CHALLENGES OF REACTIVE MAINTENANCE IN WATER INFRASTRUCTURE AT LEPELLE NORTHERN WATER IN LIMPOPO PROVINCE

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Student number:

A thesis submitted in partial fulfilment of the requirements for the degree

Master of Philosophy in Integrated Water Management

at IIEMSA

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March 2022

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ABSTRACT

Lepelle Northern Water has a mandate from the Department of Water and Sanitation to provide bulk water services in Limpopo province, South Africa. Currently, high water demand outstrips the supply, and the situation requires that infrastructure be resilient to environmental challenges, demand challenges, and economic challenges. The ageing water infrastructure needs an effective maintenance strategy that can respond to high water demand. Lack of water in the areas where Lepelle Northern Water operates necessitates immediate and effective action. The maintenance management framework and maintenance strategies such as Reliability Centered maintenance give guidelines on the processes to be put in place to respond to maintenance challenges.

Stakeholders and communities are raising concerns about the interruption of water services while others showed their frustrations by vandalising the water system. This research investigated challenges and the impact of reactive maintenance on water supply. The study further established solutions to minimise maintenance challenges as stakeholders are affected by infrastructure failures.

The study adopted a qualitative approach to collect data to address the aims and objectives of the study. Participants in the study were purposively selected and they were sourced from the four regions where Lepelle Northern Water operates. Structured interviews and questionnaires were used as the main data collection tools. Interviews were used to establish the understanding of participants on the strategic role of maintenance and their experience of the challenges of reactive maintenance.

An important finding from the study highlights that a preventive maintenance strategy was the initial strategy adopted by Lepelle Northern Water. From the implementation of the strategy, departments were operating in silos and not supporting each other. Due to internal working conditions and external economic developments over time, there was a shift from preventive to reactive maintenance.

A general observation was made that management had put in place Information

Technology Systems, processes, standards, and procedures but there was no integration of systems. The study further noted that stakeholders are negatively affected by reactive maintenance and the ageing infrastructure was another factor contributing to water supply interruptions. This study, therefore, proposes the adoption of a preventive maintenance strategy by Lepelle Northern Water and that the strategy is integrated with other maintenance strategies. It further recommends future research to consider covering other South African Water Boards to deepen the understanding of the challenges of reactive maintenance in the maintenance of water infrastructure.

Keywords: maintenance, reactive maintenance, preventive maintenance, maintenance strategies, water, infrastructure

DECLARATION

This thesis contains no material that has been accepted for the award of any other degree or diploma at any university or equivalent institution and, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signed____________________ Date 08/03/2022

Tshiamo Kwati

ACKNOWLEDGEMENTS

Firstly, I would like to thank the Lord Jesus Christ for giving me strength and confidence throughout this journey.

Secondly, I would like to express my deep and sincere gratitude to my research supervisor, Linda Downsborough for giving me the opportunity to do research and providing invaluable guidance throughout this programme. The inputs of Professor Bimo Nkhata are also acknowledged and much appreciated.

Special thanks to my fellow programme colleagues for being my support system and to the participants for your contribution to the completion of my thesis.

To my beloved daughter Resegofetse Kwati, I would like to express my thanks for being such a good girl when I was going through this journey.

Finally, I would like to express my special appreciation and thanks to Mr Neil Manson for the guidance and support you have given me.

DEDICATION

I dedicate this thesis to my parents, my mother Keikantsemang, my late father Goitsimodimo and my wife, Portia, and my daughters, Refilwe and Resegofetse.

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ABBREVIATIONS AND ACRONYMS

CCTV : Closed-circuit television

CMMS : Computerised Maintenance Management System

COGHSTA : The Department of Cooperative Governance, Human Settlement, and Traditional affairs

CSIR : Council for Scientific and Industrial Research South Africa

FMEA : Failure Mode and Effects Analysis

IIEMSA : The Independent Institute of Education South Africa

IT : Information Technology

KPI : Key Performance Indicator

LNW : Lepelle Northern Water

PDM : Predictive Maintenance

PFMA : Public Finance Management Act.

