitution, through the allotment of all spatial information. The interoperable GIS across the government of South Africa facilitates the access, sharing of data and

permits the synchronization of government initiatives and sustainable spatial progress across the nation. Interoperability means the capacity of municipal governments, business, information, systems, infrastructures and technologies to run together (NGI, 2019).

In order to attract investment and businesses to South Africa, the government departments are now employing a collaboration between GIS and demographics, talent, labour force, industry, commercial information, catalogue of available commercial buildings and locations. The Department of Rural Development and Land Reform Act (2019) indicates that the South African government has for over ninety years run the National Geo-spatial Information (NGI) system as a Department of Rural Development and Land Reform (DRDLR) component. The NGI system also termed the National Mapping Organisation of South Africa, commenced with the formulation of the joint survey scheme and delivery of aerial imagery and extensive mapping coverage of South Africa.

South Africa integrated the survey system to facilitate and expedite logical progress while the mappings and linked products enabled sustainable growth. The NGI has more recently formed the active control survey system of operating continuous GNSS-base stations that cover South Africa. A single centre of control at the NGI offices controls and manages all the stations (Department of Rural Development and Land Reform, 2019). Businesses that are resolving ‘on location’ choices can now use the government tools for selecting sites and communities, which best match their success criteria. As such, the GIS remain organization-varied, enterprise and steady technologies changing the ways the management teams of South Africa’s local municipalities operate (Chari, Hamandawana & Zhou, 2018:676).

Amongst the infrastructures for which the Government of South Africa uses GIS are the operations related to Public Safety such as Fire Prevention, Emergency Operation Centres, Dispatch, Sheriff and Police mobile technologies as well as mapping the risks of weather. The Government of South Africa also employs interactive GIS in departments such as Recreation and Parks, Land Management and Conservation, Management of Cemeteries, and Asset Inventory. The South Africa Government uses GIS in its Public Utilities and Works Department to track storm water drainage and

water, public transportation trends and assets, electrical assets, and engineering projects. Fibre-Network Management for assets of interdepartmental networks, school demographics and analytical information, management of assets, and expansion/improvement of public planning and administration of election information, records of properties, and management/zoning are some of areas in which GIS are used by the South African Government.

The South African Government is currently developing the National Spatial Information (NPI) Framework, a procedure for formulating the Enterprise Data Integrator. The Enterprise Data Integrator forms part of the second stage of developing Spatial Metadata Discovery (De Montalvo, 2017:6). The NSI Framework will run on the ArcGIS Server. Such initiatives are pushing South Africa's local municipal governments to use GIS because this technology encompasses the required attributes for the Government's open information (transparency) model (NGI, 2019). With open information, the local organisations and municipal governments can initiate Citizen Engagement applications (Apps) and the online government portals to allow citizens to access information about land, to report potholes and/or signage concerns, source assets and view parks, view actual utility repairs and rates of crime, amongst other forms of information. The thrust for open information within organizations, municipalities or government departments drives the current growth in the local spending by the South African government on GIS technologies and the management of databases (Mwange, Mulaku & Siriba, 2018:200).

2.1.7 Definition of Infrastructure Management (IM)

Dietrich (2019) states that Infrastructure Management (IM) entails managing the essential components of operation such as processes, policies, data, equipment, external contacts, and human resources, for general effectiveness. Suprayitno and Soemitro (2018:9) define IM as the design, planning, control and delivery of basic structures, facilities, equipment, information technologies and services that serve as the basis for commercial activity.

The Government of South Africa (2019) indicates that infrastructure management entails taking care of the integral aspects of an establishment's operations such as processes, data, policies, human resources and its workforce, as well as contacts

outside its own association, to ensure that the company is running like a well-oiled machine. IM seeks to: reduce duplication of effort, ensure adherence to standards, enhance the flow of information throughout an information system, promote the adaptability needed for a changeable environment and ensure interoperability among organizational and external entities (Bobbins & Culwick, 2015:49).

Faust, Abraham and McElmurry (2016:156) focus on wastewater and water infrastructure when defining systems of IM as the being package of operations that allows the coordinated, systematic programming and planning of expenditures or investments, construction, design, rehabilitation, maintenance, operation, in-service evaluation, and renovation of an area's physical amenities. Infrastructure management, therefore, includes the application of procedures, methods, software, data, decisions, and policies essential for maintaining and providing infrastructure to the public at a service-tolerable level. In consideration of all municipal infrastructure components, an integrated infrastructure management System allows the definition of cohesive rehabilitation and maintenance decisions. For instance, if there are poor pavement conditions and the nearby sewer pipeline often breaks down, then it is a suitably integrated decision to replace the sewer channel system before reconstructing the pavement (Mwange, Mulaku & Siriba, 2018:191).

Marzouk and Osama (2017:745) contend that two approaches prevail in developing an integrated system of infrastructure management. One involves maintaining the information in the present varied format, and developing methods and tools supporting the warehousing of data as well as providing access at all multiple formats and platforms. The alternative method is for the municipality to redesign the whole data resource system, using one common set-up.

The first approach permits each division of the municipality to commence using the least number of changes. Nevertheless, there is a need for linking complex methods and tools to data from the rest of the divisions which makes managing formats and linkages problematic. An even greater issue is that the information might be represented in a spatially different format in every database. Resultantly, it becomes difficult to determine the real spatial site of the physical components. Therefore, there can never be an effective collaborative use of information; a practice needed to allow

healthy spatial and graphical analysis and display using GIS (Dixon, Whipple, Lajiness & Murray, 2016:32).

Idrees (2015:383) suggests that the second approach provides the opportunity for designing a shared spatial context for alleviating the majority of the complications found in the first approach. However, this method approach has major organizational impact and needs significant rebuilding and restructuring of prevailing databases. The increased application and proliferation of progressive information technology such as GISs or DBMSs (database management systems), has caused the municipal infrastructure departments to begin to recognize the need to provide a degree of standardization in the representation, management and use of data. The integrated system will permit infrastructure departments to combine efficiently tabular and spatial data that support queries, analysis and report generation (Windapo & Moghayedi, 2018:254).

The second approach (mentioned above) that involves redesigning the entire data resource system is the best alternative for the South African Municipalities. This process involves standardizing and determining a very effective fundamental linear referencing system (LRS) to: (a) meet the needs of the municipality, (b) standardize data terminologies, (c) determine the communal needs of data in the several municipal divisions and infrastructure departments and (d) develop an all-inclusive database strategy which focuses attention on the functions of different types of data analysis every division of the municipality performs (Bobbins & Culwick, 2015:40).

2.1.8 Components of Infrastructure Management in every Local and District Municipality

Á 2.2.2.1 Planning

Mundia (2016:287) contends that both local and district municipalities and their agencies face multiple challenges in maintaining the smooth and efficient operation of their infrastructures. There is an integration of packages of infrastructure demand forecast with GIS technologies to help municipal professionals carry out the intricate analyses needed to plan infrastructure systems for the imminent future. Progressively,

infrastructure planner's focus on integrating greenhouse gas levels, land-use and environmental considerations alongside factors of energy consumption into the municipality's planning processes. As a result, the municipalities have discovered that GIS can bring all these factors together in the type of comprehensive planning models that are required for effective future planning (Sumari *et al*., 2019:243).

Á **2.2.2.2 Design**

Boon *et al*. (2016:12) state that the municipalities' infrastructure systems' engineers are appreciating the advantages of engaging GIS into their design processes. By assimilating elevation, environmental data and imagery into the Computer Aided Design (CAD) environment, the municipalities' infrastructure systems' engineers continue engaging with accustomed software while they gain access to significant data from the GIS. Aguilar, Aguilar, Hernandez and Valencia (2018:399) suggest that there can be the use of design files in the GIS that link it to monetary software for healthier materials, labour and over-all estimation of project costs. With such capabilities, GIS remain a vital element of engineering the future information arrangements of both local and district municipalities.

Á **2.2.2.3 Environmental Management**

Leitão *et al*. (2016:141) indicate that INFRASTRUCTURE MANAGEMENT entails careful environment deliberations because GIS are exceptionally capable of assisting infrastructure systems' professionals to appreciate infrastructure issues as well as to select the most environmentally friendly solutions. GIS enables users to understand the impact of land-use decisions and to evaluate 'smart-growth' alternatives. GIS integrate environmental issues with the analysis of housing, employment density and land-use data to assist communities to address issues of growth. The capacity to envisage alternatives on one common podium allows the users and/or differing parties to reach an agreement when dealing with environmentally sensitive issues.

Á **2.2.2.4 Construction Management**

Fagbeja *et al*. (2017:7808) maintain that when combined with financial software and construction management, GIS help in tracking the performance of infrastructure ventures. GIS offer a treasure of data, such as schedules, contracts and estimates that are easily obtainable from the spatial interfaces. For the tracking of infrastructure projects, GIS can, through the use of survey information, geotechnical studies and soil analysis, assist in organizing all the information that is relevant to planning,

environmental research and engineering sketches. The easy and quick access of information through the GIS greatly increases the efficiency of construction projects... The consequent project transparencies and reductions in risk lead to greater returns on investment (Windapo & Moghayedi, 2018:254).

Á 2.2.2.5 Maintenance and Asset Management

For the accounting and the central management of maintenance and construction expenses, GIS integrate mapping of an asset with tools of project budgeting and management. A system of GIS-centred maintenance and management promotes efficient scheduling and tracking of equipment, work tasks, activities, personnel and usage of material (Fourie, Chimusoro & Asekun, 2018:112). The aim of such a system is to offer municipality administrators and infrastructure manager's capacity to track and report on infrastructure and maintenance activities. At the same time, the workers in the field record information, locate the assets and complete inspections with GIS-armed mobile strategies. The deficiencies acknowledged in the field throughout the infrastructure inspections can routinely prompt the GIS to produce new repair and maintenance orders (Desai & Peerbhay, 2016:55).

Á 2.2.2.6 Operations

A study by Braga and Junqueira (2016:1602) indicates that the appeal for improved operations and safety efficiency in the contemporary infrastructure systems need access to real-time and detailed information. GIS provide solutions to management, which integrate information from every operational aspect. GIS have the capacity to analyse and track assets over time and space and provide opportunities for the intuitive conception of data through easy-to-understand maps and as reports which provide better control over all operations. In addition to positively impacting the bottom line of the municipalities, GIS offer them the capacity to assimilate disparate sources of data into one common operational picture of all infrastructure facilities and systems (Fagbeja *et al*., 2017:7801).

Á 2.2.2.7 Security Management

Comprehensive protection of infrastructure facilities requires the close organization and cooperation of many municipalities and private agencies, as well as the incorporation of different sources of information and technologies (Wright & Ribbens,

2016:69). GIS integrate numerous information sources, exhibits them on the satellite images or map, and conveys the subsequent situational cognizance on a safe network. Municipalities have the capacity to combine actual vehicle and asset tracking using sources like closed-tour TV (television) cameras to offer a live or actual security assessment of the infrastructure facilities. Such capabilities make GIS a vital technology in the management of the infrastructure security frameworks (Chari, Hamandawana & Zhou, 2018:670).

Á 2.2.2.8 Safety Management

Wright and Ribbens (2016:64) contend that the accurate accounts of infrastructure locations often hold the solution to improving the safety of motorists, railways, freight carriers as well as pedestrians. GIS maps display the records alongside the spatial examination of infrastructure congestion, the weather and zones of construction, effortlessly making clear facts that can be unexploited in modest tabular information. Together with the business and statistical intelligence apparatuses, spatial analysis helps pinpoint the actual causes of infrastructure coincidences and ascertains effective counter-measures. The infrastructure departments in South Africa's LM can use GIS apparatuses to identify tendencies, such as increases in the oversized infrastructure circulation, permit desecrations and the overall data on commercial traffic routes... These factors result in significant improvement of infrastructure safety (Ngqwala, Srinivas, Tandlich, Pyle & Oosthuizen, 2017:1202).

Á 2.2.2.9 Right-of-Way Management

A study by Willemse and Goble (2018:292) reports that from the property acquisitions of new arrangements to the removal of unwanted properties, understanding the range of the infrastructure's 'right-of-way' is one of the tasks GIS enhance. In linking assessor, parcel and survey information, the GIS offer managers of the infrastructure's 'right-of-way', better appreciation of their own properties, as well as a better approach to analysing the properties no longer required. GIS capture the position of several utilities in the 'right-of-way', simplify future activities of relocation and construction as well as prevent the occurrence of unforeseen accidents in constructions. For effective infrastructure management, there can be the management of all leases on 'right-of-

way' using the GIS that is connected to the database-led solution to lease management (Fourie, Chimusoro & Asekun, 2018:112).

2.2 CASE STUDY: ALIGNING GIS WITH THE DEVELOPMENTAL OBJECTIVES OF SOUTH AFRICAN MUNICIPALITIES.

2.2.1 Introduction

Municipalities such as the Noncore LM in the Eastern Cape Province and the Buffalo City Municipality are overseers of community infrastructures such as public facilities, roads, waste disposal sites, and sanitation and water systems. In the year 2004, the South African Government created the Municipal Infrastructure Grant as part of its commitment to extending the service delivery of infrastructure to every citizen. This Grant is intended to assist local authorities and the public entities that complement public institutions' capital budgets, including the municipalities providing the basic infrastructures to the public (Parliament of South Africa, 2019). The municipalities in South Africa, therefore, have adopted varied models of GIS to help them analyse and plan asset investment with the goal of modernizing and rehabilitating urban arrangements and advancing customer satisfaction (Mokoena & Musakwa, 2018:330). According to a study undertaken by Strijdom, Speight and Jacobs (2017:557) on the application of GIS in water supply arrangements, because of the rapid progress in population, urbanisation and migration developing nations such as South Africa face challenges linked to conservation and the management of water demand. The study concluded that that the distribution of water is connected to population growth. The municipal water utilities are faced with the management of infrastructure, as well as routine and rehabilitation maintenance challenges. Since South Africa municipalities lack the capacity to predict failure of the water infrastructure components such as pipes, researchers have developed the EPR (Evolutionary Polynomial Regression) model or technologies to generate pipe-failure susceptibility or predict failure of infrastructure components. The EPR models can be constructed within the GIS to help predict the failure of water pipes (Jewitt *et al*., 2016:2654).

According to Esterhuizen, De Jager and Jezewski (2019:87), the municipal water utilities pattern and, in particular, the scattered asset data component are significantly shifting to contemporary mobile and digital technologies. The municipality's water agencies are taking advantage of GIS and current developed technologies to bill

water, budget and also computerise systems of maintenance management. GIS allow the water agencies to manage easily all integrated data and to offer quick responses with just one click of the computer. Research on asset management in the GIS age indicates that municipalities such as the Noncore LM in the Eastern Cape Province can now map all their maintenance reports on the GIS to assess the main tendencies in water breaks and examine the entire water system (Chari, Hamandawana & Zhou, 2018:681).

Rohr, Cilliers and Fourie (2017:23) highlighted the gap in executing an operative system of asset management in their study on turning data into the knowledge required to advance infrastructure management. These researchers stated that the main component in managing the prevailing maintenance and operations infrastructure are computerised systems of maintenance management that focus on maintaining and rehabilitating work commands, monitoring inspections of the infrastructure condition evaluations. The aim of such systems is to maintain the desired level of infrastructure services at the lowest possible cost to the assets lifecycle. The level of asset management program applications determines the extent of the asset management efficiencies.

The GIS technologies comprise of the geodatabases that assist in managing and maintaining data on infrastructure resources. GIS information must have appropriate descriptions of the *status quo* of assets. The water utilities have to compile geographic databases on water assets components using sources such as Plans, 'as-built' drawings and site investigations amongst others (du Plessis & Jacobs, 2018:135).

Assets management means the procedure of retaining records of assets, conditions and ways of deploying public capital as well as the significance of assets management in reaching decisions on repairs, maintenance, use, replacement and development of infrastructure assets. Attaining maximum returns on capital investments is the leading objective of asset management which in economics is referred to as the efficient application of capital (Stone, 2016:42). Regardless of whether or not managers are aware of the position regarding assets, the absence of information on assets and conditions in South Africa has resulted in the absence of a basis for determining asset value as well as employees' performance or contribution. Yamahaki and Frynas (2016:527)'s study indicates that the application, development and management of

GIS database technologies are assisting municipalities to overcome the challenges identified above. A complete tool for functional asset-management would back different features of the assets management procedure to offer managers of assets an accurate, reliable and sufficient basis for making informed decisions on asset management.

Bonthuys, Blom and van Dijk (2018:14) contend that South Africa's LM such as the Noncore LM in the Eastern Cape Province and the Buffalo City Municipality are in charge of implementing and adopting relevant strategies that ensure ideal functioning of geographical regions. In South Africa, DM function as the predominant municipal tier that enables district-wide, regional coordination and cooperation of development and planning initiatives within integrated means across the nation. While the DM offer tools for regional planning and guidance, LM remain the agents of GIS implementation at the local level, dealing with operational matters to a large extent.

2.2.2 Background on Sekhukhune District Municipality

Established in the year 2000, Sekhukhune District Municipality is situated in South Africa's Limpopo Province. It is located in the southern part of Limpopo, and to the north west of the Mpumalanga. The Sekhukhune District Municipality covers about 13264 square-metres, most of which comprise rural areas. Sekhukhune District Municipality is situated outside key towns, such as Pretoria which is approximately 200 kilometres to the south, Nelspruit which is 150 kilometres to the east and Polokwane which is 180 kilometres to the north. It is estimated that only 5% of the Sekhukhune District Municipality population live in urban areas (Sekhukhune District Municipality, 2019).

Marble Hall, Groblersdal, Burgersfort, Ohrigstad, Jane Furse, Driekop and Steelpoort are the key urban centres. Outside the major settlements are over seven hundred and forty (740) villages that are dispersed all over the district and generally sparsely populated. The Olifants, Tubatse and Elands Rivers service the villages and towns of Sekhukhune District Municipality, all of which also supply large dams. Agriculture, tourism and mining activities drive the larger part of Sekhukhune District Municipality's economy (Municipalities of South Africa, 2019). The Sekhukhune District Municipality remains predominately rural, encompassing 2500 square kilometres of small townships and villages. Statistics cited in the 2011 Census indicate that the total

population of Sekhukhune District Municipality is one million (1 000 000) people (Statistics South Africa, 2018).

Through the use of infrastructure management, South Africa's private and public agencies have continuously endeavoured to maintain all infrastructure in a serviceable condition at the least possible cost. While the demand placed on South Africa's infrastructure since the 1960s is rapidly increasing, the majority of the nation's infrastructure systems are now at the stage of 'utmost maturity' (Bakó & Gáspár, 2018:33).infrastructure management administrators have started to concentrate on devising and implementing strategies to manage the municipal infrastructure. Today, this process is leading them towards the concept of asset management. In South Africa, the asset management process that started with developing a Pavement Management System (PMS) and then a Bridge Management System (BMS), followed by an Infrastructure Management System (IMS), which has recently evolved into an Asset Management System (AMS), (Kelly, Delaney, Chai & Mohamed, and 2016:469).

The infrastructure departments of the South African municipalities manage their infrastructures using several programs including the Integrated Information Management Systems (IIMSs) (Beitelmal, Molenaar, Javernick-Will & Smadi, 2017:48). Integrated Information Management Systems are operational packages that enable the coordinated, systematic programming and planning of expenditures or investments, the design, rehabilitation maintenance, construction, operation, in-service evaluation and renovation of the physical infrastructures. IIMSs include procedures, methods, data collection, policies, decision-aid and software tools for maintaining and providing infrastructure at service-suitable levels. All information related to infrastructures possesses a spatial factor that represents the area (highway corridors), linear features (roads) and point features (signs or accident locations). The prevailing databases and designs of the data management systems of South African municipalities traditionally have not been effective in permitting the various sections within the infrastructure departments to extensively share or use data as expected (Mawela, Ochara, & Twinomurinzi, 2017:160).

South Africa's municipalities, such as the Buffalo City metropolitan and the Noncore LM have incorrectly or ineffectively linked the data spatial component to attribute

information, a practice that has resulted in a lack of integrity, quality and availability resulting in duplication and limited access to databases in the infrastructure departments. Accordingly, this practice has a negative impact on decisions that rely on such information. In addition, municipalities still use several formats of data such as paper files and relational tables and there are no standardised practices for solving spatial questions, thus creating inordinate diversity. Such ineffective practices have produced inapt decisions that have resulted in adverse financial implications on ongoing private business operations and the municipalities' general strategic planning for future infrastructure investments.

2.2.3 GIS for Information Management in Sekhukhune District Municipality

- **Data sources, availability, collection and data management methods**

According to the Sekhukhune District Municipality's Water Services Development Plan (WSDP), the Department of Water and Sanitation (DWAS) (formerly knows as the Department of Water Affairs (DWA) has since 1996, developed a GIS to capture all water services development in South Africa. The Sekhukhune District Municipality, with assistance from Professional Service Providers (PSPs) and their sub-consultants, developed and updated the GIS throughout the project, as the WSDP's, feasibility studies and master plans were developed.

The DWAS geodatabase was developed to assist Water Services Authorities (WSAs) to report on the progress of water services development in their area of jurisdiction. This system will also assist in capturing and updating both the WSDP and the WSMP, in the near future.

The following should be noted:

- The DWAS should inform the Sekhukhune District Municipality on the requirements and functionality of the WSDP system.
- The Sekhukhune District Municipality should build in-house capacity to maintain the WSDP system.
- The WSDP system and the Sekhukhune District Municipality operation and maintenance Management system should be centrally linked and continuously updated.

It is recognised that the DWAS's GIS undergoes constant development and refinement, and will in future assist WSAs in updating annual WSDPs, provided that

the information in the system is kept up-to-date by the municipality. The PSPs included as much information as was avaialble during the time of the project execution but ongoing data capture and editing will be required over time, as and when new relevant GIS data becomes available.

It is necesasry to consider that the spatial data that was received from LMs and DMs and municipal service providers, as part of the project did not always provide accurate and easily manageable data – in some instances, duplicate records, overshoot-vertixes and non-matching records were found – these were edited where posible, however, not all the required edits could be implemented because ideally such data correction should be conducted at source, that is when the data is captured by the municipalities or their service providers.

The Sekhukhune District Municipality Technical Department provided technical documentation for all proposed and current water services projects during the preparation of the WSDP. As-built information was requested for specific regional water supply schemes such as the De Hoop-Nebo Plateau projects, Groblersdal-Lukau, Mooihoek, Moutse, Olifantspoort South and Tubatse.
In addition, the project (? which one) has facilitated the updating of GIS information to include all regional- and internal bulk water services supply systems. The GIS was also updated to include attribute data (class, condition, diameter, materials). (The GIS with attribute data is referred to as a geo-database). The geodatabase was provided to the DWAS in order to update the national geodatabase relating to Sekhukhune District Municipality.
The following should be noted:

- Á Attribute data for older water supply systems and components is not available.
- Á Data and knowledge was exchanged with the PSPs responsible for the preparation of the Sekhukhune District Municipality asset register (SMEC). Updated information generated by the development of this plan, will be provided to the PSPs for updating the SMEC.
- Á Sekhukhune District Municipality should provide the updated SMEC to DWAS to allow the updating of the national water services geodatabase (included in supporting documents annexed to this report).

- Limited water services reticulation is captured on the Sekhukhune District Municipality GIS. It is an operational reality that, given the enormous number of settlements, accurate village reticulation layouts will be difficult to develop and expensive to capture and maintain.

The data collected in all local municipality projects metadata (for bulk as-built plans) are included in the supporting documents annexed to this report.

2.2.4 Activities of the Sekhukhune District Municipality GIS modules or layers

- **Billing Information Management System (BIMS)**

The financial information system (billing system) would be integrated to the GIS system by linking the land parcels and property owner information from the Deeds Registry and this integration of information will ensure that the Sekhukhune District Municipality enhances its revenue collection and improves its service delivery. This integration of systems would result in the following practices:

- Notify the GIS system of all new registrations or changes of ownership of a property
- Obtain the billing information of a property for age analysis of outstanding fees for mapping and utilities clearance purposes.
- Provide general debtor information, ge analysis information, consumption information, balances and valuations.
- Handle account queries and allow the user to query properties and accounts.
- Display discrepancies between the GIS and the billing system.
- Generate reports that would provide billing information in a printable format.

Disaster Management Information System (DMIS)

(SDM, 2019)Sekhukhune District Municipality would through the integration of GIS and DMIS be in a better position to respond promptly to incidences such as fire, accidents, flooded areas etc. This integration would provide accurate street addresses, township, village or cadastral information and prominent landmarks for easy location of incident areas. The aim of such an integration would be to:

- Integrate the call centre, dispatch and tracking devices etc
- Capture incidence damages as they are assessed
- Map incidents on a web viewer
- Analyse spatial & non-spatial data in order to identify disaster prone areas.

Fixed Asset Management System (FAMS)

(SDM, 2019)The asset register and WSMP play a pivotal role in the integration process of FAMS with the GIS. The aim of such an integration would be to:

- Capture new installations of services such as sewers, water, storm water drains, roads and electricity.
- Maintain the infrastructure in terms of life cycle, rehabilitation, replacement.
- Manage and map infrastructure assets within the Sekhukhune District Municipality.
- Generate and print reports

Land Information Management System (LIMS)

(SDM, 2019)The Spatial Development Framework (SDF) of the Sekhukhune District Municipality is central to the linking of land parcels, street addresses, zoning and other critical information required for revenue collection and improved service delivery. The aim of this system would be to:

- Capture and maintain records of land parcels and Sectional Title schemes and units from survey general diagrams and maintain their lineage.
- Capture and maintain records of township boundaries from survey general diagrams.
- Capture and maintain records of records of street addresses of land parcels.
- Capture and maintain zoning information on land parcels.
- Capture and maintain records of engineering infrastructure such as sewer lines, connections, water meters, water lines, bulk systems.
- Capture and maintain records of utilities such as electricity lines, distribution boxes, distribution stations, telecommunication utilities etc.
- Perform spatial analysis to determine future developments and plans.
- Check owner information (linkable with Deeds Registry).

DATA INVENTORY LIST

Table 2.1: Sekhukhune District Municipality GIS Inventory List

MUNICIPALITY DATA	CURRENT STATUS	FORMAT	COMMENTS
Á **Cadastral and Administrative**			
Á Farm boundary	Á Available	Á Shape file	Á Obtained from Agriculture
Á Farm portions	Á Available	Á Shape file	
Á Small holdings	Á Available	Á Shape file	
Á Erven	Á Available	Á Shape file	
Á Wards	Á Available	Á Shape file	Á Wards obtained from the Demarcation Board
Á Towns	Á Available	Á Shape file	
Á Villages/ Subplaces	Á Available	Á Shape file	
Á Suburbs	Á Available	Á Shape file	
Á Allotment Townships	Á Available	Á Shape file	
Á Un-alienated state land	Á Available	Á Shape file	
Á Lease area	Á Not available	Á Shape file	
Á Stand number/address			
Á **Community**			
Á Schools	Á Available	Á Shape file	Á Need to be updated
Á Police Station	Á Available	Á Shape file	
Á Taxi Facilities	Á Available	Á Unknown	Á Data need to be converted to a known
Á Bus Facilities	Á Available	Á Unknown	
Á Health Facilities	Á Available	Á Shape file	
	Á Available	Á Excel	

Á Education statistics and facilities Á Social grant statistics and facilities Á Labour/employment statistics Á Income statistics Á Government buildings Á Places of Worship Á Sports Complex Á Gymnasium Á Cemeteries Á Parks Á Libraries	Á Available Á Available Á Available Á Not available Á Not available Á Not available Á Not available Á Not available Á Not available Á Not available Á Not available	Á Excel Á Excel Á Excel Á Excel Á Shape file	and usable format. Á Need to be converted. Á Data need to be captured by use of a GPS and field visit.
Á **Emergency Management Services** Á Fire stations Á Fire hazardous areas Á Accident zones Á Filling Stations Á Hazardous Production/Manufacturing and Distribution Areas		-	
Á Municipal Health Services			

Á Diseases prevalent areas – malaria, typhoid, bilharzia and cholera Á Dense business areas Á High air pollution areas Á Places listed areas in terms of Air Quality Act Á Industries/Business dealing with mobile toilets and disposal areas Á Crèches Á Food Production and Processing Areas Á Areas prone to food poisoning e.g. schools Á Cemeteries Á Community Halls			
Environmental			
Á Dams	Á Available	Á Shape file	
Á Rivers	Á Available	Á Shape file	
Á Land Cover	Á Available	Á Shape file	
Á Land Use	Á Available	Á Shape file	
Á Heritage Sites	Á Available	Á Shape file	
Á Open spaces	Á Not available		Á Some of the polygons e.g. nature reserves are
Á Wetlands	Á Not available		
Á Soil types	Á Not available		
Á Sensitive areas	Á Available	Á Shape file	

Á Nature reserves and conversation areas Á Landfill sites Á Cultivated land Á Grazing land Á Eco Tourism area Á Topography Á Geology Á EMF of Olifants and Letaba Catchment areas	Á Available Á Not available Á Not available Á Not available Á Not available Á Not available Á Not available Á Available Á Available	Á Shape file Á Shape file Á Shape file	available with no attribute data. Á Other none available data need to be digitized from maps and obtained from other sources.
Transport Á GSEKHUKHUNE DISTRICT MUNICIPALITY Transport Plan Á National Roads Á Regional Roads Á District Roads Á Á Internal Streets Á Railway lines Á Limpopo railways map Á Limpopo Road surveys map Á Limpopo Weigh Bridge	Á Available Á Á Available Á Available Á Some available Á Not available Á Available Á Á Available Á Available Á Available Á	Á PDF Á Shape file Á Shape file Á Shape file Á CAD drawing Á JPEG Á JPEG Á JPEG	Á Need to be converted

Energy Á High Voltage Substations Á Medium Voltage Substations Á Limpopo Medium Voltage Power Lines Á Spot Building Count Á Limpopo Servitude line urban Á Limpopo servitude line rural Á Limpopo servitude area urban Á Limpopo servitude area rural Á Access to Electricity Statistics	Á Available Á Available Á Available Á Available Á Available Á Available Á Available Á Available	Á Shape file Á Shape file Á Shape file Á Shape file Á Shape file Á Shape file Á Shape file Á Excel	Á Need to be converted
Á **Agriculture**	Á Available	Á Shape file	

Á Horticulture Cluster Á Meat Cluster Á Food Security: FIVMS study	Á Available Á Available	Á Shape file Á (to be verified)	
Water and Sanitation Á Water Service Master Plan Á Sekhukhune Community water supplies master plan (2007) Á Access to Water Statistics Á Glen Cowie water supply layout Á Water reticulation and Cost recovery Á Water purification plants Á Community stand pipes Á Storm water Á Sewer Á Bulk water services Á Access to Toilet o Statistics Á Boreholes	Á Available Á Available Á Available Á Available Á Available Á Available Á Available Á Available Á Available	Á Hard copy Á Hard copy Á Excel Á As Built Á CAD Á CAD Á As Built Á AS Built Á As built Á CAD	Á Obtain data from water services Á This data have also been converted to Shape file Á Need to be converted Á Need to be converted Á Need to be converted Á Need to be converted

	Á Available Á Available	Á Excel Á Shape file	Á Need to be converted Á Need to be converted
Á **Sekhukhune Images**	Á Available	Á SPOT 5 (2008) Á 2012 Spot 5	Á
Á **Infrastructure Development** Á Capital Budget Á District Municipality Á Local Municipalities Á Budget Implementation	Á Available	Á Word	Á Projects need to be extracted from the IDP document and captured in a GIS format
Á **Tourism** Á Accommodation Á Conference facilities Á Filling stations	Á Á Available Á Not available Á Not available	Á Á Shape file	Á Á To be captured by use of a GPS and field visit
Á **Economic** Á Industries Á Labour Employment Á Income	Á Á Not available Á Not available Á Not available	Á	Á Á To be captured by use of a GPS and field visit

Á Mines Á Business areas Á Filling stations	Á Available Á Not available Á Not available	Á Shape file	
Á **Disaster** Á High accident zones Á Flood lines Á Hijacking hot spots Á Disaster Areas Á High Rainfall Areas	Á Not available Á Not available Á Not available Á Not available	Á Disaster Management Plan	Á To be captured by use of a GPS and field visit
Á **Demographics** Á Population numbers Á Population age Á Population race Á Population gender Á Households	Á Not available Á Not available Á Not available Á Not available Á Not available		Á To be checked on Statistic SA website and other sources
Á **Spatial Development** Á Growth points (Provincial, District and Municipal) Á Concentration Points Á Land Use Á Land Claims Á Spatial Development Framework Á Precinct Plans	Á Available Á Available Á Available Á Not available Á Available Á Available Á Not available	Á Shape file Á Shape file Á Shape file Á Shape file Á Shape file & CAD	Á Not available data to be sourced from the Department of Human Settlement and the Department of Rural Development

Á Housing Typology			and Land Reform
Á **ITC** Á Telephone access Á Un-serviced areas (e.g. areas where there is no reception) Á Network points	Á Not available Á Not available Á Not available		Á Data to be sourced from the department of communications and other sources

Source: Sekhukhune District Municipality – Planning and Development report on GIS status of data available and unavailable

2.3 APPLICATION AND IMPLEMENTATION OF GIS IN SOUTH AFRICA

In terms of information substructures or GIS, municipalities like Noncore LM report that it is the duplication, omission, general inefficiencies and inaccuracies in the transfer, use and collection of data that delay or impede sustainable development and governance. Nationally, South Africa's municipalities presently depend on several non-affiliated data sources such as data from the national census and ad-hoc resident survey statistics. Such limited approaches offer insufficient depiction of developmental composite, qualitative and baseline directories. In regard to spatial information, South Africa's Spatial Data Infrastructure Act (RSA, 2003) does not cover the pressing need for data-creation acceleration, uniform processes of data management or the alignment of information objectives amongst sectors. This practice results in isolation rather than full integration of GIS across municipal departments. Generally, South Africa's municipalities are struggling to adopt and apply GIS (Musvoto, Lincoln & Hansmann, 2016:210).

Baloyi, Mokgalaka, Green & Mans (2017:183) offer the following solutions for GIS use in South Africa's municipalities: (a) Develop a web-centred GIS for ensuring easy access to non-spatial and spatial information. (b) Ensure that the GIS is an accessible tool of decision making for senior managers, non-technical officials and expert GIS

administrators. (c) Ensure the GIS develops the standards of data for every set of spatial data within the municipalities and captures the newly seized spatial metadata. (d) In case of gaps in spatial data, the sets of spatial data must be acquired from the relevant government departments. (e) The GIS must ensure sharing of the spatial data and co-operative examination by the different municipal units. The GIS must be integrated into the various sector strategies, giving an effective rundown of all that the municipality's plans and schedules for infrastructure development.

The Sekhukhune District Municipality is presently utilising GIS for registering infrastructures such as water reservoirs, reticulation systems, boreholes, water treatment plants, wastewater treatment plants and pumping stations. The Buffalo City metropolitan and the Sekhukhune District Municipality have also implemented a corporate geographical information system to ensure that integrated planning addresses strategic purposes in the municipality (Desai and Peerbhay, 2016:55). These two municipalities use the GIS to monitor the delivery of services to the public and also the ability of its decision makers to appropriately interpret data derived from spatial statistics.

2.3.1 Service delivery in South Africa

Rogerson and Rogerson (2019:220) indicate that the quick visualisation of all that is occurring on 'the ground' and the analysis of GIS' spatial trends in the Noncore LM and Buffalo City metro helps laypeople and experts to quickly examine the data and to reach conclusions based on their observations. Regarding service delivery, it is vital the managers and planners identify the services on which they need to focus, as stated in the Integrated Development Plan (IDP) agenda. These two municipalities have utilized progressive spatial investigation to undertake spatial comparisons between the master plans of their infrastructure departments as well as the Spatial Development Frameworks (SDF).

Johnson *et al*. (2017:434)'s study contends that South Africa's municipalities have integrated their planning schemes and GIS to assist infrastructure planners to identify the regions in which the planning would be outside municipal synchronisation, as well as the regions identified for isolated planning. The IDP seeks to address normal service delivery as well as to identify backlogs/shortfalls of service delivery using the techniques of spatial analysis. The aim is to recognize the people who benefit/do not

benefit from the services. The integration of spatial analysis with the components of service delivery immediate highlights service delivery gaps. The gaps are then compared to the master plans of the municipality's infrastructure department and the SDF before identifying priorities for planning. The interrogation of both the attribute (? which attribute) and spatial data makes it possible for the municipalities to identify the extent and quality of service delivery. For instance, infrastructure planners will know if there is a water supply at a residential settlement, have knowledge of the water pipes' capacity to service that region and determine the quality of the rendered service (Roberts and Shackleton, 2018:146).

Municipalities like the Buffalo City metropolis and Noncore LM now utilize innovative spatial analysis to carry out calculations on infrastructure distance. Spatial analysis or practice makes it possible for the municipalities to scrutinise basic service levels. Knowledge of the position or level of services such as the distance from residential areas to the standpipe points, makes it easy to calculate the layout or formats of the land parcel, including the residential units in the informal or rural areas and developments. The knowledge and calculation of the service positions make for easier public service delivery and the calculation of costs (da Cruz, Tavares, Marques, Jorge & de Sousa, 2016:893).

2.3.2 Interactive internet-based service mapping

Today South Africans have access to information about the situation of infrastructure in the country. South Africa's Department of Public Works annually releases information on its website relating to infrastructure and also provides detailed infrastructure levels at a national, provincial, area and local level. Although the Department of Public Works (2019) maintains that its website is an ideal platform through which the public can understand and monitor the infrastructure rate in South Africa, the tabular arrangement of infrastructure information negates the aspect of geography inherent in the infrastructure activities. Interactive internet-grounded infrastructure mapping websites are provocative data types that offer individuals increasing access to infrastructure data and internet maps. These interactive internet-grounded infrastructure mapping websites offer statistical information, answers to spatial queries and tools for analysis. A distribution of infrastructure data on the IMS

(internet map server) provides residents with a specific area that has an easy entree into the vast infrastructure database, and place infrastructures within a spatial outlook (Maphephe, Balkaran & Thakur, 2016:216).

According to Dobra & Mohammadi (2018:845), the government results are obtained from informed constituencies and provide an awareness of infrastructure occurrences in the cities and towns. The application of GPSs ensures the quick registration of infrastructure sites and connected attributes which are then transferred to the GIS using cell phones or the data loggers. The objective of this process is to provide online spatial and temporal infrastructure information to assist in decision making and planning. Municipal residents with internet access can access the GIS's customized mapping applications to discover infrastructure. This interactive internet-centred infrastructure mapping provides an effective communication tool between the local public and both the municipalities and government departments. Additionally, online municipal initiatives sanction community involvement in the local community forums (CF; forums that already use GIS to plot infrastructures and expected infrastructure activities.

2.3.3 Geographic profiling

Geographic profiling denotes a progressive methodology of investigation with a vast likelihood of service delivery in South Africa. Initially, Dr Rossmo Kim, developed geographic profiling as an offender-profiling aspect to concentrate on defining the area most likely to be the residence of the offender, based on sites of connected crime series (Mokoena & Musakwa, 2018:328). However, in South Africa geographic profiling has advanced as a key analytical tool in investigating the allocation of service delivery (Esir, 2019).

Today, service delivery locations are fed by digitisation, longitude or latitude (address) as well as being analysed by an original infrastructure-demand system that creates a 'surface of probability' showing the probability of in-demand service delivery and/or infrastructure areas. A study by Hart, Booyens, Fakudze and Sinyolo (2019:4) indicates that several strategies of geographic profiling are entered into some form of computerised system of geographic profiling to offer a three-dimension probability

area map. The surface offers a topographical mapping that indicates valleys and peaks through colour ramping to show the regions with high demand for infrastructure or service delivery.

According to Emeno, Bennell, Snook and Taylor (2016:12), geographical profiling is a technique that must be employed to back conventional tactics and strategies, such as database searches, that include the registration of motor vehicle, business and government databases, stakeouts, patrol saturation, neighbourhood canvasses, DNA-screening prioritisation and missing bodies. Maps created through geographical profiling are remarkably correct in defining places with the highest probabilit of regions with high demand for infrastructures. South Africa municipalities are currently using systems of geographic profiling, regretfully however, there are only a few South Africans who are authorised to use this system or have skills in geographic profiling analysis.

2.3.4 Systems of Geo-demographic segmentation

Leventhal (2016:52) defines geo-demographic segmentation as the grouping into neighbourhoods or categories of people at specific spatial levels, based on demographics and their socio-economic characteristics. The geo-demographic cluster schemes are employed to attain new infrastructure tenants or customers, select new locations for business and target the direct postings. However, there is an emerging trend in South Africa's Noncore LM and Buffalo City metropolitan municipality to use geo-demographic systems of neighbourhood segmentation in fields such as service delivery infrastructure to deploy better resources at several spatial scales. Geo-demographics is employed to survey how the extent, pattern and levels of service delivery vary between the different neighbourhoods.

There are many firms in South Africa's infrastructure marketing sector that employ geo-demographic segmentation methods to identify potential infrastructure markets and outline the communities where clients can reside. Specialised advertising businesses provide businesses client insights to empower them to reach informed choices on markets and customers (Nheta, Madzunye & Tshipala, 2017:20). There is the use of Artificial Neural Network (ANN) technologies as the clustering algorithm for defining twenty (20) infrastructure categories based on socio-economic inclines such

as the size of the population, language, income, education and race, among others (Omer, Mutanga, Abdel-Rahman & Adam, 2015:4840).

These twenty (20) infrastructure categories reflect a socio-economic outline of South African society. These categories have business planning applications and survey dissemination to provide an understanding of infrastructure service delivery and the societal context, as well as highlighting the socio-economic reasons for the development of infrastructure in South Africa. The descriptive advantages of creating infrastructure categories are the production of detailed accounts for every environment, that include social, human, economic and physical contexts as well as region prioritisation for public works such as service delivery or local infrastructure improvement (Silent, Ndivhuwo & Tondani, 2018:14).

2.4 MAINTENANCE OF INFRASTRUCTURE IN SOUTH AFRICA

South Africa's municipalities such as the Noncore LM utilize GIS in the form of updated registers of assets and layouts of infrastructure to identify high-risk regions and address the issues of infrastructure-maintenance backlogs. In order for municipalities to identify the serious issues affecting service delivery, there must be consolidation and use of information integration approaches from several systems of management into layered representations of infrastructure service delivery. Such a process assists municipalities in the prioritization of high-risk areas for maintenance planning (Chari, Hamandawana & Zhou, 2018:688).

However, even when municipalities integrate GIS into the standard municipal systems, not all the service delivery departments have yet attained the phase at which the GIS's analysis capabilities can be fully integrated into activity planning. The ability of services departments to seize the infrastructure assets' spatial components and link them to systems of asset management or maintenance results in actual spatial analysis (Selala, Senzanje & Dhavu, 2019:304).

Cobbing *et al*. (2015:32) state that the key obstacles to GIS infrastructure in municipalities is the weak harmonization of GIS objectives and activities, vertically within the hierarchies of government and horizontally across the municipalities. The

lack of a proper understanding of GIS by municipal administrators creates a situation in which the decision-makers become disinterested. This disinterest jeopardises support for GIS from top-down management. There is no alignment of resources allocated to GIS within the general objectives of municipalities. The designed or offered solutions do not fit the existing infrastructure problems. Politics, understaffing, administrative restructuring, poor management and corruption are generally some of the issues municipalities face in the process of implementing GIS into their asset management or maintenance systems.

Central to all the above worries is the inaccessibility or deficiency of information for planning and decision-making. In general, South Africa operates a top-down approach to the access and dissemination of spatial information, census and development statistics. Regrettably, this top-down method of data formation is unsuitable for use by local governments or municipalities and, consequently, creates serious failure levels in the municipalities use of GIS infrastructure (Idrees, 2015:380).

2.4.1 Monitoring procedure

When South Africa's municipalities such as Noncore LM and Buffalo City Metropolis, use the budget and IDP allocation procedure to approve projects, their planning units utilize the GIS to select and facilitate IDP project prioritisation, project analysis and project performance monitoring (Seutloali, Beckedahl, Dube & Sibanda, 2016:239). For instance, the GIS unit in Noncore lm has created a correct base map that depicts all personal land parcels (erven) and road networks. Further there has been the identification and adding of rural villages and communities to the municipality's base map. If this base map is perceived together with all the available infrastructure for service and aerial photography, an accurate picture of the municipality already exists (Chari, Hamandawana & Zhou, 2018:676).

2.4.2 Access to spatial information

According to Schramski and Huang (2016:298), the key GIS limitations are related to people and thus institution-specific and not software and hardware specific. The GIS settings in most municipalities severely lack the required structures, underlying GIS policies and legislation. As mentioned earlier, South African municipalities still run top-

down GIS actions and exclusive spatial data structures and consequently, their GIS infrastructure in is weak generally. There is still a lack of infrastructure and resources for GIS implementation. The main factors for spatial information access and GIS failure in South Africa include: (a) issues of management, poor policies on staffing, political interferences, illiteracy and poor management of funds; (b) the lack of clear geographical information system objectives; (c) insufficient GIS support and understanding by top administration or management; (d) the absence of spatial data and GIS legislation at local government levels and (e) existing top-down drivers of spatial data (Mwange, Mulaku & Siriba, 2018:200).

To plan for rural development and the realization of service level objectives, the South African municipalities are structuring and digitising spatial databases directly from aerial photography because these images accurately identify the geographical locations of rural settlements (communities) within a specific region. Alongside community demographics produced by Statistics South Africa, spatial databases offer a good indication of the situations that are currently trending in the municipalities (Schramski & Huang, 2016:298).

2.4.3 The need for relevant GIS skills

South Africa has few people who possess GIS skills. Although some government employees have received training in GIS skills, once trained, many leave public service for ‘greener pastures’ in the private sector. The issuing of contracts could help to restrict the loss of such people. There is a need for municipal and government Human Resource departments to identify the gap in skills development, in terms of the National Qualifications Framework (NQF)’s skills development and implementation goals to set guidelines and principles for the registration of learner achievement, national knowledge and skills recognition (Musakwa, 2017:208).

The aim is to ensure an integrated scheme that inspires life-long learning. The National Standards Bodies (NSB) and Standards Generating Bodies (SGBs) within the NSBs, remain responsible for generating and recommending NQF standards and qualifications. The SGB and NSB are responsible for producing standards for GIS units. The lack of GIS skills in the market is due to a limited number of trained GIS

personnel in the marketplace and the under-utilisation of existing resources, which gives effect to the term "lack of capacity". The Department of Rural Development and Land Reform Act (2019) has the mandate to facilitate the registration of GIS professionals in the country and has established the requisite policy and regulatory framework to facilitate professional registration.

South Africa’s GIS strategy entails continuous training of GIS personnel with the aim of eliminating departmental differences and attaining a similar experience level for all GIS operators. The Noncore LM organises comprehensive training programmes to achieve the required three basic GIS training levels including (a) basic operators; (b) custodians of data and (c) overview politicians and managers (users).

2.5 CHAPTER OUTLINE

This chapter indicates that in infrastructure management, the preferred standard for effective GIS utilisation entails developing and applying a GIS strategy to service delivery as well as providing access to spatial data and the formulation of the continuous development of GIS skills capacity.