PPM : Planned Preventive Maintenance

RCA : Root Cause Analysis

RCM : Reliability-Centred Maintenance

SAAWU : South African Allied Workers Union

SAICE : South African Institute of Civil Engineers

SALGA : South African Local Government Association

SANDF : South African National Defence Force

SAPS : South African Police Service

SDG6 : Sustainable Development Goal 6

SOE : State-Owned Enterprise

TSU : Technical Service Unit

WSA : Water Service Authority

WTP : Water Treatment Plants

CHAPTER ONE

BACKGROUND AND INTRODUCTION

1.1 Introduction

For many years, maintenance strategies and categorisations have varied, and the strategies have contributed significantly to ensuring the efficient operation of systems (Erola et al., 2019). Scholarly papers and studies have iterated the importance of maintenance to keep infrastructure complete and operational (Oyedele, 2015). However, in recent times, the public has raised concern over the ongoing deterioration of water infrastructure that affects critical services. It is also noted that water services are key to sustainable socio-economic growth, environmental well-being, and quality of life for the global population (Mnguni, 2018). Maintenance of infrastructure does not only affect production, but it creates internal and external demand challenges. Little (2002) argues that the consequences of infrastructure failure due to lack of maintenance can cause catastrophic incidents for example when a fire could not be extinguished within a residential area due to shortage of water supply, life can be lost, or property can be damaged. The interrelationships between infrastructure and economic growth are many and complicated (Oyedele, 2015). Studies have shown that when infrastructure is constantly operated, it deteriorates over time, therefore appropriate and regular maintenance must be conducted (Rioja, 2013). Without proper maintenance, the budgets spent on maintaining infrastructure result in fruitless and wasteful expenditure.

There have been previous studies which have discussed the challenges of reactive maintenance and made suggestions to find solutions to ensure infrastructure is maintained effectively. The study by Ali et al. (2009), addressed the issues of reactive maintenance related to projects, information, and communication technology in support of the business process. This study highlights the inadequacy of reactive maintenance in projects and some actions that need to be taken to improve the process. The study indicated the following challenges with reactive maintenance:

“Poor communication between different parties, lack of knowledge sharing, and poor quality of information, which often lead to the longer time taken to fix the problem and incurs higher cost”

Another study by Linnéusson et al. (2018), did not only discuss issues of reactive maintenance but also acknowledged challenges that organisations experience in identifying a sustainable maintenance strategy that can be developed to monitor maintenance performance. This study analysed objectives of maximising availability, minimising maintenance costs, and minimising maintenance consequences costs.

The study by Jin et al. (2016), acknowledges the contribution of technology adopted by the United States (U.S) in the manufacturing sector to achieve productivity and quality targets. The authors indicate that the various maintenance strategies adopted by the manufacturers are in a sustainable state of development. They argue that a combination of reactive maintenance (RM), preventive maintenance (PM), predictive maintenance (PdM), and proactive maintenance (PaM) depends on the complexity of the machine in which the maintenance strategy is employed.

This study was carried out in Lepelle Northern Water (LNW) in the Limpopo province of South Africa. The surrounding areas are predominantly rural. Lepelle Northern Water is the main water board that operates in Limpopo province and its primary mandate from the Department of Water and Sanitation (DWS) is to provide bulk water services. Most of the Water Treatment Plants (WTP) operated by LNW are in remote areas with a lack of water reticulation services in the villages. This study highlights the challenges of reactive maintenance in water infrastructure faced by Lepelle Northern Water. The study was prompted by the need to investigate why a reactive maintenance was being followed and propose possible solutions to move from a reactive to an effective maintenance approach.

The concept of maintenance involves infrastructure condition assessment, servicing, repair, refurbishment, and replacement of system units (Zyl, 2014). When maintenance strategies, procedures, and standards are correlated in maintaining infrastructure by participants, it can improve water supply services and minimise failures. The common understanding of maintenance concepts and support by management can render the system effective and the organisation can achieve its business objectives.

The view by Segzdaite (2021), is that reactive maintenance is a short-sighted strategy that has negative results that affect production, and this statement is well supported in the present study. The intention of the study is also supported by Christiansen (2020), who indicates that a preventive maintenance strategy is considered by many organisations as a better option because of its benefits of reducing the costs of maintenance operations. These studies offer support to the approaches to be taken in dealing with the consequences of reactive maintenance and consider an alternate effective maintenance strategy that can confront the challenges of reactive maintenance which affect water supply. This is the context in which Lepelle Northern Water currently finds itself. The challenges of reactive maintenance and its effects are experienced by other water boards and municipalities in South Africa (Toxopeüs, 2019). While some investigations and recommendations have been made by the previous studies, little has been achieved to see organisations that supply water resolving the issues of infrastructure maintenance and providing uninterrupted water supply services (Toxopeüs, 2019).

This chapter comprises four sections. It provides the research issues, research aims, objectives, and the overall structure of this research thesis.

1.2 The research issue

Chapter 2 of the Constitution of the Republic of South Africa states that everyone has the right to have access to sufficient food and water (South Africa, 1996). Therefore, Lepelle Northern Water as the bulk water service provider in Limpopo province has the mandate to ensure that water infrastructure is maintained properly, and water services are delivered to the citizens of South Africa. As a result of lack of maintenance, infrastructure ages and deteriorates, and the water supply is negatively affected. The reactionary approach of maintaining infrastructure as opposed to preventive increases repair costs and reduces the functional life span of water infrastructure (Toxopeus, 2019).

Water supply disruption encourages vandalism and illegal connections to water infrastructure. When community members experience water shortages, they resort to vandalism and illegal water connections on the main water pipelines. Water utilities, especially in poor countries continue to operate with significant inefficiencies in terms of water and revenue losses. With increasing water demand and scarcity, utilities need effective strategies for optimum utilisation of available water resources (Mutikanga et al., 2011). Failure by Lepelle Northern Water to implement an effective maintenance strategy that can support the operations, results in businesses losing revenue, and the community questioning the capability of the organisation in providing essential basic services.

In terms of this study, the maintenance of water infrastructure contributes to the success of the implementation of the business objectives of Lepelle Northern Water (LNW). There is therefore a need for LNW to manage the challenges of reactive maintenance of water infrastructure to achieve its mandate of supplying uninterrupted bulk water services to surrounding communities. Reactive maintenance poses a challenge to all stakeholders because the poorly maintained water infrastructure has consequences on the lives of people and the socio-economic growth of the country. So, the key issue that LNW must address is the challenge of reactive maintenance of water infrastructure.

1.3 Purpose of the study

The purpose of this study was to explore the challenges of water infrastructure maintenance and management and recommend an effective maintenance strategy that can benefit Lepelle Northern Water in improving the supply of bulk water services. To focus in on LNW, a case study approach was adopted to try and achieve this.

Organisations adopt different maintenance strategies or even a combination of strategies to improve their services to make a profit and satisfy their customers. The services rendered by Lepelle Northern Water is considered a basic human right therefore more is expected from LNW to provide uninterrupted water services. Everyone has a right to access basic water supply and sanitation services and every water services institution is expected to ensure these rights are realised (SAHRC, 2018). Due to a variety of reasons, organisations tend to fail in maintaining the strategy that was initially adopted. According to Erola et al. (2019), a reactive maintenance strategy is traditionally adopted by organisations because it is believed to be economical but on the other hand, it increases the total cost of maintenance for more complicated and large systems, it also has a disadvantage in loss of production, long maintenance periods and it increases the risk of safety and environmental risks.

This study explored the challenges of reactive maintenance that affects the business objectives of Lepelle Northern Water (LNW) on water supply. In suggesting the solutions to address reactive maintenance challenges faced by Lepelle Northern Water, the study collected data from participants who are employees of the organisation, to assist in making recommendations.