2.6 CONCLUSION

The commonality in the two case studies (Noncore LM and Buffalo City Metropolis) discussed in this chapter is that employment of GIS must yield a satisfactory response to politicians and citizens as well as to the requests of the non-technical managers. The GIS needs to improve municipality productivity and efficiency. For reporting purposes, GIS need to offer users the ability to create accurate maps and reports timeously and offer municipality administrators the capacity to identify and prioritise the need for infrastructure maintenance which will assist them to reach effective conclusions. Municipalities must utilise GIS to comply with government legislation on service delivery.

3 CHAPTER 3

3.1 RESEARCH DESIGN AND METHODOLOGY

3.1.1 Introduction

The chapter covers the specific procedures and approaches used in the selection, processing, identification and analysis of data on the assessment of IM by applying GIS in the Sekhukhune District Municipality. It focuses, therefore, on the identification of the study design, techniques of sampling, target population, analysis and collection of data on IM and use of GIS in Sekhukhune District Municipality.

3.1.2 Research Paradigm

Research paradigms are common and shared beliefs and agreements on ways of understanding and addressing the study problem (Antwi & Hamza, 2015:225). Research paradigms comprise the ways a study can describe the studied world view, informed by the following philosophical assumptions: (a) ontology, the nature of social reality (what people believe to be the nature of reality, (b) epistemology − the approaches to knowledge (ways people know all they have knowledge of and (c) axiology − the systems of value and ethics (everything people hold as being true) (Iofrida, De Luca, Strano & Gulisano, 2018:480). Research paradigms, therefore, lead people to ask particular questions or use appropriate methodology (methods of orderly investigation). Epistemology, ontology, methods and methodology are the four (4) components of all research paradigms (Blaikie & Priest, 2017:11).

Ontology concerns itself with peoples' socially built beliefs that can include multiple realities or just a single and demonstrable reality. Epistemology concerns itself with the nature of truth and knowledge by asking questions about the sources of such knowledge, the reliability of these sources and the ways a person can recognise and know the truth. Together, these philosophical assumptions help to determine the beliefs and assumptions that frame the researcher's views in terms of the study problem, which direct how investigations are conducted as well as the methods employed to answer the study questions (Mertens, 2016:17).

Motamedi-Fraser (2017:23) states that methodology means the expressed, and supposedly informed, method of data production. Methodology refers to the critical examination and study of the techniques of data production. The method is the

strategy, action plan, design or process informing one's study method choices. The methodology focuses on the discussion of the ways of undertaking a particular study and. thus, guides the researcher's decisions regarding the required data types and the most appropriate tools for data collection. The methodological study question directs the study by questioning the ways of studying the world. On the other hand, method refers to the specific approaches to data collection and analysis, such as open-ended interviewing or questionnaires. The research methods are dependent on the project design and the study's theoretical outlook. However, the use of specific methods never entails epistemological and ontological assumptions.

The main types of research paradigms are Critical Theory, Positivism and Interpretivism. Critical theory emanates from the works of Theodor Adorno, Herbert Marcuse, Max Horkheimer, Jürgen Habermas and Erich Fromm (Müller-Doohm, 2017:274). The ontological perspective of critical theory asserts that there is a reality formed by political, cultural, ethnic, religious and gender factors that interact with one another to form the prevailing social system. Critical theory is epistemologically subjective because it assumes that all research is impacted by researcher. Critical researchers are self-conscious about personal epistemological assumptions in that they clearly communicate such predispositions before conducting investigations which often results in readers or research participants becoming confused by the political and epistemological baggage the researcher brings to the field of study (Brierley, 2017:154).

The aim of critical theory paradigm research is to understand and explain certain entities as well as to change the society in which the research is conducted. Critical theory, therefore, is judgemental, of both the interpretivism and positivism research paradigm because both these theories are entangled in dominant ideologies yet neither of them has an emancipatory goal or an interest in improving the world. Critical theorists endeavour to expose the actions and beliefs limiting people’s freedoms with the aim of changing the situation rather than generating social world knowledge or preserving the *status quo* of knowledge. Critical theorists are tasked with challenging power positions and exposing the cruel structures subjugating individuals and creating inequalities (Khan, Qianli & Zhang, 2017:86).

The study methodology exercised in the critical research paradigm is both dialectic and dialogic because it calls the study to engage all participants in a dialogue aimed

at changing their attitude towards their social situation, while continuing to demand satisfaction of their social and intellectual needs (Long, 2017:213). To avoid the marginalization of the participants, critical theory studies employ collaborative approaches and involve the participants in data analysis and collection, the formulation of study questions. There can be realization and transformation of the social systems built on discrimination and injustice using critical theory methodologies such as critical discourse analysis, critical ethnography, ideology critique, action research amongst others.

With the aim of changing awareness, critical ethnography focuses on criticizing and probing for definitive assumptions on issues such as culture, race, economy, gender and politics. Critical discourse analysis involves studying the ways that powerful institutions employ language to uphold authority. According to Gratch and Warren (2018:472) it is possible to regulate people's awareness through control of language. Action studies or research are the methods used to investigate a research problem through the identification of the study problem, intervention planning, plan implementation, change observation and observed change reflection. Critical theorists use action studies to expose the practices and values which keep individuals subjugated (Long, 2017:210).

Critical studies are mostly qualitative in nature, even though they can employ the use of quantitative information. The critical research paradigm has good qualities provided that the researcher takes cognizance of the situation's cultural, political, gender and ethnic antecedents. The other criterion for ensuring the quality of critical studies is the extent of the exposure of the participants' misapprehensions regarding the *status quo* and leading ideology, as well as the extent to which the ideology facilitates action intended to recompense the exposed oppressive and unequal structures. Positivism ideology contends that science is the only approach to establishing the objective truth or reality. Positivism maintains that natural sciences' techniques, procedures and methods offer the finest framework for social world investigations (Kelly, Dowling & Millar, and 2018:13). According to Iofrida, De Luca, Strano and Gulisano (2018:469) Auguste Compte coined the term 'positivism' to indicate a strictly experimental approach that claims knowledge is directly based on people's experiences; and stresses facts as well as the behavioural causes. Positivism naturally employs scientific study methods to study people's actions. Today positivism prevails as an

objectivist ideology, contending that the objects in peoples' lives have existence and meaning independent of peoples' consciousness. For positivism theorists, the purpose of any research study is the prediction of results, the testing of theory and/or finding the strength in relations between study variables, as well as the cause-and-effect relations (Iofrida, De Luca, Strano & Gulisano, and 2018:469).

Interpretivism and constructivism are correlated concepts addressing peoples' understanding of the world with regard to the ways other people experience it. Constructivism differs from positivism in its assumptions about reality's nature, the nature of knowledge and the sources of knowledge, the nature of values as well as the role of values in the process of research. The phenomenological philosophy of Edmund Husserl (the study of people's self-awareness and consciousness) together with the hermeneutics philosophy (interpretation) of the German philosopher, Wilhem Dilthey, form the basis of constructivism. Interpretivism maintains that people's behaviour is multi-layered and thus pre-defined models of probabilism cannot determine people's behaviour. People's behaviour is dependent upon prevailing situations and remains pre-determined by the environmental features rather than by genes (Kivunja & Kuyini, 2017:41).

Figure 3.1: Summary of Research paradigms

Paradigm	Ontology *What is reality?*	Epistemology *How can I know reality?*	Theoretical Perspective *Which approach do you use to know something?*	Methodology *How do you go about finding out?*	Method *What techniques do you use to find out?*
Positivism	There is a single reality or truth (more realist).	Reality can be measured and hence the focus is on reliable and valid tools to obtain that.	Positivism Post-positivism	Experimental research Survey research	Usually quantitative, could include: Sampling Measurement and scaling Statistical analysis Questionnaire Focus group Interview
Constructivist / Interpretive	There is no single reality or truth. Reality is created by individuals in groups (less realist).	Therefore, reality needs to be interpreted. It is used to discover the underlying meaning of events and activities.	Interpretivism (reality needs to be interpreted) • Phenomenology • Symbolic interactionism • Hermeneutics Critical Inquiry Feminism	Ethnography Grounded Theory Phenomenological research Heuristic inquiry Action Research Discourse Analysis Femenist Standpoint research etc	Usually qualitative, could include: Qualitative interview Observation Participant Non participant Case study Life history Narrative Theme identification etc
Pragmatism	Reality is constantly renegotiated, debated, interpreted in light of its usefulness in new unpredictable situations.	The best method is one that solves problems. Finding out is the means, change is the underlying aim.	Deweyan pragmatism *Research through design*	Mixed methods Design-based research Action research	Combination of any of the above and more, such as data mining expert review, usability testing, physical prototype
Subjectivism	Reality is what we perceive to be real	All knowledge is purely a matter of perspective.	Postmodernism Structuralism Post-structralism	Discourse theory Archaeology Genealogy Deconstruction etc.	Autoethnography Semiotics Literary analysis Pastiche Intertextuality etc.
Critical	Realities are socially constructed entities that are under constant internal influence.	Reality and knowledge is both socially constructed and influenced by power relations from within society	Marxism Queer theory feminism	critical discourse analysis, critical ethnography action research ideology critique	Ideological review Civil actions open-ended interviews, focus groups, open-ended questionnaires, open-ended observations, and journals.

Source: (Antwi & Hamza, 2015:225).

3.2 RESEARCH DESIGN

Research methodology means the techniques or procedures the study uses in identifying, selecting, processing and analysing information on the study topic. Leavy (2017:66) indicates that currently the three main methodologies of research are: the quantitative research methodology, the qualitative research methodology and the mixed-methods research methodology. This study employed a quantitative research methodology.

3.2.1 Quantitative vs Qualitative research methodology

Hammarberg, Kirkman and de Lacey (2016:498) state that the qualitative research methodologies are detailed. To draw logical conclusions, qualitative research methodologies focus on observation descriptions, the phenomenon's circumstances and background. According to Kumar (2019:19), the qualitative research methodology is a study method which concentrates on the actual examination of offered data with the objective of ascertaining or anticipating a theme, configuration and pattern which occasions impartial deductions. Instead of offering mathematical data, the qualitative methodology of research places emphasis on inherent aspects such as the feelings of the people displayed in a descriptive manner (Julia, 2017:60).

The study chose the quantitative methodology of research because the researcher wanted to enumerate opinions, attitudes and behaviours and also generalize the results from the larger sample population. In addition, the quantitative research methodology remains reliant on hypothesis development to achieve objectivity through visually-centred information and narratives. Brannen (2017:24) insists that quantitative research methodologies can be used to measure the study problem by way of generating numerical data that can be converted into applied statistics. Analytical enumerations are key features for using the quantitative methodology of research because the quantitative study process offers a relationship between the mathematical expressions and the depicting of empirical observations, using relations and arithmetical controls.

3.2.2 Explorative research

Rahi (2017:5) indicates that an explorative research design focuses on a study problem which has not been researched in great detail with the aim of establishing priorities, developing operational descriptions and improving the actual research

results. While this practice is often carried out to ascertain the nature of the study problem, the exploratory research design is not projected to offer conclusive proof but helps the study to provide a better understanding of the study problem. In carrying out exploratory studies, the researcher is willing to modify the study's direction due to revelations perceived from new information and/or insights. The exploratory research design, therefore, never focuses on providing a final conclusive answer to the study questions but merely enhances the exploration of the study topic with erratic depth levels (Creswell & Creswell, 2017:13).

This study used the explorative research design to explore the complete nature of the study phenomenon, the ways in which it was established and other such applicable factors. The study was exploratory in nature because it examined GIS application within municipality IM; a phenomenon with little existing research data. The study explored the dimensions of the study problems through a review of literature and a structured questionnaire that was sent to GIS experts in the Sekhukhune District Municipality. The study had the potential to research new possibilities and ideas and did not permit predetermined hypotheses and ideas to direct the process of research.

3.2.3 Contextual

Holtzblatt & Beyer, 2016:23 developed the contextual research model as a user-centred design that incorporates the ethnographic approaches to data collection and is relevant to the study product through field study, workflow rationalization as well as the designing of computer-people interfaces (Holtzblatt & Beyer, 2016:23). This study used the contextual research design in all three research phases in order to understand and describe GIS IM in the Sekhukhune District Municipality within a natural but concrete context of occurrence. The study would only be able to claim a true understanding of the context if it understood the events forming the background to the entire context (McNie, Parris & Sarewitz, and 2016:889).

Therefore, it was imperative for this study to examine the setting within which the Sekhukhune District Municipality employed GIS in its IM. In other words, if it explored how an IM process that employs GIS influences infrastructure operation and maintenance, in order to improve basic service delivery through the efficient asset management of infrastructures such as water and the roads. This study was context-certain because it described the essential competencies of GIS in infrastructure management. The study had to be conducted within the Sekhukhune District

Municipality context, because the questionnaires were distributed to various officials within the municipality.

3.3 POPULATION AND SAMPLING

3.3.1 Target Population

The target population is municipal officials within the various departments of Sekhukhune District Municipality. The objective of the GIS in the district are:

- To coordinate sharing of GIS resources (personnel, hardware, software and data) to support decision making
- To facilitate acquisition of hardware and software
- To promote effective maintenance (updating) and integration of district wide GIS layers for strategic planning
- To improve service delivery and management efficiencies
- To collaborative efforts within all the municipal strategic business units
- To decrease redundancy
- To visualize data to create new information
- To support daily work flows throughout the municipality.

The GIS system should be used by the official within the following department which makes them the target populations: Finance, Planning and Economic Development, Infrastructure and Water Services, Community Services and Municipal Manager' office department. Allison et al. (2016:11) defines the total (target) population as the subjects of interest from which the study sample is chosen. The target population are the people on whom the survey data reaches interpretations to generalize study findings. The target population has similar features in regards to engagements, age, trends, work and pattern that easily influences the results of the study or suits the aim of the study (Yin, 2017:23).

3.3.2 Sampling

Sampling means the process of orderly selection of participants from the target (total) population. Sampling entails choosing people from the total population for the study as a representation of the population for the purposes of deriving strong findings. Elfil and Negida (2017:2) state that the main categories of sampling are probability sampling and non-probability sampling.

Sarstedt, Bengart, Shaltoni and Lehmann (2018:663) contend that for probability sampling, all subjects or participants have an equal chance to be selected, while in non-probability sampling, they do not have an equal chance of selection due to a non-orderly procedure. The main difference between probability and non-probability sampling is the ability of the selection criteria to randomize. Randomization occurs when the members of a sampling frame possess similar characteristics or identical chances of being selected from the actual or total study population and are not selected based on pre-set criteria.

3.3.3 Sampling criteria

Creswell and Creswell (2018:27) state that the methods of probability sampling include the following methods:

(a) Simple random sampling, which comprises assigning numbers to the study participants and employing random number generators to select the numbers of the participants to be included in the study sample.

(b) Stratified random sampling that involves dividing the study participants into similarly exclusive groups as well as using simple random sampling to select and group them.

(c) Systematic sampling that involves an exclusive selection of participants; for instance, every fifth (5th) person on the list of participants.

(d) Cluster random sampling that entails the random selection of study participants from a huge simple-random list of possible participants. For example, from a total population of ten thousand (10 000) potential participants, the study can randomly choose people according to their home city, country of origin and/or area boundary.

(e) Multi-stage random sampling which entails combining all the sampling techniques described above (Creswell & Creswell (2017:26).

This study opted for snowballing and convenience sampling. Vehovar, Toepoel and Steinmetz (2016:327) state that consecutive sampling, convenience sampling, purposive (judgmental) sampling, snowball sampling and quota sampling are key criteria of non-probability sampling. Consecutive sampling includes using every available subject in order to offer a true representation of the total population. Convenience sampling involves choosing the participants because of their accessibility and/or easiness in the listing of samples. Purposive (judgmental)

sampling entails choosing the participants for an explicit purpose and using these subjects because they are more suitable for that particular study than the rest of the total population. Quota sampling involves ensuring balanced or identical representation of the subjects, and using the measured attribute as the basis for the research quota.

Snowball sampling entails requesting the study participants to find other participants who meet the research criteria (Etikan, Alkassim & Abubakar, and 2016:55). For this study, the employment of the snowball sampling approach meant reaching out to one participant involved in IM and GIS, then requesting that study participant to identify the remaining 100 participants, all of whom would need to fit the study criteria. The study began by approaching particular GIS experts who were involved in the municipality's IM from the early stages of management and development. The study then requested these experts to identify local government employees who have the requisite IM knowledge and are applying GIS in water management projects (that is those employees who fit the inclusion criteria) such as operation managers, artisans, GIS specialists who were either involved or have been previously involved in IM in South Africa. Depending upon their physical address, the researcher contacted the participants either by telephone or scheduled personal visits.

3.3.4 Sample size

According to McConville (2017:35), sample size means observations in a numerical manner; for instance, scientific trials and/or the public-opinion surveys. Sample size includes all the individuals selected for the collection of data. The sample size for the study will be based on the number of officials within the departments that are supposed to apply GIS system functions (SDM, 2019). The municipal organisational (Sekhukhune District Municipality, 2018) structure was used to calculate to determine the sample size as follows.

- Á Infrastructure Water Services = 45 employees only up to junior level artisan and general worker not included they are not part of the target population.
- Á Planning and Economic Development = 10 employees at various level.
- Á Community Service = 15 employees at various level.
- Á Budget and Treasurer = 30 employees at various level.

A target total of 100 population within four departments which should apply GIS system of the Sekhukhune District Municipality. One hundred (100) individuals were the sample size for this study. Kibe and Muathe (2018:20) contend that one hundred (100) participants are an appropriate representation of the actual features of the target population. According to Kibe and Muathe (2018:29), a seventy percent (70%) sample size is reasonable, while a ninety percent (90%) and above percentage sample size is excellent. Therefore, the seventy percent (70%) sample is a satisfactory representation of the total (target) population. In this study, the justification for the 70% sample size is that, due to limitations in time, it would be challenging to assess every GIS expert in the Sekhukhune District Municipality in regard to study scope. The aim of the sample size and frame is to offer researchers the capacity to adequately represent the total (target) population (Creswell & Poth, 2017:35).

3.4 RESEARCH DESIGN FOR THIS RESEARCH STUDY

3.4.1 Data Collection

After considering the various research approaches, the researcher decided to use the quantitative research method, which is exploratory in nature, as the primary data collection method for the purpose of this research.

The researcher initially conducted a literature review (see Chapter Two) as a means of collecting secondary data through a study of relevant literature such as books, published journals, articles and legislation. Structured questionnaires were then compiled and disseminated in order to attain the desired primary data required for this research study.

3.4.2 Structured questionnaires

According to King, Parmar and Towheed (2019:533), questionnaires are instruments of research that contain several questions and/or such other type of prompts aimed at collecting information from the study respondent. The Statistical Society of London developed questionnaires in the year 1838 as a set of several questions used typically for purposes of research that can naturally be quantitative as well as qualitative. The design of a questionnaire is dependent on the kind of information required or data being collected. Qualitative research questionnaires are employed when ii is necessary to gather exploratory data to prove or disprove a study hypothesis.

Researchers also use quantitative questionnaires to test or validate formerly generated study hypotheses (Zaman & Iqbal, 2018:63).

Krosnick (2018:439-455) states that research questionnaires are suitable for the collection of respondents' demographic evidence, personal thoughts, attitudes or facts. The elementary characteristics of the study questionnaire include: (a) Uniformity: uniformity and standardization are leading characteristics of study questionnaires because each study participant receives similar research questions. Uniformity helps in data collection and the statistical examination of such information. All the questionnaires in this study contained questions on participant demographics, knowledge, application and experience of GIS. The questions were uniform for every study participant. (b) Exploratory: no restrictions prevail as to which questions and/or objectives must be included in a study questionnaire. (c) Question Sequence: research questionnaires typically follow some structured question flow to increase the response numbers. The question sequence includes screening the questions, transition of questions and the classification of questions.

Questionnaires typically consist of structured (close-ended) questionnaires and unstructured open-ended questionnaires (Dalati & Gómez, 2018:186). Structured questionnaires are designed and planned to gather specific evidence which is mainly quantitative information. Structured questionnaires also initiate formal enquiries, supplement information, check the previously gathered data and help in validation of any previous hypothesis. Unstructured questionnaires have basic outlines and pose specific open-ended questions that do not limit the respondent's responses and thus are suitable for gathering qualitative information (Taherdoost, 2016:41).

The main types of questions in a questionnaire include: (a) Open-ended questions where the participant may answer in an unrestricted manner (Shah, Ahsan, Bukhari, Abbas & Shah, 2017:44). (b) Dichotomous questions – these are yes/no (close-ended) questions used for validation of basic needs. (c) Multiple-choice (close-ended) questionnaires that allow respondents to choose a single or multiple-choice response from a specified list of choices that includes incomplete questions, right answers, incorrect distractors and alternatives. (d) Scaling questions that are founded on measurement-scale principles, including nominal, interval, ratio and ordinal. (e) Pictorial questions which are the easiest kind of question and require the respondent

to choose between images, while limiting participants' responses they also increase the response numbers (Jain, Dubey & Jain, and 2016:3).

- **The main advantages of Questionnaires**

According to Arora (2017:34), questionnaires are inexpensive because there is no need to hire people to undertake the distribution and collection of the questionnaire. Avenues like online distribution and collection are either free or inexpensive. A study questionnaire provides a practical method for gathering information, including targeted, choose and pick questions. Questionnaires permit the researcher to collect vast amounts of data on the study topic from the large participant audience. Questionnaire data is quantifiable and can be compared and contrasted to other data and used to measure changes. Questionnaires are naturally quantitative and permit easy data analysis. Results from questionnaires can be displayed in an extensive variety of tables and charts that are easily understood. Questionnaires permit comprehensive invisibility and maximize the respondents' comfort when answering questions. Such concealment ensures respondents' privacy while encouraging truthful responses, (Zhou, Wang, Zhang & Guo, 2017:1279).

Table 3.1: Advantage of Questionnaires

Advantage of Questionnaires	
Á Inexpensive Á Easy analysis Á Validity and reliability Á Standardised Á Practical Á Scalability	Á Fast results Á Comparability Á No pressure Á Respondent anonymity

The main disadvantages of questionnaires

Respondents to questionnaires often are not 100% open with their responses due to social appeal biases and an attempt to guard privacy. It is anticipated that when participants reply to questionnaires certain questions will be left unanswered or ignored (LaDonna, Taylor and Lingard, 2018:349). The problem with not engaging in face-to-face question and answer sessions is that respondents will have differing interpretations of questions whose meaning seems obvious and clear to the researcher. As such, the responses are subjective because there is no one to clarify the meaning of questions and, thus, guarantee every respondent has an identical understanding of a question. A questionnaire does not capture fully the respondents' emotional feelings or answers. Deprived of face-to-face interaction, the researcher cannot observe the respondents' facial reactions or body language (Yaddanapudi & Yaddanapudi, 2019:335).

Table 3.2: Disadvantage of Questionnaires

Advantage of Questionnaires	
Á Dishonest answers	Á Lack of nuance
Á Hidden agenda	Á Survey fatigue
Á Skipped questions	Á Unconscientious response
Á Interpretation issues	Á Analysis issue
Á Lack of personalisation	Á Accessibility issues

This study adopted a structured questionnaire to collect data on the assessment of IM through the application of GIS in Sekhukhune District Municipality. The questionnaire contained three main sections, Sections A to C. Section A covers the participant' demographics including age, gender, work experience and level of education. Section B covers the participants' knowledge of GIS. Section C covers the application of GIS in Sekhukhune District Municipality and participatory experiences in the application of GIS in Sekhukhune District Municipality.