1.4 Research aim and objectives

This study aims to explore the challenges of reactive maintenance in water infrastructure which affects bulk water supply at Lepelle Northern Water and to make recommendations for alternative approaches/strategies.

The objectives for this study were,

- To explore the challenges of reactive maintenance on water supply
- To analyse maintenance management system
- To establish an effective strategy for Lepelle Northern Water

1.5 Structure of the thesis

This thesis is organised into six chapters.

Chapter 1 provides the background and introduction to the study and explains the role of maintenance as an activity undertaken to ensure effective operations of infrastructure. It discusses the maintenance strategies, the challenges, and solutions to reactive maintenance. The chapter further introduces the research issue, the purpose of the study, research aim and objectives, and lastly presents the structure of the thesis.

Chapter 2 presents the literature review that is guided by the research topic. More specifically this chapter presents literature related to maintenance, the organisational support to maintenance as well as challenges. The final section considers some of the proposed solutions to reactive maintenance.

Chapter 3 outlines the research design and methodology that was used to collect data. The case study area, data collection methods, and data analysis techniques are clarified within this chapter, as well as ethical processes and possible limitations to the study.

Chapter 4 presents the findings of the study. Key policy and business documents from LNW were analysed and key informants were interviewed to gather the raw data.

Chapter 5 presents the discussions of the research findings around the challenges in the reactive maintenance of water infrastructure in Lepelle Northern Water.

Chapter 6 presents conclusions and recommendations. The recommendations were based on the aims and objectives of the study and directed towards Lepelle Northern Wate.,

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, the literature reviews all the aspects of water infrastructure management including maintenance, in Lepelle Northern Water. The literature review is informed by and structured by the objectives of the study. The focus point for the review of the literature was on the keywords of the study namely ‘maintenance’, ‘reactive maintenance’, ’preventive maintenance’, ‘management’ ‘water’, and ‘infrastructure’. The challenges and measures to deal with reactive maintenance are also discussed in this chapter.

According to the Department of Water and Sanitation (2018), South Africa is facing a water crisis because of insufficient water infrastructure maintenance, lack of investment, perennial droughts caused by climate change, inequalities in access to water and sanitation, deteriorating water quality, and a lack of skilled water engineers. The Department of Water and Sanitation (2018) further indicates that while there has been progress in addressing some of these challenges, issues of water supply interruption, blocked and overflowing sewers are the two main contributors to community protests and infrastructure vandalism.

Access to a regular safe water supply is a basic human right and lack of clean drinking water has a major effect on people’s health (Mello, 2003). Communities in the water supply area of Lepelle Northern Water have been experiencing water supply challenges while those with access to water are facing water leaks (Mashudu, 2022). Therefore, there is a need to come up with a solution to ensure that the water supply reaches intended users. Regular maintenance is important as it ensures that water production equipment is always operating at 100% efficiency (Krar, 2015). The support and participation of top executives and employees in the implementation of a good maintenance programme will minimise problems that can cause a shutdown of services (Krar, 2015). Maintenance ensures that the plant is functional, it achieves its design life, the plant is environmentally safe, cost-effective, and there is effective usage of resources (Galar, et al., 2017).

2.2 Maintenance

Maintenance is a combination of activities, that includes technical, administrative, and managerial, to retain the life cycle of an item or renew it to the original equipment manufacturer's specification (Márquez, 2007). Maintenance activities correct the unreliability of an engineered item (Daya et al., 2016). Similarly, Sullivan et al. (2010) agree by defining maintenance as the activity or the work of keeping something in a good normal working condition to prevent it from failing prematurely.

When businesses develop their objectives, they prioritise the maintenance of their infrastructure so that they can meet the needs and wants of the customers, and shareholders. The objectives of the organisation can include, profitability, growth, risk, and social (Márquez, 2007). Assets or infrastructure start to deteriorate as soon as they go into operation. Operational factors will then cause equipment to fail when operated beyond their design standard. Hence, issues of breakdowns, quality problems, and safety hazards start to become visible. The negative impact of these outcomes will be high operating costs, loss of profitability, and customer demand dissatisfaction. To resolve these indicated challenges, organisations need to decide on the maintenance objectives and effective maintenance strategies that need to be adopted (Muchiri et al., 2011). Therefore, in the context of this study, Lepelle Northern Water (LNW) should ensure that resources are combined so that the life cycle of infrastructure is retained or renewed and the challenges of reactive maintenance of water infrastructure are resolved.