3.5 DATA ANALYSIS

3.5.1 Process of data analysis

According to Bryman (2017:77), data analysis involves the procedure of gradually applying rational and numerical practices to illustrate, describe and recap all the information that has been collected. Data analysis consists of changing, breaking-down, numerical exhibition and cleaning to maintain data integrity, with the objective of supporting the study's aim and decision-making. Data analysis involves scrutinizing the collected information and reaching specific interpretations, suppositions and understandings. This process involves matching the responses of the participants with mathematical suggestions (Brace, 2018:43).

This study systematically analysed all collected data, using content analysis, with the aim of reaching logical recommendations and conclusions. To ascertain its capacity to solve the study questions, the questionnaire was edited for precision, inclusiveness, consistency, clarity and extensiveness. Using a pilot study, the study carried out a further inspection to ascertain whether the study questionnaire respected earlier study features.

3.5.2 Statistical Analysis

The study used version 23 of the SPSS software to analyse the facts and perceptions of the different participants, as well as to compare them with the study results. In Chapter One the study delineated the issues identified by the individuals who completed the structured questionnaire and these are very similar to those revealed through the statistical analysis. This study included collecting information regarding the application of GIS to infrastructure management in the Sekhukhune District Municipality.

3.6 ETHICAL CONSIDERATION

The study maintained a high standard on all matters of confidentiality. Consideration of all ethical issues was given according to the Belmont Report (Nicolaides, 2016:24). The study addressed all ethical considerations with regard to the researcher's competence and actions, as well as the publication of study findings as set out below:

3.6.1 Informed consent and autonomy

In regard to informed consent and autonomy, all the study participants were well-informed about this study, its objectives and the likely benefits and risks of participation. The participants were also presented with a letter approving the research project from the North West University's School of Business and Governance, together with the questionnaire, prior to signing the consent form.

3.6.2 Principle of beneficence

The principle of beneficence encompasses ensuring the greatest possible benefit for the research participants (Pierce, Steele, Flood & Elliott, and 2019:39) including:

3.6.3 Freedom of harm

Due to the fact that participants' harm and discomfort can be emotional, physical, spiritual, legal, economic or social, the study conducted the process of research with utmost sensitivity and in a very safe study environment. The study gave careful consideration to the framing of questions to prevent them causing harm to participants.

3.6.4 Freedom of exploitation

There were assurances given to the participants regarding their choice of participation as well not using the information they would provide in this study against them in any kind of manner. Consideration was given to the benefit/risk ratio to establish if the risk to the study participants was commensurate with the anticipated social benefits relating to the IM profession. Therefore, it is the researcher's honest opinion that the study will be of benefit to the public, Sekhukhune District Municipality and the infrastructure management profession in South Africa.

3.6.5 Principle of respect for human dignity

In this study, the principle of respect for human dignity entails:

3.6.6 Diminished autonomy

There shall be protection of people with moderated autonomy in this research. There shall be protection of individuals who agree to complete the structured questionnaire by disclosing their real name or who choose to complete the questionnaire anonymously.

3.6.7 The right to self-determination

The study guaranteed the right to self-determination by guaranteeing that the participants voluntarily accepted to participate in the study or voluntarily declined to

have their information disclosed in any way at any stage of the research. Throughout this study, the participants were at liberty to request explanations on the research purpose or any other matter related to the study. There was no coercion when a potential participant applied or refused to participate in the study.

3.6.8 The right to full disclosure

The researcher agreed not to withhold the right to full disclosure to participants at any time during or after the research. The full nature of the research, the participant's responsibilities and the likely risks and benefits that could be incurred, would be fully disclosed in writing prior to the commencement of the research project.

3.6.9 The right to fair and equitable treatment

By adhering to the following practices, this study observed the participants' right to fair and equitable treatment during, before and after participation in the research: (a) the participants were selected in a non-discriminatory and fair manner to equitably share any benefits and risks. (b) Selection of the 100 participants was based on study requirements not gullibility, convenience or the compromised situation of some people (c) The study did not treat with prejudice anyone who declined to engage or participate in the study or who decided to withdraw their participation during the course of the study. Besides continuously treating all participants with courtesy and respect, the study honored all agreements between the participants and researcher.

3.6.10 Actions and competence of the researcher

The researcher is obliged ethically to guarantee that both she/he and the participants are sufficiently skilled and competent to undertake the study project (Ferreira, Buttell & Ferreira, and 2015:40). For this reason, the researcher completed a postgraduate program in research methodology and ensured that the supervisor who was actively involved in the research project is an expert in the research field.

3.6.11 Publications of the study findings

The study ensured that the report of the study findings remains accurate, clear and objective. Similarly, the researcher strived to ensure that study remained objective throughout the study project, giving credit to people and literature consulted through appropriate and accurate in text citations and a comprehensive Reference List. On completion of the study, the findings will be communicated to the participants, without damaging the confidentiality principle, to express the researcher's recognition and gratitude for their participation (Ferreira, Buttell & Ferreira, and 2015:42).

3.6.12 Trustworthiness

According to Connelly (2016:437), Trustworthiness relates to the methodological adequacy and accuracy of the research. Amankwaa (2016:23) states that trustworthiness involves ensuring rigour in the study without forgoing relevance... The following principles of trustworthiness – transferability, credibility, conformability and dependability were addressed in this study.

3.6.13 Truth value

Truth value determines the level of confidence other researchers and readers have in the truth of the study findings, based on the study context, design and participants. This study acquired truth value from its examination and recording of participants' perceptions of and experiences with GIS.

3.6.14 Credibility

Credibility addresses the issue of whether the researcher has established confidence in the truth of the results, and deals with the question of how the research results match the reality within the context of the study (Connelly, 2016:435). This study used a process of extended engagement with GIS experts, continual field observations, peer debriefings, negative analysis and reflexivity as well as participant validation and checks to ensure credibility.

3.6.15 Applicability

Applicability is the extent to which the study findings may be applied to other settings and contexts or by other people groups. Applicability is also includes the ability to generalize from the study findings to total populations. To establish its applicability, the study gave adequate data about the researcher, the study processes, context, study-participant connection and members, to ensure that it would be conceivable for other researchers to choose ways of transferring the findings to similar situations.

3.6.16 Dependability

Dependability involves the participants of the study assessing the researcher's findings, recommendations and interpretations in order to guarantee their support of the collected data (Amankwaa, 2016:25). The study provided proof that there would be comparability of findings in the case of repetition of the study. The study sufficiently used the renowned code-recode technique or strategy of credibility to demonstrate its dependability.

3.6.17 Conformability

The study recorded and securely saved all the structured questionnaires on a computer in transcript or spreadsheet. The researcher also kept the reflective notes, the captured decisions as well as all the coding process versions - all features that illustrated the progression towards achieving the study findings.

3.6.18 Criteria of trustworthiness

Á Code-recode procedure

The code-recode procedure involves the study coding information twice and giving a gestation period of two weeks between each coding. Therefore, after coding a section of data, the researcher waited for two weeks before returning to recode the data as well as evaluating the study results. The study then compares the outcomes from the two sets of coding to ascertain similarity or the difference in the results. The code-recode procedure (code agreement) necessitated using a study process that allowed multiple study observations to suggest inter-observer or inter-rater coding of the data, as well as comparing the inter-rater coding (De Beer & Du Toit, 2015:217). The fact that there was harmony in the results from the dual coding enhanced the dependability of the study. This trend helped the researcher gain a profound understanding of the patterns of data and, thus, improved the presentation of the participants' accounts.

3.7 CHAPTER OUTLINE

Chapter Three has outlined the methodology of the research employed in this study project and also includes in-depth discussions of the three (3) phases used in the research process. The following chapter covers data collection and analysis.

4 CHAPTER 4

DATA PRESENTATION AND ANALYSIS

4.1 INTRODUCTION

This chapter gives the study findings and analysis as indicated in the research methodology, to link the core study with the data analyses results – which is to assess the infrastructure management by applying the Geographical Information System (GIS) in Sekhukhune District Municipality.

This study targeted to collect information from one hundred (100) officials of the Sekhukhune District Municipality. Ninety (95) of the one hundred (100) targeted participants completed and returned the questionnaire provided to cause a 95% response rate. Only five (5) questionnaires remained; these included ones that were either not returned or properly completed. As such, this study does not consider the five questionnaires in the various data analysis.

Figure 0.1: Response Rate Distribution

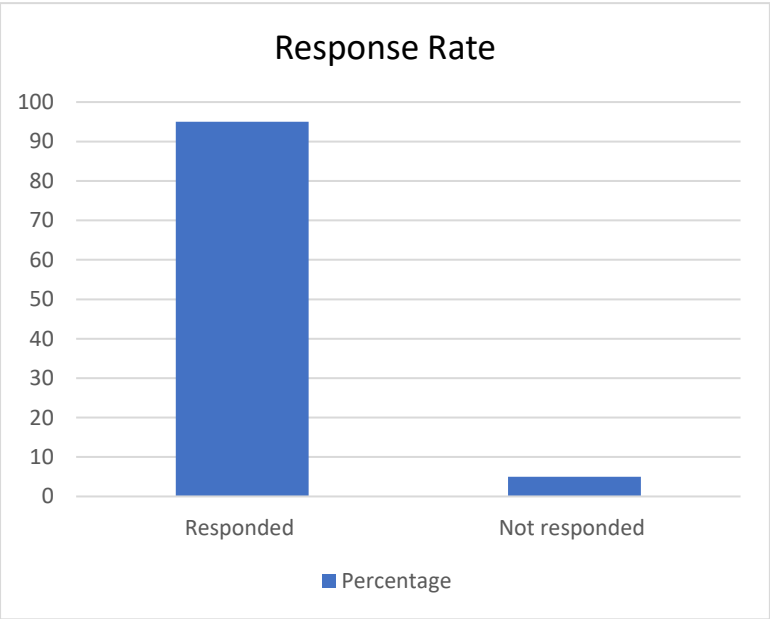


Figure 0.2: Response Rate Distribution

The response rate is calculated as indicated below:

95/100*100= 95 %

The response rate above is appropriate and acceptable for data analysis and reporting. In quoting Mugenda & Mugenda (2003), Oromo and Mwangangi (2017:58) contend that 50% response rate is tolerable for reporting and analysis, a 60% response rate is respectable while a 70%-and-above response rate is outstanding. With a 95% response rate, this study recorded an excellent response rate in terms of the above declaration and is, thus, a representative and acceptable rate for the conclusions in this study.

The questionnaire in this study was derived from the literature review and the objectives of the study for assessing the effectiveness of the infrastructure management within the Sekhukhune District Municipality through the application of the GIS. The questionnaires are divided into three sections, Section A – Demographic information, Section B – Dichotomous questions and Section C – Rating questionnaires.

4.2 DEMOGRAPHIC ANALYSIS

4.2.1 Gender

Table 4.2-1 indicates the respondents' gender. The delineated data indicates that there are more male respondents (71%) than female respondents (29%) with 0% respondents failing to indicate their gender. This result indicates that the sample selected in terms of gender consists of more males than females.

Table 4-0.1: Gender

	Category	Frequency	Percentage
Gender	Male	67	**71%**
	Female	28	**29%**
	Total	95	**100**

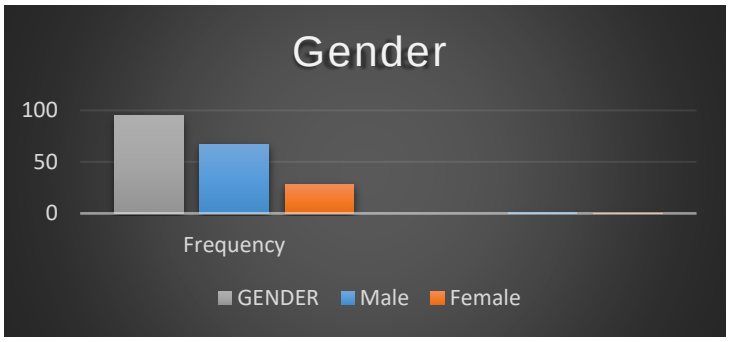


Figure 0.3: Gender

The 29% representation of women as against the 71% representation of men in the sample population chosen for this study indicates that Sekhukhune District Municipality has made an effort to retain both males and females as employees and participants in this study respectively. Hanaysha (2016:172) states that such action is a decent strategy for guaranteeing enhancement of the general employee and municipality productivity.

4.2.2 Age Group

Table 4.2-2 indicates a breakdown of the respondents by age while in Figure 4.2-2 this information is depicted in graphical form. Both Table 4.2-2 and Figure 4.2-2 indicate that the majority of study respondents (46.8%) are aged between 30 - 39 years old and the smallest groups of respondents (2.1%) are those aged between 18 – 29 years and 60-69 years respectively. The researcher is of the opinion that there is a fair representation of youth amongst the study participants.

Table 4-0.2: Age Group

	Age Group	Frequency	Percent
Valid	18-29	2	2.1
	30-39	44	46.8
	40-49	25	26.6
	50-59	21	22.3
	60-69	2	2.1
	Total	94	100.0

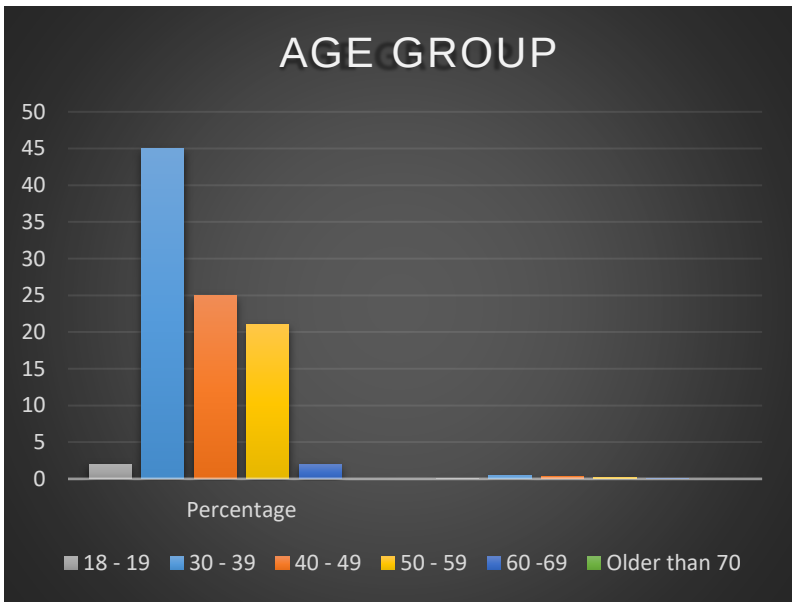


Figure 0.4: Age Group

4.2.3 Educational Qualification

Table 4-0.3: Educational Qualification

Qualification Level		Frequency	Percent
		1	1.1
	Post Matric	93	98.9
	Total	94	100.0

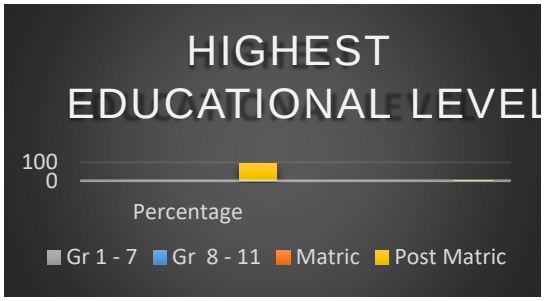


Figure 0.5: Highest Educational Qualification

Both Table 4.2-3 and Figure 4.2-3 indicate that 98.9% of the study respondents have a post matric qualification, with only 1% of the respondents not indicating their educational qualification level.

Table 4-0.4: Position level in the Organisation

Position level	Frequency	Percent
	2	2.1
Lower Management	38	40.4
Middle Management	44	46.8
Senior Management	10	10.6
Total	94	100.0

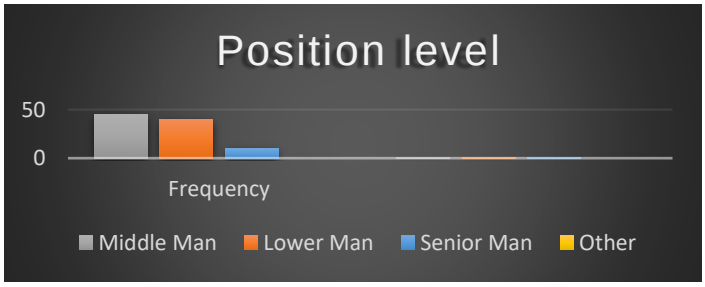


Figure 0.6: Position level in the Organisation

Table 4.2-4 indicates that majority of the participating respondents are in the middle management (46.8%) and lower management (40.4%) levels. The lowest number of participants (10.6%) are in the senior management level.

4.2.4 Work duration within the organisation

Table 4.2-5 and Figure 4.2-5 below demonstrate that the majority of the study respondents have been employed by Sekhukhune District Municipality for a period range of between 1 – 10 years (94.7%), only 2.1% of the respondents have been working for Sekhukhune District Municipality for a period range of between 11 – 20 years, and only 3.2% have been with the organisation for less than a year.

Table 4-0.5: Work duration within the Organisation

Work Duration	Frequency	Percent
1 – 10 yrs	89	94.7
11 – 20 yrs	2	2.1
less than 1 yr	3	3.2
Total	94	100.0

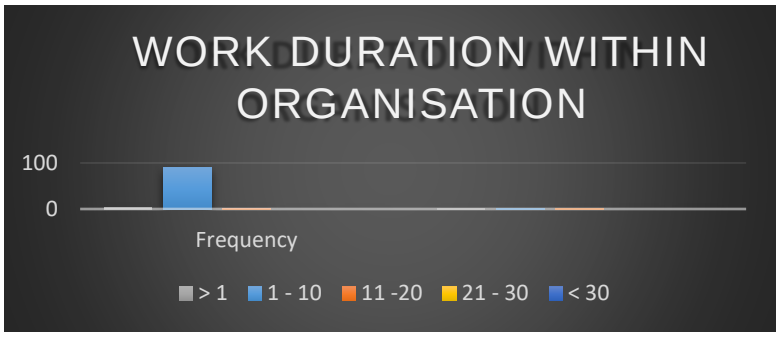


Figure 0.7: Work duration within Organisation

4.2.5 Department/ Unit within an Organisation

Table and Figure below indicate that the infrastructure water services department employs the highest percentage of the respondents at 51.1%, followed by the finance department at 26.6%. These results reflect the fact that the infrastructure water services department is the largest key performance area of Sekhukhune District Municipality, which, as mentioned previously, is the Water Services Authority.

Table 4-0.6: Department/Unit within Organisation

Unit	Frequency	Percent
Finance	25	26.6
Infrastructure Services	48	51.1
Municipal Manager	6	6.4
Planning and Economic development	15	16.0
Total	**94**	**100.0**

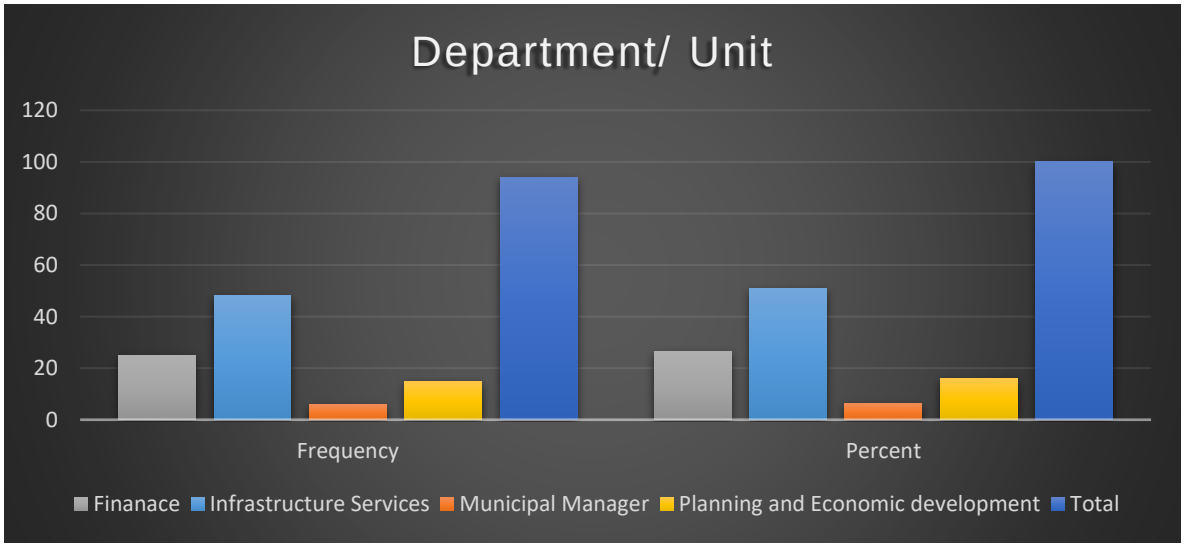


Figure 0.8: Department/Unit within Organisation

4.2.6 Population Group

Table below indicate that the population group of almost all the study respondents is African, with only 1.1% of the respondents being White.

Table 4-0.7: Population Group

Population Group	Frequency	Percent
African	93	98.9
White	1	1.1
Total	94	100.0

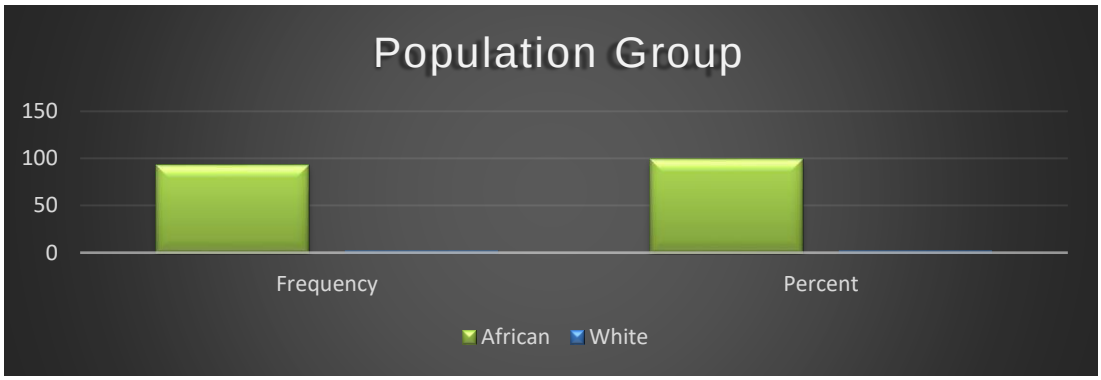


Figure 0.9: Population Group

4.3 STATISTICAL DATA ANALYSIS

In this study questionnaires were used as the technique for collecting the required data from respondents. The questionnaires are divided into three sections, Section A – Demographic information questions, Section B – Ordinal variables questions and Section C – Rating questions.

After data collection the information was captured onto the relevant spreadsheets and then sent to the statistician to calculate descriptive statistical analysis. Only two statistical methods were used to interpret data for purpose of this study.

1. Descriptive and Frequency analyses.
2. Reliability (T-test, Homogenity test and Correlation matrix test)

Descriptive and Frequency analyses

There are three aspects to descriptive statistics which are **frequencies, measure of variability** and **measure of central tendency**. Frequency counts the number of times that each variable (such as the number of females and males) occurs within the sample.

Table 4-0.8: Descriptive and Frequency Statistics

		Gender	Age Category	Qualification	Position level	Department/Unit	Years worked in municipality (years)	Population Group	Knowledge of GIS	GIS training Offer	Contribution of GIS positively	Easing of work through GIS	Access of GIS referenced info	Reference info key to the Unit	Quality and integrity of information improvement	Financial improvement if all info was centrilised	Poor assets management impact on services delivery	Infrastructure assets linked on the GIS system	Effectiveness of existing information distribution?
N	Valid	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94
	Missing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean																			**3.33**
Std. Deviation																			**0.955**

4.3.1 Knowledge of GIS in SEKHUKHUNE DISTRICT MUNICIPALITY.

Out of the ninety-seven (95) respondents who engaged with this study, 92% of them indicated they had knowledge of the GIS operating within the Sekhukhune District Municipality, while 8% of the participants indicated that they had no knowledge of the GIS.

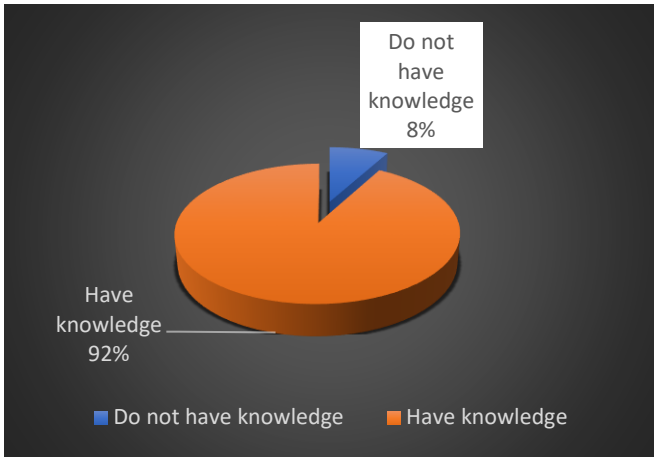


Figure 0.10: Knowledge of Geographic Information System (GIS)

The figures and findings above indicate that knowledge of the GIS's capabilities and the available spatial information has made the Sekhukhune District Municipality more responsible for the development and growth of GIS in South Africa.

4.3.2 GIS training offers

Eighty-three (83%) of the study respondents indicated that the Sekhukhune District Municipality has not offered them any GIS related training. While 13% of the respondents agreed that the Sekhukhune District Municipality has offered them GIS related training.

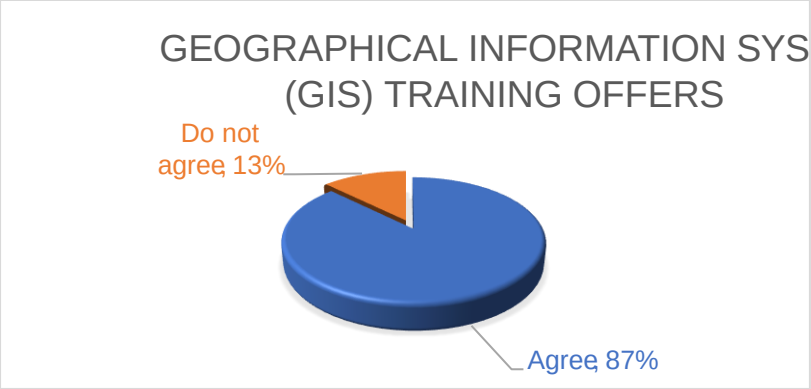


Figure 0.11: Geographic Information System training offers

The above findings indicate that the Sekhukhune District Municipality does not capacitate the majority of its officials by offering them training and workshops on GIS.

4.3.3 Positive contribution of GIS

All of the participants (95 respondents) indicated that the GIS contributes positively to the Sekhukhune District Municipality's operations. None of the participants indicated that the GIS impacts negatively on Sekhukhune District Municipality's operations.

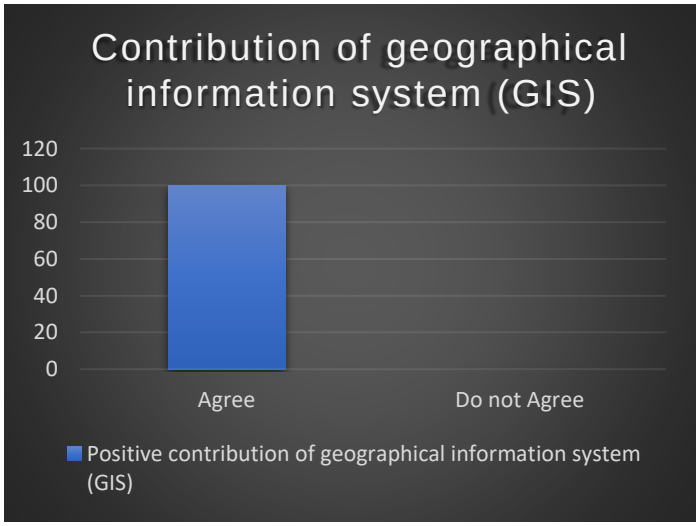


Figure 0.12: Positive contribution of GIS

The results above indicate that GIS can contribute positively to Sekhukhune District Municipality's operations, including the integration of the GIS and planning schemes to aid infrastructure planners to identify regions for secluded planning or where the planning is out of synchronisation.

4.3.4 Ease of work

All of the participants (100%) indicated that the GIS eases their working operations at the Sekhukhune District Municipality, and no one indicated that it does not do so.

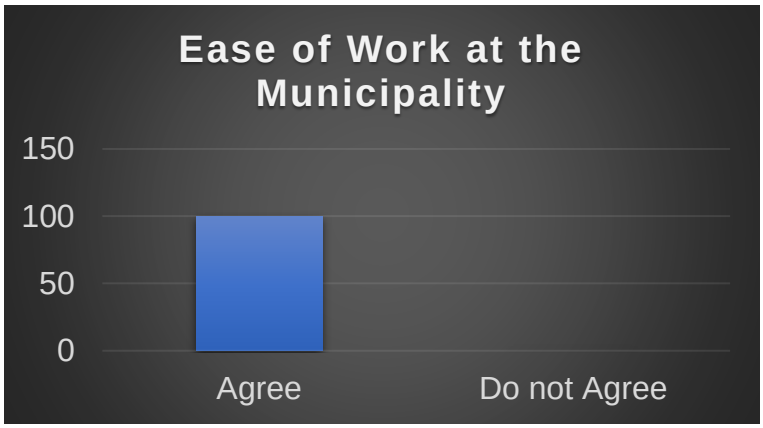


Figure 0.13: Ease of work in Sekhukhune District Municipality

The above results establish that the GIS could make it easier for employees to perform their daily work if all spatially mapped information was available through GIS. The GIS will help the workers to quickly and efficiently access information throughout the process of construction or infrastructure development, thereby reducing the time dedicated to probing for essential information.

4.3.5 Access of GIS referenced information

62% of the study respondents indicated that there is access to GIS referenced information at Sekhukhune District Municipality. 38% of respondents indicated that there is still limited access to GIS referenced information at Sekhukhune District Municipality.

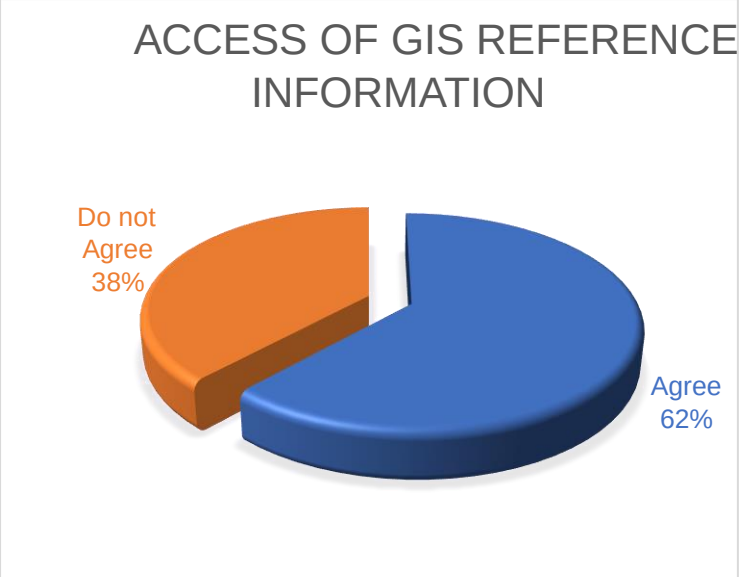


Figure 0.14: Access of GIS referenced information

The findings presented in Figure 4.3-5 above establish that a majority of the Sekhukhune District Municipality's stakeholders have access to GIS-referenced information without the need to raise detailed commands on GIS software.

4.3.6 GIS reference information key to the municipal unit

79% of the study respondents indicated that GIS reference information is key to their department's operation of the GIS, while 21% of the respondents indicated that GIS reference information is less important to them.

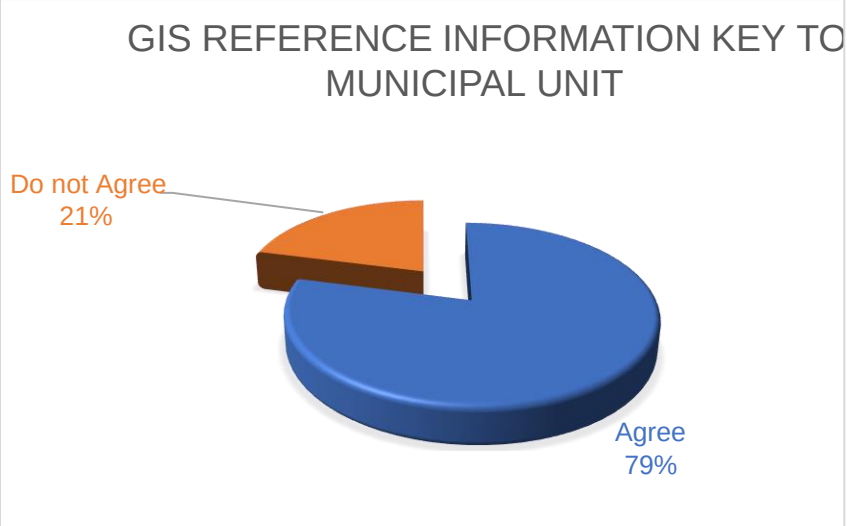


Figure 0.15: Geographical Information System reference information key to the municipal unit

The findings in Figure 4.3-6 above indicate the 79% of respondents agree that the GIS reference information is key to their units' ability to enable the majority of the Sekhukhune District Municipality's stakeholders to receive referenced information that is fundamental to the operation of the municipal unit.

4.3.7 Quality and integrity of the information

93% of the study respondents agreed that the quality of information and data integrity would improve if all the municipal information was available spatially on the GIS while seven (7) respondents (7%) indicated that the GIS used by the Sekhukhune District Municipality offers low quality information that lacks integrity.

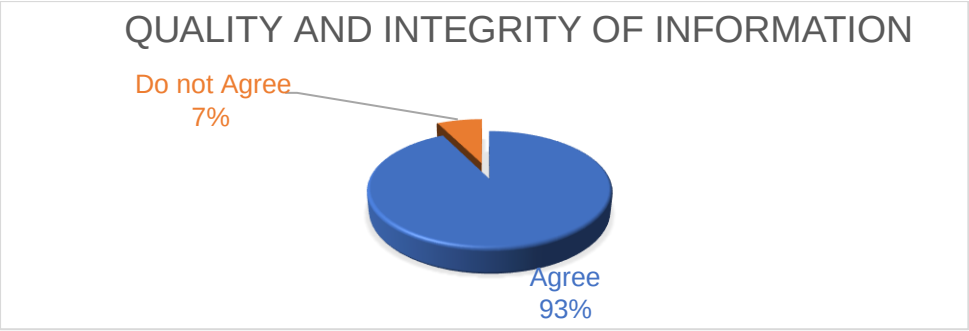


Figure 0.16: Quality and integrity of information

The results in Figure 4.3-7 above indicate that the majority of respondents believed that the data from the different GIS arrangements used by the Sekhukhune District

Municipality did not contain inconsistencies in regard to displacement, resolution and orientation.

4.3.8 Financial improvement if all information was centralized

All of the study participants (100%) indicated that there would be a financial improvement if all Sekhukhune District Municipality's information was centralized using a GIS and none of them indicated that such centralization would not result in financial improvement.

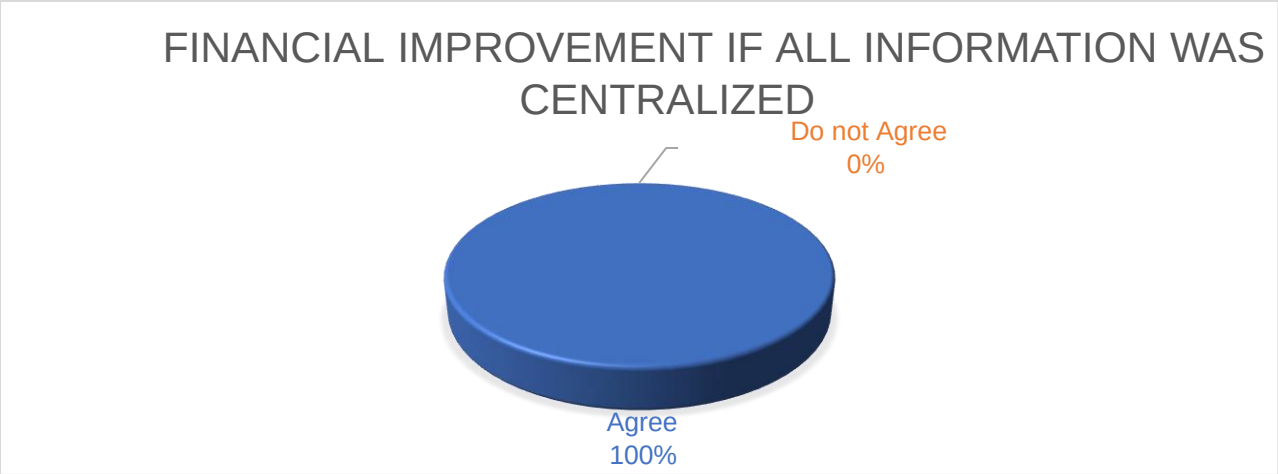


Figure 0.17: Financial improvement if all information was centralised

The results in Figure 4.3-8 above establish that the GIS's capacity to amalgamate and collaborate all the data from the different departments, as well as the convenience of using the system to trace the needed payment options, has improved Sekhukhune District Municipality's finances.

4.3.9 Poor assets management impact on service delivery

92% of the study respondents agreed that poor asset management can impact negatively on service delivery, while eight (8) of the respondents (8%) indicated that poor asset management has no impact service delivery.

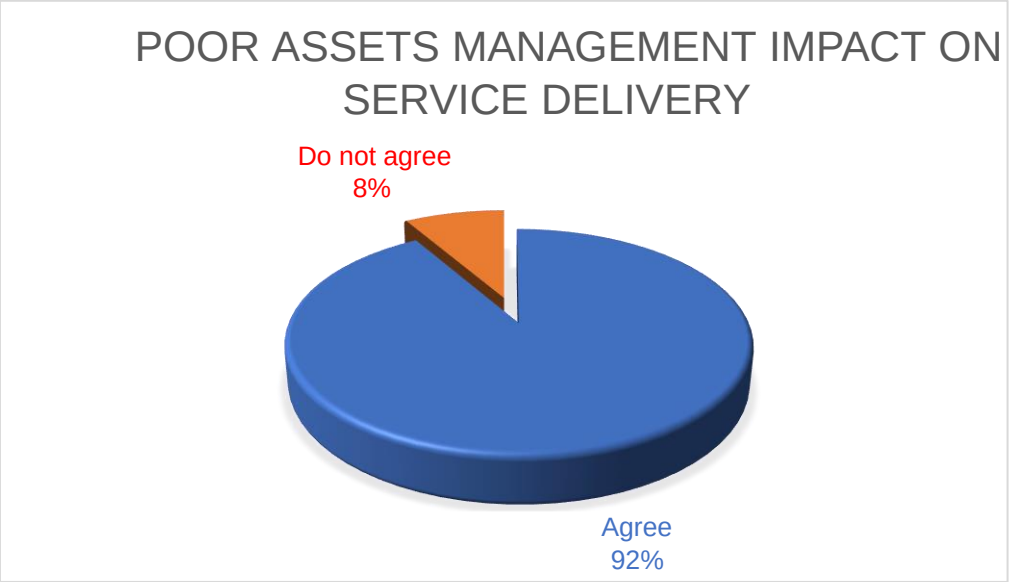


Figure 0.18: Poor assets management impact on services delivery

The GIS mapping of Sekhukhune District Municipality's assets offers the municipality more layers of asset information and, consequently, better asset management and analysis.

4.3.10 Infrastructure assets linked on the GIS system

29% of the study respondents maintained that Sekhukhune District Municipality's infrastructure assets are linked to the GIS while 71% of the respondents maintained that Sekhukhune District Municipality's infrastructure assets are not linked to the GIS.

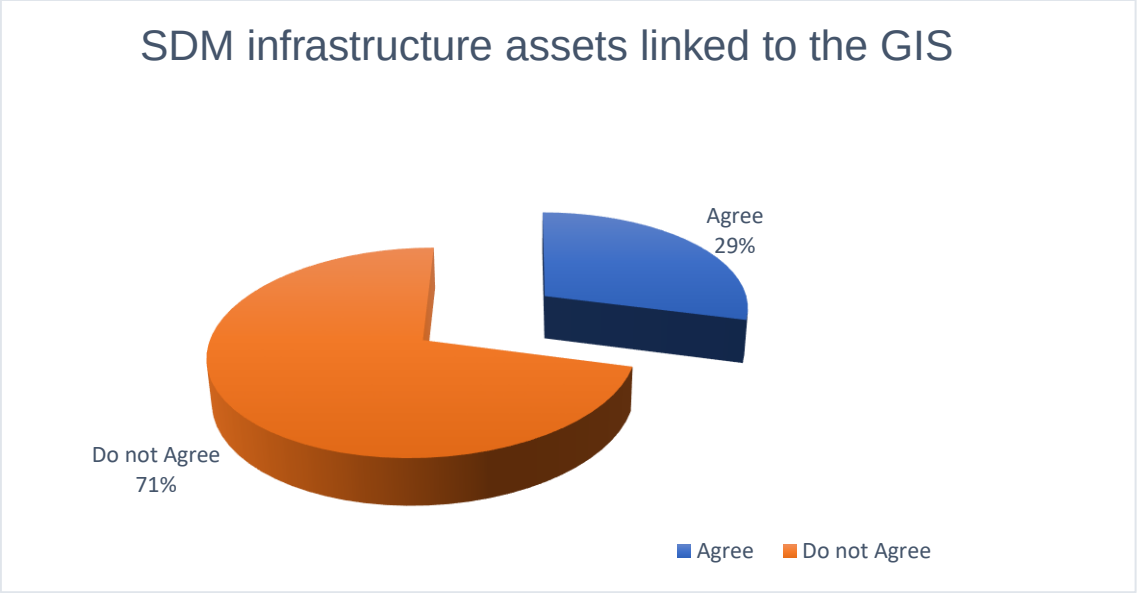


Figure 0.19: Sekhukhune District Municipality's infrastructure assets linked to the GIS

The results shown in Figure 4.3.-11 above indicate that the Sekhukhune District Municipality's present structure constrains the GIS's communication across the municipality. The majority of the respondents indicated that the Sekhukhune District Municipality's Data and GIS team, as well as the Property and Infrastructure Management Department, have no strong support from the Sekhukhune District Municipality's infrastructure executive and, therefore, find it hard to provide an equal level of tactical support for the Sekhukhune District Municipality as a whole.

4.4 SECTION B

4.5 IMPLEMENTATION OF GIS BY THE SEKHUKHUNE DISTRICT MUNICIPALITY

Through the questionnaire provided to respondents, this study sought to establish the extent to which the Sekhukhune District Municipality has implemented a GIS.

4.5.1 Effectiveness of existing information distribution

The study respondents rated the effectiveness of existing information distribution at the Sekhukhune District Municipality at three out of five (3/5). In terms of percentage,

75% of the respondents maintained that there is effectiveness of existing information distribution at the Sekhukhune District Municipality.

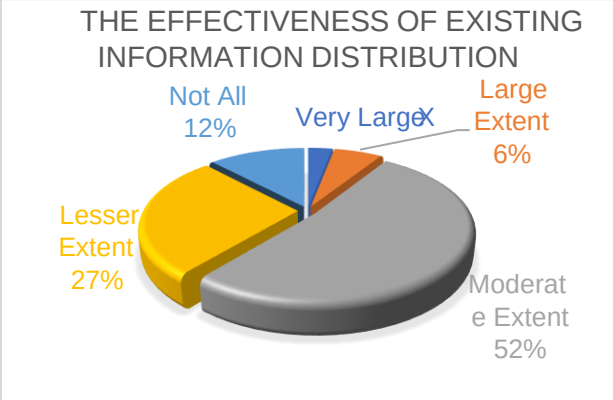


Figure 0.20: The effectiveness of existing information distribution

The findings in Figure 4.5-1 above indicate that there is effectiveness in the distribution of prevailing information at Sekhukhune District Municipality.

Respondents = Rate - 1 Very large extent	**3%**
Respondents = Rate - 2 Large extent	**6%**
Respondents = Rate - 3 Moderate Extent	**52%**
Respondents = Rate - 4 Lesser extent	**27%**
Respondents = Rate - 5 Not at all	**12%**

The existing method of disseminating information by the Sekhukhune District Municipality is very effective.

4.5.2 Accessibility of information

Three out of five (3/5) of the study respondents indicated that there is information accessibility within the Sekhukhune District Municipality in terms of percentage:

Respondents = Rate - 1 Very large extent	3%
Respondents = Rate - 2 Large extent	12%
Respondents = Rate - 3 Moderate Extent	39%
Respondents = Rate - 4 Lesser extent	24%
Respondents = Rate - 5 Not at all	20%

60% of the respondents maintained that Sekhukhune District Municipality has endeavoured to use the GIS for the effective accessibility of information by stakeholders.

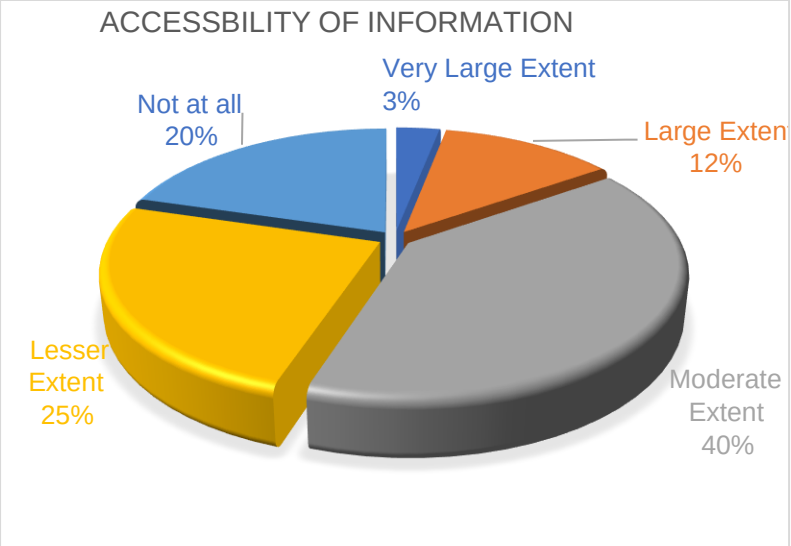


Figure 0.21: Accessibility of information

The findings shown in Figure 4.5-2 above indicate that there is a moderate to lesser extent of accessibility of information at Sekhukhune District Municipality. Only certain units within Sekhukhune District Municipality, such as Planning and Development and Infrastructure, are able to access the GIS information.

4.5.3 Up-date of Geo-data Information at Sekhukhune District Municipality.

Four out of five (4/5) of the study respondents indicated that Sekhukhune District Municipality's information is not regularly updated using the GIS. The respondents stated that Sekhukhune District Municipality does not regularly update its information.

Respondents = Rate - 1 Very large extent	**5%**
Respondents = Rate - 2 Large extent	**16%**
Respondents = Rate - 3 Moderate Extent	**21%**
Respondents = Rate - 4 Lesser extent	**33%**
Respondents = Rate - 5 Not at all	**25%**

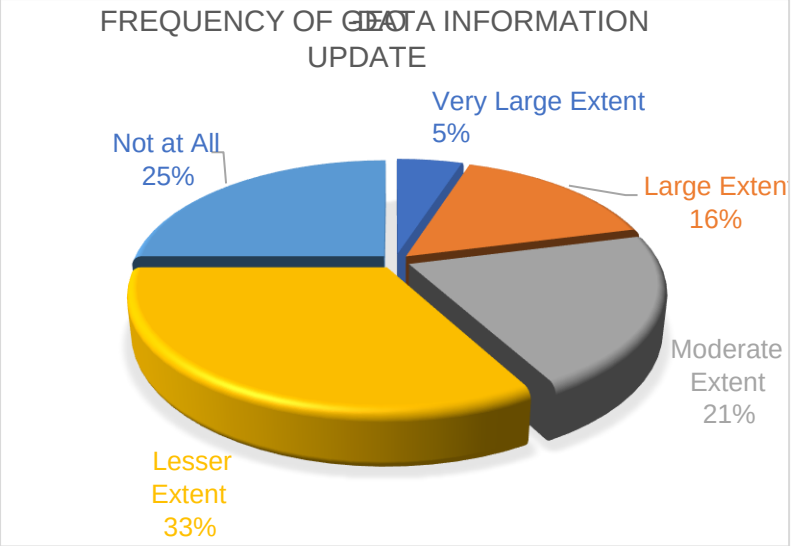


Figure 0.22: Up-date of Geo-data Information

The results shown in Figure 4.5-3 above establish that the Sekhukhune District Municipality does not regularly update its Geo-data or Geo-reference information which can result in managers making uninformed decisions regarding infrastructure availability and conditions.

4.5.4 Quality of municipality information

Three out of five (3/5) study respondents indicated that Sekhukhune District Municipality has a high quality of municipality information.

Respondents = Rate - 1 Very large extent	**0%**
Respondents = Rate - 2 Large extent	**13%**
Respondents = Rate - 3 Moderate Extent	**32%**
Respondents = Rate - 4 Lesser extent	**35%**
Respondents = Rate - 5 Not at all	**18%**

In percentage terms, none of the study respondents agreed that the Sekhukhune District Municipality has quality GIS information. 60% the respondents found that the Sekhukhune District Municipality does not have a sufficiently high quality GIS to offer its stakeholders a high quality of municipality information.

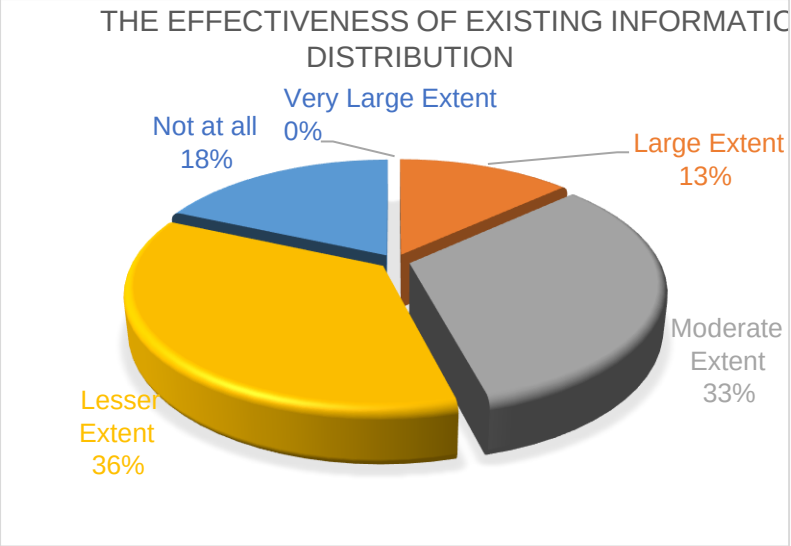


Figure 0.23: Quality of municipality information

The findings shown in Figure 4.-5-4 above stablished that Sekhukhune District Municipality has not used its GIS to offer its stakeholders a high quality of municipality information.

4.5.5 Department/units use of GIS system to make decisions

Three out of five (3/5) of the study respondents indicated that departments or units of the Sekhukhune District Municipality are effectively using the GIS to reach municipality decisions.

Respondents = Rate - 1 Very large extent	19%
Respondents = Rate - 2, Large extent	11%
Respondents = Rate - 3, Moderate Extent	17%
Respondents = Rate - 4 Lesser extent	24%
Respondents = Rate - 5 Not at all	29%

In percentage terms, 40% of the respondents maintained that departments or units of the Sekhukhune District Municipality have effectively used the GIS for effective decision making, while 60% indicate that their department/units do not use the GIS system for this purpose.

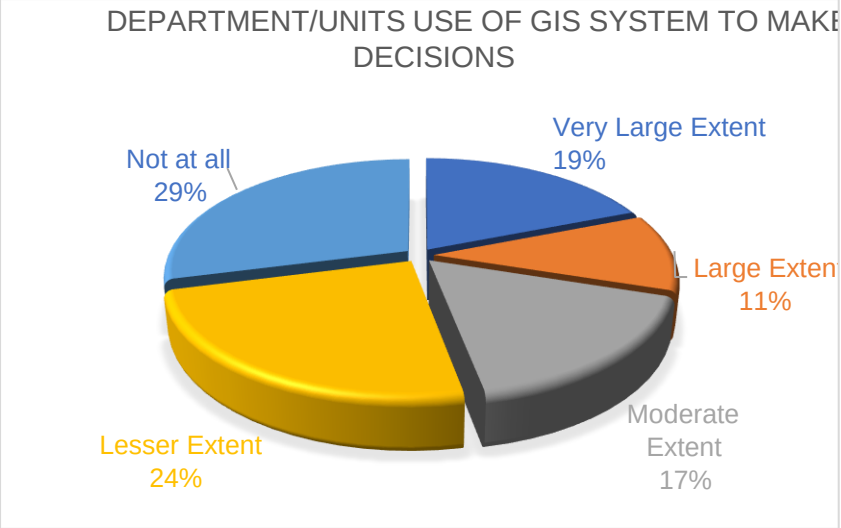


Figure 0.24: Department/units use of GIS system to make decisions

The study findings depicted in Figure 4.5-5 above indicate that only a few departments/units of the SEKHUKHUNE DISTRICT MUNICIPALITY have effectively used the GIS for decision making.

4.5.6 GIS assisting IWS to provide solutions to infra challenge.

Two out of five (2/5) of the study respondents indicated that the GIS can assist the Sekhukhune District Municipality and its departments or units to solve infra challenges.

Respondents = Rate - 1 Very large extent	45%
Respondents = Rate - 2 Large extent	14%
Respondents = Rate - 3 Moderate Extent	15%
Respondents = Rate – 4 Lesser extent	6%
Respondents = Rate - 5 Not at all	20%

In terms of percentage, only 60% of the study respondents agree that GIS can provide solutions in the Sekhukhune District Municipality to address infrastructure management challenges and then accelerate the service delivery to the communities within the Sekhukhune District Municipality.

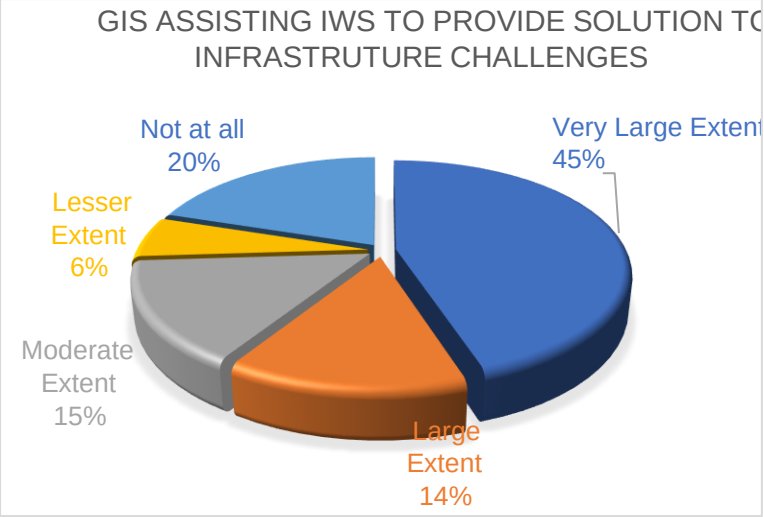


Figure 0.25: GIS assisting IWS to provide solutions to infra challenge.

The study findings shown in Figure 4.5-6 above indicate that the Sekhukhune District Municipality and its departments or units are moderately utilizing the GIS to solve infrastructure challenges.

4.5.7 GIS promotes efficiency in the scheduling of maintenance such as scheduling, tracking task and personnel.

Two out of five (2/5) study respondents indicated that the GIS does improve efficiency in the operation and maintenance in terms of maintenance scheduling, tracking task and resources.

Respondents = Rate - 1 Very large extent	44%
Respondents = Rate - 2 Large extent	11%
Respondents = Rate - 3 Moderate Extent	16%
Respondents = Rate - 4 Lesser extent	15%
Respondents = Rate - 5 Not at all	15%

In terms of percentage, only 70 % of the study respondents agreed that the GIS can improve the operations and maintenance of infrastructure efficiency.

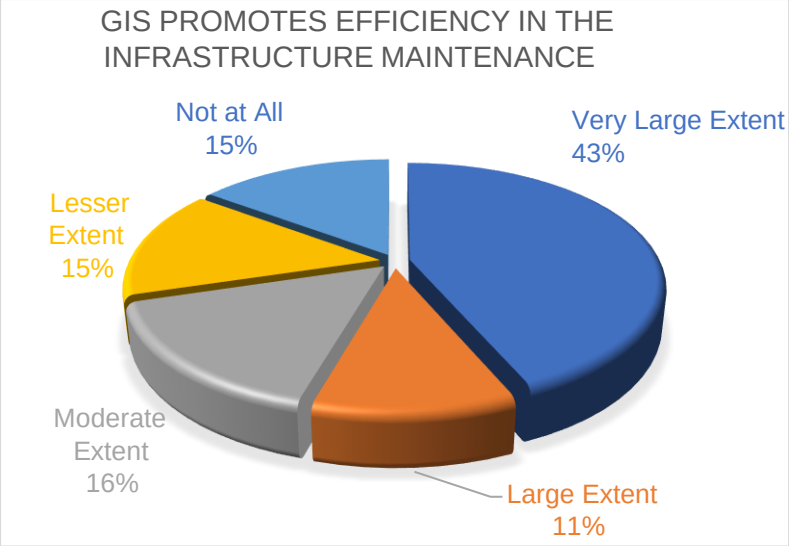


Figure 0.26: GIS promotes efficiency in the scheduling of maintenance by tracking the task and personnel.

The study findings shown in Figure 4.5-7 above indicate that the majority of the respondents agreed that the GIS system does help to improve maintenance efficiency by scheduling the infrastructure maintenance needed to improve the service delivery.

4.5.8 GIS capacity to assimilate disparate sources of data into one common picture

An average of two out of five (2/5) study respondents indicated that the GIS does have capacity to integrated different types of data into a common picture.

Respondents = Rate - 1 Very large extent	**36%**
Respondents = Rate - 2 Large extent	**22%**
Respondents = Rate - 3 Moderate Extent	**15%**
Respondents = Rate - 4 Lesser extent	**13%**
Respondents = Rate - 5 Not all	**12%**

In terms of percentage, only 70% of the respondents use GIS capacity to assimilate disparate information into one common picture

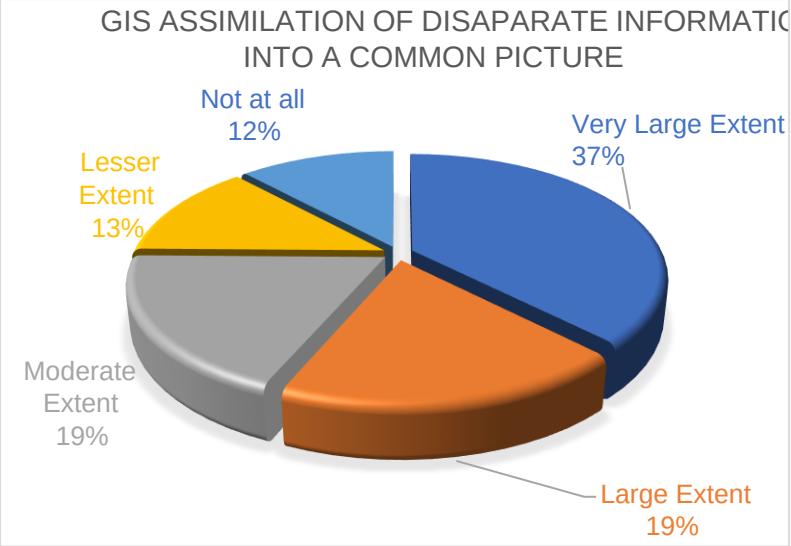


Figure 0.27: GIS capacity to assimilate disparate sources of data into one common picture

The study findings shown in Figure 4.5-8 above indicate that the majority of the study respondents agreed to a very large extent that the GIS system does help to improve the maintenance efficiency by scheduling of the infrastructure maintenance needed to improve Sekhukhune District Municipality's service delivery.

4.5.9 Extent of GIS ô s assistance with the reduction of water losses in Sekhukhune District Municipality

An average of two out of five (2/5) study respondents indicated that the GIS is helping the Sekhukhune District Municipality and its departments or units to reduce water losses in Sekhukhune District Municipality.

Respondents = Rate - 1 Very large extent	38%
Respondents = Rate - 2 Large extent	19%
Respondents = Rate - 3 Moderate Extent	19%
Respondents = Rate - 4 Lesser extent	13%
Respondents = Rate - 5 Not at all	12%

In terms of percentage, only 80% of the respondents agreed to a very large extent that the GIS can provide a solution that will reduce Sekhukhune District Municipality's water losses.

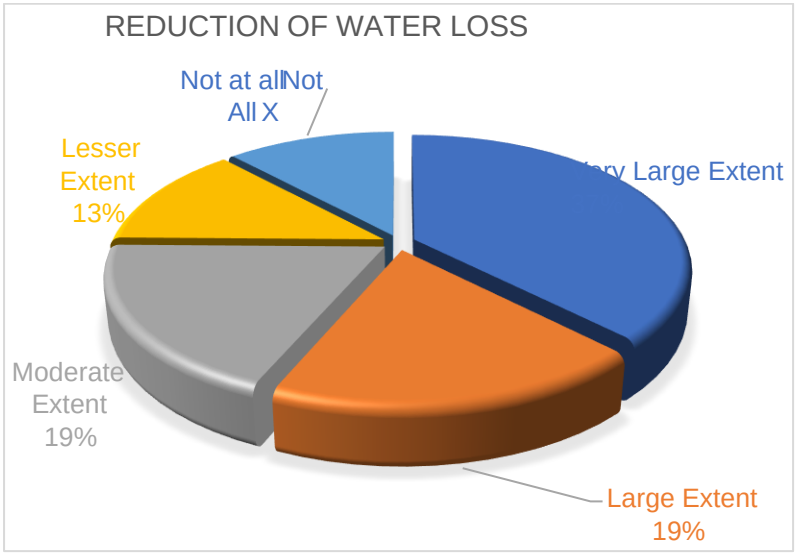


Figure 0.28: Extent of GIS assistance with the reduction of water losses in Sekhukhune District Municipality

The study findings shown in figure 4.5-9 above indicate that officials, particularly those from the infrastructure water services and finance departments, strongly believe that the implementation of GIS in Sekhukhune District Municipality can assist them to deal with water losses and, thus, improve the municipal revenues stream.

4.5.10 Being informed about GIS and its benefits in order to address service delivery

Three out of five (3/5) of the study respondents indicated that they are well informed about the GIS and its benefits for addressing services delivery challenges within Sekhukhune District Municipality.

Respondents = Rate - 1 Very large extent	31%
Respondents = Rate - 2 Large extent	9%
Respondents = Rate - 3 Moderate Extent	31%
Respondents = Rate - 4 Lesser extent	16%
Respondents = Rate - 5 Not at all	14%

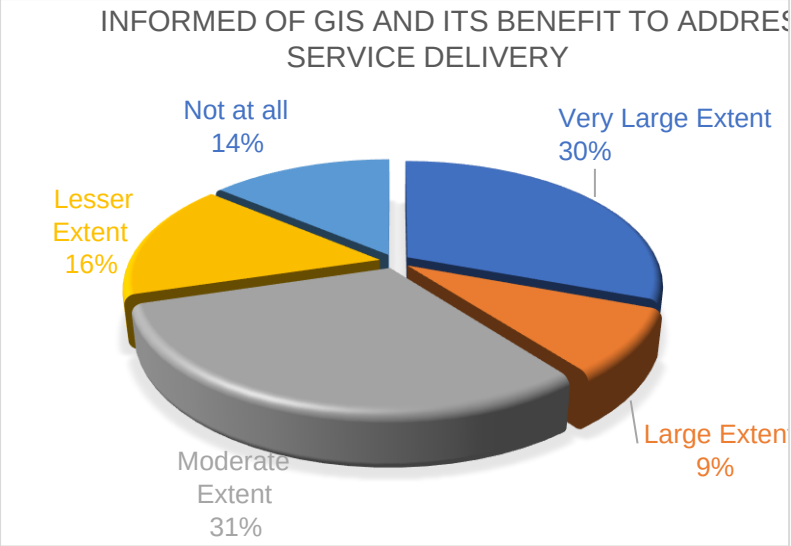


Figure 0.29: Officials being informed of GIS and its benefits to address service delivery

In terms of percentage, only 70 % of the respondents agreed on a moderate to a very large extent that the GIS can provide a solution to service delivery within the Sekhukhune District Municipality and, in particular, in the infrastructure water services department's operation and maintenance of water infrastructure, to reduce water losses which, in turn, will decrease revenue loss.

4.5.11 Does the GIS make it easier for you to perform your daily activities?

Three out of five (3/5) study respondents agreed that GIS will make it easier for them to perform their daily work activities particularly in the Planning and Development and Infrastructure water services departments.

Respondents = Rate - 1 Very large extent	33%
Respondents = Rate - 2 Large extent	19%
Respondents = Rate - 3 Moderate Extent	13%
Respondents = Rate - 4 Lesser extent	19%
Respondents = Rate - 5 Not at all	17%

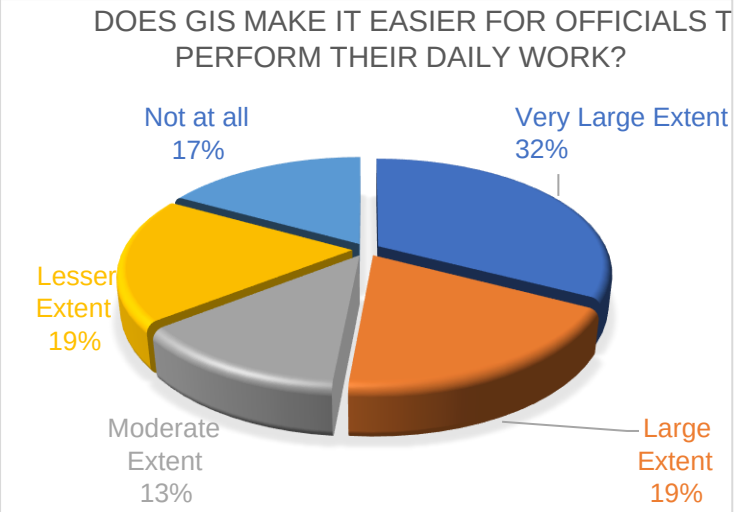


Figure 0.30: GIS makes it easier for you to perform your daily activities

In terms of percentage, a combined 70% of the respondents agreed from moderately to a very large extent that the GIS can make it easier for Sekhukhune District Municipality's officials to perform their daily activities.

4.5.12 The interest within the Sekhukhune District Municipality to build or enhance the GIS capacity in its employees

Three out of five (3/5) study respondents agreed to disagree that Sekhukhune District Municipality has interest in enhancing the GIS capacity within the municipality.

Respondents = Rate - 1 Very large extent	13%
Respondents = Rate - 2 Large extent	6%
Respondents = Rate - 3 Moderate Extent	32%
Respondents = Rate - 4 Lesser extent	39%
Respondents = Rate - 5 Not at all	11%

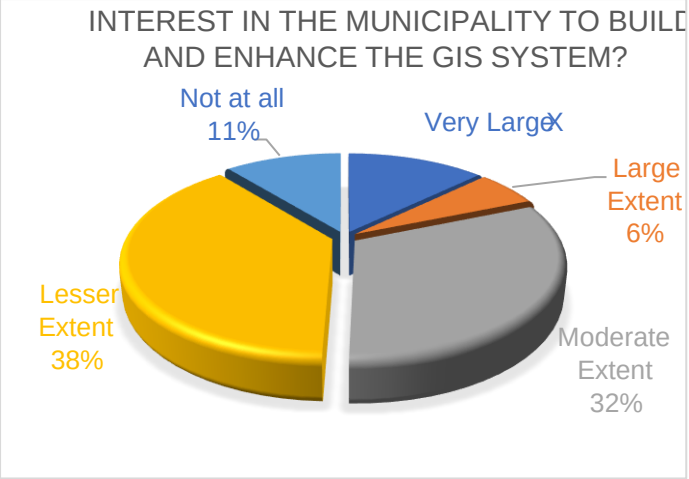


Figure 0.31: GIS makes it easier for you to perform your daily activities

In terms of percentage, only 50% of the study respondents agree to disagree that SEKHUKHUNE DISTRICT MUNICIPALITY has a plan to enhance and capacitate the municipal officials with GIS skills.

4.5.13 Completeness of integration of Sekhukhune District Municipality information?

An average of four out of five (4/5) study respondents rated the completeness of information integration within Sekhukhune District Municipality.

Respondents = Rate - 1 Very large extent	0%
Respondents = Rate - 2 Large extent	9%
Respondents = Rate - 3 Moderate Extent	24%
Respondents = Rate - 4 Lesser extent	40%
Respondents = Rate - 5 Not at all	26%

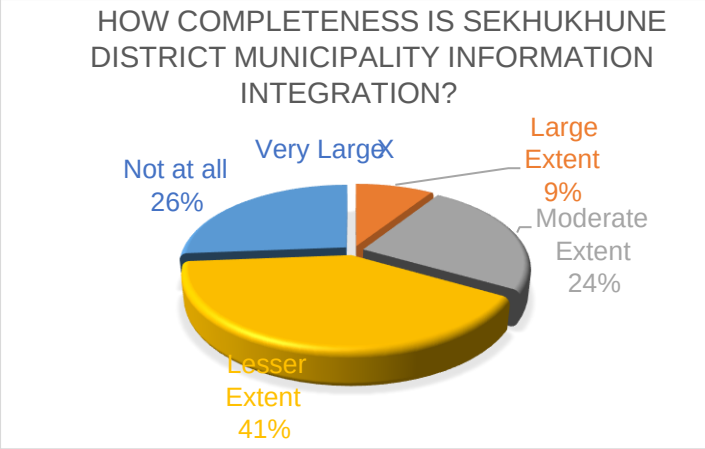


Figure 0.32: Completeness of Sekhukhune District Municipality information integration

In terms of percentage, 90% of the study respondents rated Sekhukhune District Municipality completeness of the information integration at a lesser extent while 10% believed the information is adequately integrated.

4.6 DATA ANALYSIS AND INTERPRETATION USING THE STATISTICAL TECHNIQUES

Data is organised and summarised to promote an understanding of the data characteristics, Pietersen and Maree in Petzer (2010:79) indicate that by means of descriptive statistics. This section presents the responses obtained from the study participants for Section C. The researcher has grouped the questions of Section C according to the response scale used in the questionnaire – all the questions related to e.g. Yes, No as a group, and Very Large Extent, Large Extent, Moderate Extent, Lesser Extent, Not At All as a group.

The tables 4.6-1 obtained from the study participants for Section C of the questionnaire. The data for the responses will be summarised with percentages (%), mean, standard deviation and also missing in percentage (%).

Table 4-0.9: Frequency and Descriptive Statistics for Section C

		Accessibility of information?	Up-date of Geo-data Info?	Quality of municipality information?	Department/units use of GIS system to make decision?	GIS assisting IWS providing solutions of infra challenges?	GIS promotes efficiency in scheduling maintenance such as, scheduling, tracking, task and personnel?	GIS capacity to assimlate disaparate sources of data into one common pic of operation?	Extent of GIS assist with reduction of water losses in SEKHUKHUNE DISTRICT MUNICIPALITY?	Well informed of GIS and its benefit to address poor service delivery?	GIS system making it easier to perform daily activities?	SEKHUKHUNE DISTRICT MUNICIPALITY interest to build and enhance GIS system?	Completeness of integration of SEKHUKHUNE DISTRICT MUNICIPALITY information?
N	Valid	92	94	91	94	94	94	91	94	94	94	94	94
	Missing	2	0	3	0	0	0	3	0	0	0	0	0
Mean		3.48	3.57	3.60	3.37	2.41	2.44	2.38	2.43	2.72	2.66	3.27	3.82
Std. Deviation		**1.053**	**1.187**	**0.941**	**1.466**	**1.589**	**1.528**	**1.405**	**1.403**	**1.410**	**1.499**	**1.138**	**0.927**

4.7 DATA ANALYSIS AND INTERPRETATION: COMPARISON BETWEEN SECTIONS A, B AND C.

This study will test the impact of the biographic information (personal data) from Section A variables on the participants' responses. The biographical data variables are examined to determine their influence on the respondents' perceptions regarding infrastructure management using GIS in Sekhukhune District Municipality to improve service delivery (Section C). Although there are seven variables in Section A, for the purpose of this study the researcher will only focus on Section A (Gender test) and Section B (GIS training offer) The following statistical techniques were conducted namely:

- **Reliability test** – To measure the internal consistence using the **Cronbach's alpha coefficient** and effect size.
- **Inferential Statistics** – for all variables in Section A (Gender) and Section B (GIS training offer). The **T- test** and **Anovs analysis** technique were used.

In the researcher's opinion the remaining variables which were not used in the data analysis and interpretation do not have an impact on the study. Based on the nature of the study, the research responses should only be impacted by the socio-economic factors. The biographic variables such as gender, population group, and age group do not necessarily impact on how implementation of the GIS system within the municipality improves the infrastructure management. In fact, personal information such as education, might demonstrate respondents' knowledge of GIS and the operation skills required, and their position level in the organisation, in terms of accessing the GIS information, unit and department – the GIS integrates various geo-referenced information and can be used specifically for spatial planning and infrastructure mapping.

For the researcher to determine any statistically significant differences between the response groups using the questionnaires in Section C, the following variables were considered: Gender- section A and certain questions in Section C – GIS training offer. The responses were compared for each of the aforementioned questions in Section A and all questions in Section C. The researcher will focus on the practical significance of the relationship between variables as indicated by the Cronbach's alpha coefficient (r value) and effect size.

4.7.1 Reliability Test

- **Cronbach's Alpha**

Cronbach's Alpha is a measurement of internal consistency which indicates how closely related a set of items are as group and as a measure of scale reliability. (Bruin, 2016) indicates that high value for alpha does not mean the measure is unidimensional. He further explains that Cronbach's Alpha is not a statistical test but rather a coefficient of reliability or consistency measure.

Note: Reliability coefficient of 0.70 or higher is considered 'acceptable' in most social science research situations (Bruin, 2016).

Table 4-0.10: Reliability test using the Cronbach's Alpha coefficient of Section A

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
0.732	0.727	13

The alpha coefficient for Section A was found to be 0.727, which is greater than 0.70, suggesting that the items have a relatively high internal consistency (Sullivan & Feinn, 2012).

4.7.2 Inferential Statistics

Inferential statistics for specific variables in Section A and Section B were tested using the **T- test** and **ANOVA** analysis technique namely:

- Gender – Section A
- GIS training offer – Section C

In order to understand what the statistics want to tell researchers, initially tests or analyses look at statistical significance, which indicates to researchers that there is a correlation or a difference, depending on the purpose of the test. Statistical significance further allows researchers to say how sure they are that, what they see in the sample, they will also see in the population. For this situation they use p-values, the cut-off is 0, 05, thus if p≤0,05, there is a 95% chance of finding something relevant in the population. However, since the sample

is not random, researchers cannot generalise the results, so all p-values are reported for the sake of being incomplete.

Á T- Test

A t-test is commonly used to determine whether the mean of a population significantly differs from a specific value (called the hypothesized mean) or from the mean of another population (Trochim, 2018). To determine whether the difference is statistically significant, the t-test calculates a t-value. (The p-value is obtained directly from this t-value.)

Table 4-0.11: T - test for Gender using the Levene's test

Independent Samples Test											
		Levene's Test for Equality of Variances		T-test for Equality of Means							
									95% Confidence Interval of the Difference		
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper	
Factor	Equal variances assumed	0.512	0.476	0.796	92	0.428	0.11655	0.14647	-0.17435	0.40745	
	Equal variances not assumed			0.835	57.033	0.407	0.11655	0.13954	-0.16286	0.39596	

The Levene's test for gender was used to test for constant variances and the p-values (Sig 2 tailed) = 0.428 > 0.05, if P-value is found to be greater than 0.05 then null hypothesis is retained and the results are not statistically significant.

Table 4-0.12: Effect size for Gender

Group Statistics						
Gender		N	Mean	Std. Deviation	Std. Error Mean	Effect size
Factor	1	28	3,1154	0,59529	0,11250	
	2	66	2,9988	0,67062	0,08255	0,17

The effect size measures the practical significance using the standard difference between the mean of two populations, which is the difference between the two means divided by the estimate for standard deviation.

According to Sullivan & Feinn (2012) Table 4.7-4 below displays the standardised measure of effect size.

Table 4-0.13: Common Effect Size Indices

Index	Description[b]	Effect Size	Comments
Between groups			
Cohen's *d*[a]	$d = M_1 - M_2 / s$ $M_1 - M_2$ is the difference between the group means (M); s is the standard deviation of either group	Small 0.2 Medium 0.5 Large 0.8 Very large 1.3	Can be used at planning stage to find the sample size required for sufficient power for your study
Odds ratio (OR)	Group 1 odds of outcome / Group 2 odds of outcome If OR = 1, the odds of outcome are equally likely in both groups	Small 1.5 Medium 2 Large 3	For binary outcome variables Compares odds of outcome occurring from one intervention vs another
Relative risk or risk ratio (RR)	Ratio of probability of outcome in group 1 vs group 2; If RR = 1, the outcome is equally probable in both groups	Small 2 Medium 3 Large 4	Compares probabilities of outcome occurring from one intervention to another
Measures of association			
Pearson's *r* correlation	Range, −1 to 1	Small ±0.2 Medium ±0.5 Large ± 0.8	Measures the degree of linear relationship between two quantitative variables
r^2 coefficient of determination	Range, 0 to 1; Usually expressed as percent	Small 0.04 Medium 0.25 Large 0.64	Proportion of variance in one variable explained by the other

[a] Adapted from Ferguson et al.[9]
[b] Based on Soper.[7]

Thus, the effect size indicated in Table 3 (Table 4.7-4) above was found to be r – value (0.17) 0.17 is found between 0.13 – 0.25 resulting in a medium effect size.

- **ANOVA Analysis of Variance**

ANOVA of variance is used when comparing three or more groups on one variable. There are two ANOVA methods (Bruin, 2016):

- **One-way ANOVA**
- **Factorial ANOVA**

Table 4-0.14: Test of Homogeneity of Variances

Test of Homogeneity of Variances					
		Levene Statistic	df1	df2	Sig.
Factor	Based on Mean	2,286	2	89	0,108
	Based on Median	2,006	2	89	0,141
	Based on Median and with adjusted df	2,006	2	82,344	0,141
	Based on trimmed mean	2,239	2	89	0,112

The P-value (sig) = 0.108 > 0.05, p-value is greater than 0.05, null hypothesis retained which means that the result is not statistically significant. Consequently, because the results are not statistically significant, analysis and interpretation revealed no significant difference between groups (Bruin, 2016).

Table 4-0.15: ANOVA Variance Analysis

Factor					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0,500	2	0,250	0,578	0,563
Within Groups	38,513	89	0,433		
Total	39,013	91			

P value = 0.563 < 0,5, meaning there is no statistical significance between the group. There is no practical significant relationship, as the effect size is small and there is no real effect between Section A (Position level) and Section C.

4.7.3 Inter-Item Correlations Matrix

Inter-Item Correlation Matrix (a way of analysing the internal consistency reliability) was performed for this study. It is the measure used if individual questions on a test or questionnaire consistently obtain appropriate results. The various items that are meant to measure the same idea or general construct are checked to see if they obtained a similar score (Trochim, 2018).

Table 4..7-8: Inter-Item Correlation and Cronbach's Alpha coefficient between a set of Section C group questionnaires (Assessing infrastructure management by applying GIS in the Sekhukhune District Municipality.

Table 4-0.16: Item - Statistics

Item Statistics			
	Mean	Std. Deviation	N
Effectiveness of existing information distribution?	3.40	0.885	86
Accessibility of information?	3.44	1.047	86
Up-date of Geo-data Info?	3.56	1.204	86
Quality of municipality information?	3.64	0.957	86

Department/units use of GIS system to make decision?	3.41	1.434	86
GIS assisting IWS providing solutions of infra challenges?	2.50	1.614	86
GIS promotes efficiency in scheduling maintenance such as, scheduling, tracking, task and personnel?	2.57	1.530	86
GIS capacity to assimilate disparate sources of data into one common pic of operation?	2.47	1.403	86
Extent of GIS assistance with reduction of water losses in SEKHUKHUNE DISTRICT MUNICIPALITY?	2.52	1.420	86
Well informed of GIS and its benefits to address service delivery?	2.71	1.430	86
GIS making it easier to perform daily activities?	2.69	1.513	86
SEKHUKHUNE DISTRICT MUNICIPALITY's interest to build and enhance GIS system?	3.37	1.041	86
Completeness of integration of the SEKHUKHUNE DISTRICT MUNICIPALITY information?	3.81	0.901	86

Table 4-0.17: Inter-Item Correlation Matrix

Item-Total Statistics					
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Effectiveness of existing information distribution?	36.69	62.312	0.215	0.603	0.729
Accessibility of information?	36.64	56.798	0.520	0.699	0.700
Up-date of Geo-data Info?	36.52	66.511	-0.095	0.786	0.763
Quality of municipality information?	36.44	62.579	0.172	0.516	0.733
Department/units' use of GIS to make decision?	36.67	66.105	-0.088	0.651	0.771
GIS assisting IWS by providing solutions of infra challenges?	37.58	53.987	0.401	0.731	0.710
GIS promotes efficient in scheduling maintenance, such as, scheduling, tracking, task and personnel?	37.51	51.876	0.539	0.935	0.689
GIS capacity to assimilate disparate sources of data into one common pic of operation?	37.62	52.427	0.576	0.921	0.685
Extent of GIS's assist with reduction of water losses in Sekhukhune District Municipality?	37.56	52.438	0.566	0.861	0.686
Well informed of GIS and its benefit to address service delivery?	37.37	49.319	0.734	0.744	0.661
GIS system making it easier to perform daily activities?	37.40	51.983	0.542	0.789	0.689
Sekhukhune District Municipality interest to build and enhance GIS?	36.71	59.385	0.351	0.519	0.717
Completeness of integration of the Sekhukhune District Municipality information?	36.27	62.834	0.172	0.232	0.732

The alpha coefficient for the four items depicted in Table 4.7-8 above is 0.839, suggesting that the items have relatively high internal consistency. (Note that a reliability coefficient of .70 or higher is considered ‘acceptable’ in most social science research situations.)

3. 4.5 CHAPTER OUTLINE

This study chose the quantitative research methodology, thus hand-delivering a set of questionnaires to participants was used as the data collection technique. The collected data was then analysed using the frequency and descriptive statistical analyses, the reliability test was conducted using statistical techniques such as T-test- using Levenne p(value) method, Cronbach's Alpha and Inter-Item Correlation Coefficient (r) to assess the infrastructure management by applying GIS in the Sekhukhune District Municipality.

The findings delineated in this chapter indicate that the Sekhukhune District Municipality is moderately utilizing the GIS for infrastructure management. The next chapter covers the summary, conclusions and recommendations on infrastructure management by applying GIS in the Sekhukhune District Municipality.

5 CHAPTER 5

5.1 INTRODUCTION

The purpose of this chapter is to evaluate whether the objective of this study, namely that of assessing the effectiveness of infrastructure management (IM) by applying the Geographical Information System (GIS) within the Sekhukhune District Municipality (SDM), has been achieved or not. The chapter covers a discussion of the findings of this study as related to the findings outlined in the literature review (recorded in Chapter Two above) and participants' responses to the questionnaires (recorded in Chapter Four above). This chapter also offers a summary of this research study, together with the conclusions drawn and the recommendations made for enhancing infrastructure management by applying the GIS in SDM, as well as the suggested areas for further research based on the research objectives.

This chapter will cover the following aspect:

- Á The study overviews,
- Á Literature review findings,
- Á Empirical research outcomes,
- Á The objective of the research outcomes,
- Á Conclusions and
- Á Recommendations.

5.2 `OVERVIEWS OF THE STUDY

This study intends to provide information on how the SDM manages infrastructure by applying the GIS in order to improve the efficiency of its service delivery. The study conducted an empirical study in order to establish how effectively South African Municipalities have utilised GIS tools to implement and monitor free basic service delivery. The study also sought to measure the benefits of utilising a GIS in the operation and maintenance of water assets and improving service delivery of water supplies by reducing water interruption and curbing common water services interruptions.

5.3 CHAPTER 1

The problem statement set out in this chapter stated that "Failure in the supply of water and services delivery to communities and businesses by water utilities, such as water boards,

water service providers and municipalities, is commonly caused by a lack of both proper maintenance plans and geographic information about assets, such as conditions, locations, historical data and performances".

The primary objective of this study was to understand the status of the GIS in SDM and how effectively this municipality has utilised the GIS tools to implement and monitor free basic service delivery. The SDM has endeavoured to offer various and avenues to freely access information. The SDM moderately utilises the GIS and does not frequently update its departmental databases as well as offer updated and better-quality geo-information to staff involved in infrastructure management. The SDM has endeavoured to use the GIS to offer the residents and other stakeholders high quality updates on national and municipal information.

The secondary objective of this study was to indicate how the SDM manages infrastructure by applying the GIS.

This study found out that the SDM has not endeavoured to equip, train and empower its employees with the appropriate GIS skills for managing infrastructure effectively. As such, not all the SDM staff have the knowledge and skills necessary for ensuring the effective use of the GIS for infrastructure management. The SDM moderately use the GIS in its operations to establish or highlight the instantaneous gaps in spatial analysis, service delivery and/or the consolidation of service-delivery components. Throughout the infrastructure or construction development process, SDM's officials from other departments/units do to some extent utilise the GIS to swiftly and efficiently access data, thereby decreasing the time required to probe or search for important information. The SDM's officials use the GIS mapping to develop stronger communication and collaboration processes between the SDM's employees and infrastructure management teams.

5.4 **CHAPTER 2**

This chapter focused mainly on providing knowledge and insight on the effectiveness of infrastructure management by various institutions, through the application of the GIS system in local government as a tool for enhancing infrastructure management. The results of this literature review indicate that in infrastructure management, the preferred standard for effective GIS utilisation entails developing and applying a GIS strategy to service delivery

issues as well as providing staff and stakeholders with access to up-to-date spatial data and continuously developing their GIS skills.

5.5 CHAPTER 3

This chapter outlined the methodology of the research employed in this research study and also includes in-depth discussions of the three (3) phases used in the research process.

The study gathered data from employees of the SDM, which is situated in Limpopo Province, South Africa. Out of the projected one hundred (100) targeted respondents employed by the SDM, only ninety-five study participants completed and returned the provided questionnaire, resulting in a 95% response rate. Five respondents (5%) could not complete the questionnaires and, therefore, they were not subjected to data analysis. The 95% rate of response is an acceptable representation of the total population and adequate for the conclusions reached in this study.

With regard to the demographical aspects of the respondents, the study established that SDM has a fair representation of male and female employees. This study indicates that SDM makes an equal effort to retain both male and female employees. The SDM, considers fair representation to be the appropriate strategy for guaranteeing the enhancement of the general employee and municipality productivity, as well as the effective management of infrastructure by applying the GIS.

5.6 CHAPTER 4

This study chose the quantitative research methodology and a set of questionnaires that were hand delivered to the participants was used as the data collection technique. The data was then analysed using frequency and descriptive statistical analyses, and a reliability test was conducted using statistical techniques, such as T-test- using Levenne p(value) method, Cronbach's Alpha and Inter-Item Correlation Coefficient (r) to assess the infrastructure management by applying the GIS in the SDM.

The findings set out in this chapter indicated that the SDMis moderately utilizing the GIS for infrastructure management.

The next chapter (Chapter Five) covers the summary, conclusions and recommendations on infrastructure management by applying GIS in the SDM. The results from the empirical

research described in Chapter Four also showed that the SDM did not implement GIS fully nor does it regularly update its geo-data information and this deficiency results in data integrity deteriorating, for example billing statements for the services rendered by the SDM might be addressed and/or sent to wrong consumer.

5.7 EMPIRICAL RESEARCH AND LITERATURE REVIEW FINDINGS

Á **The status of geographic information system (GIS) in Sekhukhune District Municipality (SDM).**

- **Knowledge of geographical information system (GIS) in Sekhukhune District Municipality (SDM):** the findings indicate that 92% of SDM's staff have knowledge of the GIS. Such knowledge of the GIS's capabilities and the available spatial information has made the SDM more responsible in terms of the development and growth of GIS in South Africa. The results of this collaborate Schoeman (2018:32)'s claim that both the national and provincial governments in South Africa are growing their knowledge of the existing spatial information and practical capabilities of GIS. Today, the SDM plays a significant role in the offering of basic geospatial information structures. Spatial knowledge within these service levels and positions, including the water pipes' capacities and distance from the residential areas or standpipe points, makes it easier for the SDM's employees to calculate land parcel layouts, as well as the residential units in the municipality's developmental areas (refer to Figure 4.3-1).

-

  The results in this study are supported by Da Cruz, Tavares, Marques, Jorge and de Sousa (2016:893)'s claims that the calculation and knowledge of such positions of service using the GIS make it easy for the municipalities to deliver efficient public services and accurately estimate expenses (refer to chapter 2, 2.4.1).

- **Geographical information system (GIS) training offer:** the study findings listed herein establish that the 83% of SDM's departments have endeavoured to train, equip and empower its employees with GIS knowledge and skills. This figure demonstrates that to eradicate the differences in the SDM's departments and accomplish a comparable GIS experience level, the SDM's GIS strategy includes the continuous training of specialised GIS personnel. Only 13% of the participating respondents

agreed that they had been offered GIS training and the majority of these were from the Planning and Local Economic Development Department (refer to Figure 4.3-2).

Such efforts and strategies by the SDM are in line with Gumbo (2019) and Musakwa (2017:208)'s pleas for the development and implementation of a National Qualifications Framework and GIS strategy that details the guidelines and principles for apprentice achievement, as well as recognition of national GIS knowledge and skills (refer to chapter 2, 2.4.3).

- **Positive contribution of geographical information system (GIS):** according to the findings detailed herein, the GIS can positively contribute to SDM's operations, including the integration of infrastructure planning arrangements and the GIS to assist the SDM's infrastructure planners in identifying the isolated planning regions or those areas where the SDM's is out of synchronisation. The results of this study prove that the GIS can positively contributed to SDM's operations by establishing or highlighting the immediate gaps in service delivery, spatial analysis or amalgamation of service delivery components. To some degree the SDM has been able to identify the quality and extent of service delivery by successfully using the GIS to compare and consolidate its infrastructure master plans, the SDF, as well as its planning priorities (refer to Figure 4.3-3).

  The study results above confirm Silent, Ndivhuwo and Tondani (2018:14)'s conclusions that the descriptive rewards for such infrastructure consolidation are comprehensive accounts of every location in the municipality including human, economic, physical and social settings as well as the areas prioritised for public works, service delivery, as well as improvement of the residential infrastructure (refer to chapter 2, 2.4.4).

- **Ease of work:** the study findings also maintain that the GIS system integration in the SDM can contribute to officials productivity of its officials by making information access quick and easy across all the departments and outside stakeholders. The GIS has assisted the SDM workforce to professionally and swiftly access data throughout all the municipal departments and the construction (infrastructure) development process. As such, GIS has reduced both the time and expense the SDM

dedicates to searching for important material. Such transparencies and reductions in risk have led to the SDM registering improved returns on investment (refer to Figure 4.3-4).

In the literature review, Windapo and Moghayedi (2018:254) stated that besides reducing the time dedicated to pursuing the required data, the quick and easy access of data during the infrastructure development projects significantly increases efficiency. It is such measures that result in better investment returns for both local and national governments. The wide-ranging data collaboration amongst infrastructure developers and the SDM is an outcome of the GIS enabling improved working results for the SDM (refer to chapter 2, 2.2.1).

- **Access of GIS referenced information:** according to the study findings delineated herein, 62% of the SDM's agreed to having access to the GIS and GIS-referenced data. The GIS software and user-friendly interface of SDM have allowed technical and non-technical users to have easy access to the analytical abilities of the GIS although they do not necessarily understand the software's complex commands (refer to Figure 4.3-5).

  According to the SDM's Planning and Development Report on the status of GIS, there is limited municipal Geo-data (refer to chapter 2, Table 2.3-1).

  The study results are supported by Yamahaki and Frynas (2016:527) research that indicates that the development, application and management of GIS technologies are helping municipalities management, and organisations to solve institutional challenges (refer to chapter 2, 2.3.1).

- **Reference information key to the municipal unit:** the recorded study findings also suggested that the 79% of the SDM's officials believe that the Geo-reference information is key to the effective management of their department (refer to figure 4.3-6).

  Section 5 of South Africa's 2003 Spatial Data Infrastructure Act advocates for municipalities to function as the major tier enabling regional and district-wide cooperation and coordination in the planning and development of integrated GIS strategies across South Africa (refer to chapter 2, 2.1.6).

- **Integrity and Quality of information:** 93% of the study respondents agreed that the quality of information and data integrity would improve if all the municipal information was available spatially on the GIS – orientation and resolution. Nevertheless, the majority of the study respondents indicated that the SDM's GIS's data and arrangements did not contain discrepancies in regard to infrastructure displacements, GIS orientation and resolution, (refer to Figure 4.3-7). Such mixed opinions established that data quality and integrity are central pillars to GIS application. It is, therefore, necessary that South Africa's municipalities, including SDM, offer the necessary reliable data to allow the users of the GIS to make meaningful deductions or conclusions. The participants categorized the quality of the spatial information at SDM as precise, complete, consistent and accurate when applying the municipality's GIS.

  The above results are in line with Baloyi, Mokgalaka, Green and Mans (2017:183)'s findings that GIS must guarantee the sharing of quality spatial information as well as cooperative scrutiny by the different departments within the municipality (refer to chapter 2, 2.4).

- **Financial improvement if all information was centralized:** the study results established that the centralization of information using GIS can help SDM improve its financial status. The research respondents attributed the improvement in SDM's finances to the GIS's capacity to amalgamate and collaborate data from the different departments (refer to Figure 4.3-8).

  The findings of this study agree with Grabowski and Chang (2019:2)'s claim that the application of the GIS entails the integration of ERP (Enterprise resource planning), health and financial systems, as well as other management software on infrastructure maintenance and management as a means for solving complex municipality complications, improving and streamlining revenue or tax collections and worker productivity.

- **Poor assets management impact on services delivery:** the delineated study findings established that, due to the constant base or location of the SDM's assets, the most effective tool for logging such assets is the GIS mapping of such assets, using the capacities of the GIS, (refer to Figure 4.3-9). Notwithstanding the fact that

knowing the location of the SDM's assets results in the municipality developing less than a simple geographical inventory, mapping using the GIS's capacities, offers the SDM additional layers of asset information together with more chances for a more profound analysis of data.

The use of the GIS mapping by the SDM has similarly developed stronger communication and collaboration processes between the SDM personnel. The reason for such continual and successful communication and collaboration processes is the fact that there is easy and free access of the SDM's databases through several devices that permit the stakeholders' participation in theSDM's decision-making process.

- **Infrastructure assets linked on the GIS system:** 71% of the study respondents indicated that while the data and GIS department at the SDM has the capacity to offer professional advice on the GIS openings that can increasingly influence on the SDM's corporate roles, the SDM currently finds it hard to provide an equal level of tactical support for the municipality as a whole because its infrastructure executive does not offer a strong backing to either the municipality's data and GIS team or its property and infrastructure management department (refer to Figure 4.3-10). The SDM's department in charge of GIS is not well represented at the municipality's management level. In addition, the SDM's Property and Infrastructure Management Department remains focused primarily on asset management; and has a limited knowledge of GIS application. As such, this department is unaware of the the GIS's capacity to enhance service delivery. The SDM should must appreciate that guidance by GIS specialists comes with certain high-level sector considerations centred around the directions of the national and local governments.

  The study findings set out above agree with those of Snyders and Landman (2018:284) and Musakwa (2017:208) that state that national and local municipalities should realise that GIS have become the fundamental tool to decision-making processes in many municipal sectors including health, social welfare and, lately, crime (refer to chapter 2, 2.1.6).

Á 5.3.2 Objective of the study findings: Implementation of GIS by Sekhukhune District Municipality

This study also sought to evaluate to certain extent the rate at which the SDM has implemented a GIS and the following related activities:

- ¶ GIS related training workshops,
- ¶ Investigated the status of GIS within the SDM,
- ¶ Utilised the GIS to improve service delivery within the SDM,
- ¶ Integrated the various departments and their access to spatial information,
- ¶ Improved the accessibility of information such as billing, spatial layout and water reticulation etc.

The study findings demonstrated that the SDM to some extent **utilizes the GIS** to effectively dispense information. In regard to information accessibility, many of the study respondents indicated that information is easily accessible because, the SDM has endeavoured to use the GIS as a means of providing stakeholders with effective accessibility of information (refer to chapter 4, section B 4.5.1-4.5.13).

The findings of this research study have established that there is a high rate of **accessibility to information at the SDM**. The SDM is moderately using various the GIS approaches to enable the effective accessibility of information by and between its stakeholders (refer to Figure 4.5-2). The findings described above collaborate those of Adeyemi, Markus, Gbolahan and Edeki (2018:1445) who state that access to GIS's large-scale data together with the open-source structures of GIS mapping have resulted in GIS becoming prominent in South Africa (refer to chapter 2, 2.1.6).

Regarding, **the quality and updating of Geo-data Information:** the study findings indicate that SDM d does not regularly update its geo-data information and, thus, often offers outdated and low-quality geo-statistics. However, the SDM has endeavoured to use the GIS to offer its stakeholders a higher quality of municipality information and services (refer to Figure 4.5-2).

The use of GIS Sekhukhune District Municipality: the study findings show that some of the SDM's departments or units are currently applying the GIS moderately in their departments to reach mandated decisions. The study confirms that few of the respondents agreed that the GIS is helping the SDM and its departments or units to solve infrastructure challenges (refer to Figure 4.5-5).

Does the GIS assist the Infrastructure water service department to provide solutions to infrastructure management challenges: the study findings show that 60% of the study respondents agreed that the GIS provided a solution to infrastructure challenges in SDM

and its departments or units that have not fully utilized the GIS to solve the region's infrastructure challenges (refer to Figure 4.5-6).

The study findings are supported by the claims of Hamandawana & Zhou (2018:688) that South Africa's municipalities, such as the Noncore LM, utilize GIS in the form of updated registers of assets and layouts of infrastructure, to identify high-risk regions and address the issues resulting from infrastructure-maintenance backlogs. In order for municipalities to identify the serious issues affecting service delivery, there must be consolidation and use of information integration approaches from several systems of management into layered representations of infrastructure service delivery. Such a process assists municipalities in the prioritization of high-risk areas for maintenance planning (refer to chapter 2, 2.5).

Extent to which GIS is assisting the SDM with water losses reductions: few of the study's respondents believed that the GIS is helping the SDMand its departments or units to reduce water losses. The findings of this study established that the SDM and its infrastructure departments have not utilized fully the GIS) to decrease the water losses in the municipality (refer to Figure 4.5-9).

The study findings echo Esterhuizen, De Jager and Jezewski (2019:87)'s conclusions that the water agencies of municipalities must take advantage of the GIS to solve water loss challenges, including proper billing, budgeting, and computerising of water maintenance and management systems. For Chari, Hamandawana and Zhou (2018:681), the GIS allows municipalities and their water maintenance departments to easily handle all joint information and give fast responses, including mapping all water maintenance reports on the GIS in order to assess the key trends in water disruptions and study the municipality's entire water arrangements (refer to chapter 2, 2.3.1).

Completeness of the Sekhukhune District Municipality information integration: the study found that the current district information is not integrated, accordingly the district GIS uses objectives across various departments and units (refer to Figure 4.5-9). The SDM's data inventory lists indicate that currently certain information is unavailable across all the departments. Such data needs to be converted into shapefile so that it can be stored in the SDM's GIS which is located currently at the Planning and Development Department (refer to Chapter 2,Table 3.2-1).

Being informed about GIS and its benefits in order to address service delivery: 70 % of the study respondents agreed that the GIS can provide solutions to current problems facing the SDM particularly in the infrastructure water services department's operation and maintenance of water infrastructure in order to reduce water losses which would then decrease revenue loss (refer to Figure 4.5-10).

Adeyemi, Markus, Gbolahan and Edeki (2018:1445) and Snyders & Landman (2018:284). contend that the accessibility to large-scale datasets on population, and the spread of the open source systems of desktop mapping in 1990, has led to the development and implementation of GIS technologies becoming the fastest-growing sector in South Africa. South Africa's private sector, semi-privatised institutions, national and local governments presently are applying GIS technologies in research, business and planning. Even though South Africa is still technologically less advanced than the more developed nations, it has benefitted from the development of GIS. The preliminary application of GIS technologies in South Africa was in the environmental field from where it spread to the larger municipalities and areas that finally recognised the value of using GIS for managing information and infrastructure. The use of GIS technologies has availed South Africa of a vital connection to the progress that has been made in global spatial mapping technologies. GIS has become the pivotal tool to decision-making in several municipal sectors such as social welfare, health and, lately, crime (refer to Chapter 2, 2.1.6).

The interest within the district to build or enhance the GIS capacity in its employees: 50% of the study respondents agree to disagree that the SDM has plans to capacitate and, thus, enhance the municipal officials with GIS skills.

Such findings are in accordance with the findings of Musakwa (2017:208) that South Africa has a limited number of people who possess GIS skills. Although some government employees have received training in GIS skills, once trained, many leave public service for 'greener pastures' in the private sector. The issuing of contracts could help to restrict the loss of such trained people. There is a need for municipal and government Human Resource Ddepartments to identify the gap in skills development, in terms of the National Qualifications Framework (NQF)'s skills development and implementation goals for setting guidelines and principles for the registration of learner achievement, national knowledge and skills recognition (refer to Chapter 2, 2.5.3).

GIS ability to integrate various source of data into one common picture: 70% of the study respondents agree that GIS has the ability to integrate various sources of data into a single source which, in turn, will allow easier and quicker sharing of information both within the municipality and with outside stakeholders. This improvement can assist the SDM to make an informed decision regarding when to deploy the infrastructure investment.

This study's findings support those of Chirikure *et al*. (2017:513) which define the GIS as an arrangement designed to store, capture, manipulate, manage, present and analyse all geographical information, and those Liu, Lin, Wang, Peng & Hong (2016:768) which state that a GIS is a framework for managing, analysing and gathering data. Entrenched within the geography science, the GIS integrates several data types, analyses spatial locations and organizes information layers into needed visualizations by way of 3D scenes and maps (Mayunga,2018:1).

With the above unique capabilities, a GIS provides deeper insight into information, including patterns, situations and relationships, all of which help its users to make smarter and better decisions. According to Mathey (2018:164), GIS are software programs that capture geographic information by manipulating, analysing and viewing the user's needs or desires, with the intent of analysing geographic or spatial information for both a possible and a given purpose. National Geographic (2019) defines GIS as the computer arrangement intended to capture, check, display and store data linked to the earth's surface positions. GIS technologies include collaborating and understanding apparatuses and are, thus, applicable to the science of geography.. A GIS is a computer-based tool which allows the capturing, storing, editing, displaying, analysing and printing of geographically referenced data. A GIS helps individuals and institutions reach a mutual goal − namely to attain actionable intelligences from the entire data types. Boyda *et al*. (2019:2) maintain that GIS technologies integrate with financial and Enterprise Resource Planning (ERP) systems, project management software, the leading computer programs on work-order management and maintenance in order to improve productivity, as well as to assist in solving complex organizational or municipal problems (refer to Chapter 2, 2.1.2.1).

5.8 RECOMMENDATIONS

5.8.1 To the administration and management of S

The SDM has an organized approach to initiating conducting, maintaining and reporting on the municipality's infrastructure inventory. Such a practice and use of GIS by the municipality can make it easy to manage infrastructure and appreciate the existing facilities and their location. Therefore, it is recommended that the SDMfurther develops a method to enable it to: a) measure its capability of space in order to realize the requirements of its existing infrastructure programmes, (b) assess the present operational expenses of its GIS facilities and (c) begin early planning for future infrastructure needs using GIS.

The SDM needs to secure a GIS that can allow the compiling of infrastructure plans, facilitate the connection and accessing of general and database mapping layers through a standard browser. Such an intranet-centred GIS will ease the designing, development, visualization and reportage on the utilization of space across the municipality. The GIS should have the capacity to connect municipality plans and maps to the national database as well as to provide charting and reporting capabilities,

To achieve maximum benefits from the GIS in their infrastructure management and planning, South African municipalities need to train GIS users as part of their educational curriculums, add some value to the municipalities' process of infrastructure planning by holding digital or online development plans. South African municipalities should organise public participation, provide easy public access to information such as infrastructure plans. Throughout the area re-planning or planning processses, the municipalities should also increase the pace of the digitization of prevailing infrastructure maps as well as the development plans, to allow full utilization of GIS strengths in the planning of such areas. Good asset or infrastructure information is the foundation for effective water infrastructure issues and infrastructure management. By managing, maintaining and storing accurate infrastructure or asset accounts that are sharable throughout the municipality, the GIS helps the municipalities to manage asset and infrastructure information. Most infrastructure departments in all municipalities will possess complete data on infrastructure or an asset which is kept in numerous systems. The GIS GIS stores the infrastructure or asset's location and provides connectivity to the rest of the basic assets and private attributes.

SDM should focus on integration amongst all the numerous systems that store information about an asset so that data about its location, connectivity, status, history and description can be easily accessed. A GIS has information that can be shared across an entire utility

and used to support many of its information needs. Municipalities can significantly increase their return in a GIS investment by sharing it within the entire utility and using it to support its many business patterns.

The study findings described herein establish that South African municipalities should employ GIS' spatial analysis and infrastructure data to support the municipality's infrastructure planning needs. The SDM's water and infrastructure departments remain involved in both long-term and short-term infrastructure planning. For the short-term infrastructure planning, the South African municipalities should use the GIS for the creation and optimization of proactive and reactive infrastructure management. The SDM's long-term infrastructure planning should involve the use of GIS analysis, infrastructure and performance data to appreciate how the municipality's infrastructure department is performing. Such data will also be useful for the determination of where the municipality can best devote its capital assets to exploit the value of the department's infrastructure and assets.

In providing the field infrastructure personnel with applications and maps that are easy to use and quickly updated, the GIS will support the field mobility business pattern of the SDM. GIS will also allow the municipality's field personnel to gather GIS information and revert it to the municipality's central workplace thus benefitting the SDM's infrastructure commercial patterns, including asset performance, personnel and department networks, as well as the way the patterns impact one another. With access to the GIS, infrastructure managers will have the capacity to reach conclusions based on up-to-date and accurate information.

Access to GIS will enable the municipality's departments to have interactive maps of the existing state of infrastructure operations which will provide an easy approach for collecting information from numerous arrangements and displaying it using a joint application. Stakeholder engagement and the infrastructure commercial patterns of municipalities should include sharing data with the municipality's stakeholders such as elected administrators, customers, regulatory initiatives and other organisations in the area of public service. The current tendency is for the water and infrastructure departments of South African municipalities to engage actively with the stakeholders using publicly assessible technological programs to provide accurate evidence that reduces data misinterpretation. Municipalities and their infrastructure management departments should use the GIS to create interactive and static maps for the stakeholders. GIS map applications comprise

coordination of capital projects, the client self-service, management of service interruption and infrastructure performance transparency.

5.9 CONCLUSION

The findings of this study manifest that the GIS is an important apparatus that South African municipalities, such as the SDM can use to plan for their regions, especially with regard to infrastructure management preparation and optimum decision-making. There are GIS governance aspects suitable for municipality needs and requirements in the formation of maps which have the capacity to produce custom-made services to meet users' needs.

The extended connections of GIS applications delineated in this study illustrate the value of GIS as an instrument for planning development and the management of infrastructure in South African municipalities. As continually expressed in this study, GIS can advance the power and quality of infrastructure management analysis, guide the municipality's development initiatives and help infrastructure planners to mitigate measures as well as implement responsible actions and emergency preparedness.

This study also indicated that as much as the use of GIS seems enticing, it is not an appropriate tool for planning all municipality applications. Much of the advantage of GIS' automated system remains short of the required standard, especially with regard to its capacity to undertake repetitive spatial calculations.

The PC-grounded GIS is the recommended choice for the SDM's infrastructure planning department or team. The municipality's infrastructure planners should choose carefully between the scores of accessible software capabilities and hardware conformations, compatibility, and prices that are currently available. Hardware configuration has to remain affordable and simple due to the technical and financial constraints that exist in South Africa and, particularly, within the SDM. For the IBM-companionable systems, such as the standard central processing unit (CPU), the high-resolution monitors, small digitizers and colour printers, should be effective for the needs of the SDM's infrastructure planning department because they can be purchased easily at affordable prices across the Sekhukhune region. The more sophisticated GIS equipment requires more technically-endowed operational skills and will be harder to repair and maintain locally. Also, the

additional capabilities are not necessary for the current needs of SDM's infrastructure planning department.

Added GIS capability, in particular, the cartographic-quality output area, is not necessary for the SDM. Although the less expensive versions of the GIS may lack some features, they possess functional competences that are adequate to meet the elementary requirements of infrastructure management. It would be advisable for the SDM to start with the purchase and implementation of some of these modest systems and later to expand them according to the municipality's needs. Institutional support and data availability are aspects of the municipality's consideration in the application of GIS. For any GIS to be effective, the SDM must resolve any existing difficulties and problems relating to obtaining information from organizations with the different mandates. To ensure the GIS's dynamic nature, the SDM must establish good cooperation for information sharing between entities involved in infrastructure management and the generation, use and collection of data. When it comes to the translation of GIS outcomes into the planning mandates or guidelines, the SDM's infrastructure planners should give consideration to the economic, political and other extents of the region. Due to people's comprehensive knowledge of their local area, the generalization of information of local needs and its inclusion in the GIS often results in conflicts.

The rest of the SDM's stakeholders or utilities will also benefit from the GIS' vertical and horizontal assets. These vertical assets of the municipality currently remain excluded from the GIS because the SDM's service points, such as the pump stations, remain represented by one single point in the GIS. Therefore, instead of employing reactive rather than proactive approaches, the SDM's pump stations would benefit by using the GIS to track the risk factor of the service's vertical asset. As the pump stations or infrastructure ages, maintenance becomes expensive and frequent, in addition, their dependability deteriorates to the point of compromise in the overall SMD's infrastructure operations. To decrease such costs, the SDM should establish an asset management programme which is a GIS based to monitor its infrastructure assets such as pump stations, pipelines, valves, treatment plants or buildings and practice proactive maintenance.

For the infrastructure machinery and water bodies of municipalities such as the SDM, the GIS offers proactive upkeep; that is, the SDM can prepare and plan for when any water asset is projected to fail. Similarly, it will be prepared for the cost of repairing or replacing

the asset when its life expectancy is coming to an end. The SDM can use the GIS to plan proactive infrastructure maintenance, prolong the life expectancy of the asset and even save the municipality future costs on a replacement. The GIS' regular provision of new data to the municipality's water department is an indication of the assets (such as pump stations) which previously may have been held as not critical but now require inspection or assessment to determine if they are close to failure. GIS offers municipalities such as SDM a healthier understanding of the spatial impact and level of criticality of the region's water facilities. GIS offers an improved understanding of the reasons why certain water facilities must take preference over others in regard to replacement or repairs. To prolong their life expectancy, the GIS also proposes the machinery to be prioritized when investigating the need for infrastructure or mechanical conditioning and repairs.

This study's findings indicated that for infrastructure management to succeed in South African municipalities, there is a need for cooperation at all level of municipal administration. It also demonstrates that the infrastructure department personnel and the municipality's decision-makers should be convinced of the GIS' advantages, including the fact that the provision of cost-effective, timely and accurate information remains crucial for the maintenance and support of the municipality's infrastructure management programme. This study similarly suggests that spatial features are important for the infrastructure management of the municipality's vertical assets. The municipality's attitude towards its assets influences the general score on asset risks. The GIS' spatial relations and geographic locations typically identify, associate or reference infrastructure information. As such, spatial data and GIS analysis play an important part in the municipality's asset and infrastructure management. For instance, the water machinery's spatial location influences both its score, together with those of other related machinery, on the risk factor.

5.10 SUGGESTIONS FOR FURTHER STUDIES

The results of this study suggest that before focusing on the application of GIS, future research or studies should focus on the impact of infrastructure and asset management on the municipality's culture. This study also suggests that future studies compare practices of infrastructure or asset management in public and private organisations that use GIS. Future studies could similarly concentrate on international GIS application and infrastructure or asset management because nations have different infrastructure or asset management and GIS implementation. While it will be difficult to produce a catalogue that intersects national GIS information, future studies should attempt to collect data from several countries in order to produce an assortment of pragmatic results.

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ANNEXURE 1

NORTH WEST UNIVESRITY

Dear participant

In this survey you will be asked to participate in a survey concerning **Assessing the infrastructure management by applying Geographical Information System in Sekhukhune District Municipality.** Your participation is voluntary and please be assured that records of your participation and any data collected will be anonymous and the responses will only be presented in the aggregate form. This survey will take you 15 minutes to complete. Thank you for your participation. (**Please answer ALL of the following questions in the order presented. Do not leave any question unanswered. Thank you for your cooperation!)**

SECTION A

1. Your gender

Male	Female

2. Your age category?

18 – 29	30 - 39	40 – 49	50 – 59	60 - 69	Older than 70

3. What is your highest educational qualification?

Grade 1-7	Grade 8-11	Matric	Post matric

If other, please specify.....

4. Level of your position?

a) Lower management	b) Middle Management	c) Senior Management

5. Which department does your unit falls within in the municipality? Indicate one

Infrastructure Services	Finance	Planning and Economic development	Community Services	Municipal manager office

6. How long are you employed at the municipality in years?

a) Less than 1 year	b) 1 – 10	c) 11 - 20	d) 21 - 30	e) Over 30

7. Population Group

African	White	Coloured	Asian

SECTION B

a) A GIS is a computer system designed to capture, store, manipulate, analyse, manage, and present a variety of spatial and geographical data. This computer system is very important especially when it comes to planning. GIS is functions can be integrated and used by all the units/departments within Sekhukhune District municipality for various reasons.

8. Do you know what is **Geographic information system (GIS)**?

Yes	No

9. Have the municipality offer any form of GIS training since your employment?

Yes	No

10. Do you think that GIS could positively contribute to the work of municipality?

Yes	No

11. Do you think your work will be made easier if all information was spatially mapped or fed into GIS system?

Yes	No

12. Does your department/ unit have access to the geographically-referenced information (GIS)?

Yes	No

13. Are the geographically referenced information key to your Department/Section?

Yes	No

14. Do you think the quality and data integrity would improve if all information was spatially?

Yes	No

15. Do you think municipality financial integrity would improve if all information and datasets was stored centrally and made available between different departments?

Yes	No

16. Does poor municipal assets management impact negatively on the service delivery?

Yes	No

17. Is the municipality infrastructures assets such as water bulk and reticulation, reservoirs, pump station, treatment plant, boreholes, water meters etc linked on the GIS system?

Yes	No

SECTION C

a) Objectives/ Aims for introducing GIS technology or applications were set in the Sekhukhune District Municipality.

Note: Please rate the following question in scale of 1 - 5, where 1 –very large extent, 2-Large extent, 3-Moderate extent, 4- lesser extent, 5-Not at all by tick one answer)

18. How ***effective*** is the existing method of dissemination of the information by Sekhukhune District Municipality (on Scale of 1 -5)?

1	2	3	4	5

19. How would you rate the ***accessibility*** of the information in the Sekhukhune District Municipality?

1	2	3	4	5

20. Does the Sekhukhune District ***Geo-data information*** get updated regularly?

1	2	3	4	5

21. How would you rate the ***quality*** of these ***municipality information***?

1	2	3	4	5

22. Does your department/unit make use of the GIS system when ***making decision*** such as capital projects, spatial planning, land use zoning, developments and budgeting etc?

1	2	3	4	5

23. GIS can assist infrastructure professionals by providing solutions for infrastructure issues?

1	2	3	4	5

24. GIS promotes efficient scheduling and tracking equipment, task and personnel?

1	2	3	4	5

25. GIS has the capacity to assimilate disparate source of data into one common picture of operation?

1	2	3	4	5

26. To what extent do you think the GIS will assist with the reduction of the water losses in the municipality?

1	2	3	4	5

27. I am well informed about GIS and its benefits in order to address services delivery?

1	2	3	4	5

28. Will the GIS system make it easier for you to perform your daily activities?

1	2	3	4	5

29. Is there interest within the municipality to build or enhance GIS capacity in its employees?

1	2	3	4	5

30. . GIS is used as ***central data centre*** to ***integrate*** the *information* across units/departments within Sekhukhune District municipality, how would you rate the ***completeness of integration*** of the Sekhukhune District Municipality information?

1	2	3	4	5

Thank you very much for your friendly co-operation in completing this questionnaires

ANNEXURE 2

DECLARATION OF LANGUAGE EDITING

This is to certify that the mini-dissertation entitled

Assessing the infrastructure management by applying the Geographical Information System in Sekhukhune District Municipality

presented by **Mr F Phaswana, Student No: 28282736**

Supervisor: Dr Gino Alberts

in partial fulfilment of the requirements for
the Master's in Business Administration degree
at the NWU School of Business and Governance, North-West University

has been subjected to an English language edit by

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ANNEXURE 3