Regular and proactive maintenance is important in increasing the service life span of equipment and reducing service disruptions. While deferring the maintenance to the coming years may be an easy option in short term, however, this creates a false economy (Ochieng and Ominde, 2020). The organisation can achieve its mandate when objectives are aligned to the performance of infrastructure maintenance. Maintenance enables an organisation to become profitable and save on operational costs. The reliability of infrastructure depends on the resources invested in it. Reliability should be built into the infrastructure even when it is costly to do so while technical and economic factors can also be a challenge. Without reliable infrastructure, maintenance can be costly (Daya et al., 2016).

Direct and indirect costs are incurred during the maintenance and repair of infrastructure. Labour, material, spares, and tools costs are regarded as direct maintenance costs while other costs can be due to breakdowns, unplanned maintenance, accidents, loss of revenue, and insurance policies. These costs are incurred by the organisation and are classified as indirect costs. As infrastructure is maintained over the years to keep it functional, the effect of ageing makes the maintenance and labour costs increase (Daya et al., 2016).

Campbell and Jardine, (2001) explain that it is challenging at times to understand the areas that need change or improvement to achieve excellence in maintenance and that there is still the same pressure today as it was in the past to ensure the availability and reliability of assets. For infrastructure to be readily available and reliable, there is a need to implement maintenance strategies that can ensure that infrastructure is resilient to environmental challenges. Infrastructure improvement or renewal will require a proper and implementable process to be in place (Campbell and Jardine, (2001).

According to Sullivan et al. (2002), the design life expectancy of most equipment requires periodic maintenance. Maintenance strategies or programmes that include, preventive maintenance, predictive maintenance, or reliability maintenance can be utilised to preserve or prolong the life expectancy of equipment. The utilisation of these strategies will prevent equipment failing prematurely.

Having discussed the role of maintenance in infrastructure, next will be the discussion on the maintenance strategies and more emphasis will be on reactive maintenance as one of the keywords of the research thesis

2.3 Maintenance management system defined

Maintenance management refers to a set of procedures for planning, organising, directing, managing, monitoring, evaluating, and reporting on maintenance activities to achieve maximum program effectiveness at the lowest possible cost. It is not a set of new technical techniques for executing maintenance jobs more effectively, but rather a method of becoming organised so that the proper actions are carried out, scheduled, and performed at the appropriate times in a cost-effective and efficient manner (Wyatt, 1989). Maintenance management is defined by Gouws and Trevelyan (2006), as the systematic management of the below-indicated elements throughout the asset's life cycle to maintain an asset's ability to perform safely:

- The asset - the plant equipment is kept in good working order.
- People - the group of people in an organisation who are active in maintenance, either directly or indirectly. Some people are very visible in the maintenance workflow process (for example, asset managers, maintenance engineers, maintenance supervisors, maintenance technicians, and plant operators), while others are less visible but equally important (for example, reliability engineers, inspectors, accountants, purchase buyers, and CMMS Administrators).
- Processes and strategies – the processes and strategies are explained as maintenance-related business processes, maintenance strategies designed to reduce maintenance costs, and maintenance engineering and analysis methodologies.
- Computerised Maintenance Management Systems (CMMS) - the CMMS is at the heart of every contemporary maintenance system, and it serves as the primary interface between, people, processes and strategies, and assets.

Anderson (1984) describes maintenance management as a process of planning, budgeting, scheduling, reporting, and analysing resources to achieve a set level of service. The author further explains that maintenance operations, creating a feature inventory, setting priorities, establishing quality, quantity, and performance standards, and compiling cost data are all part of the maintenance management planning process. Figure 2.1 illustrates the maintenance management planning process.

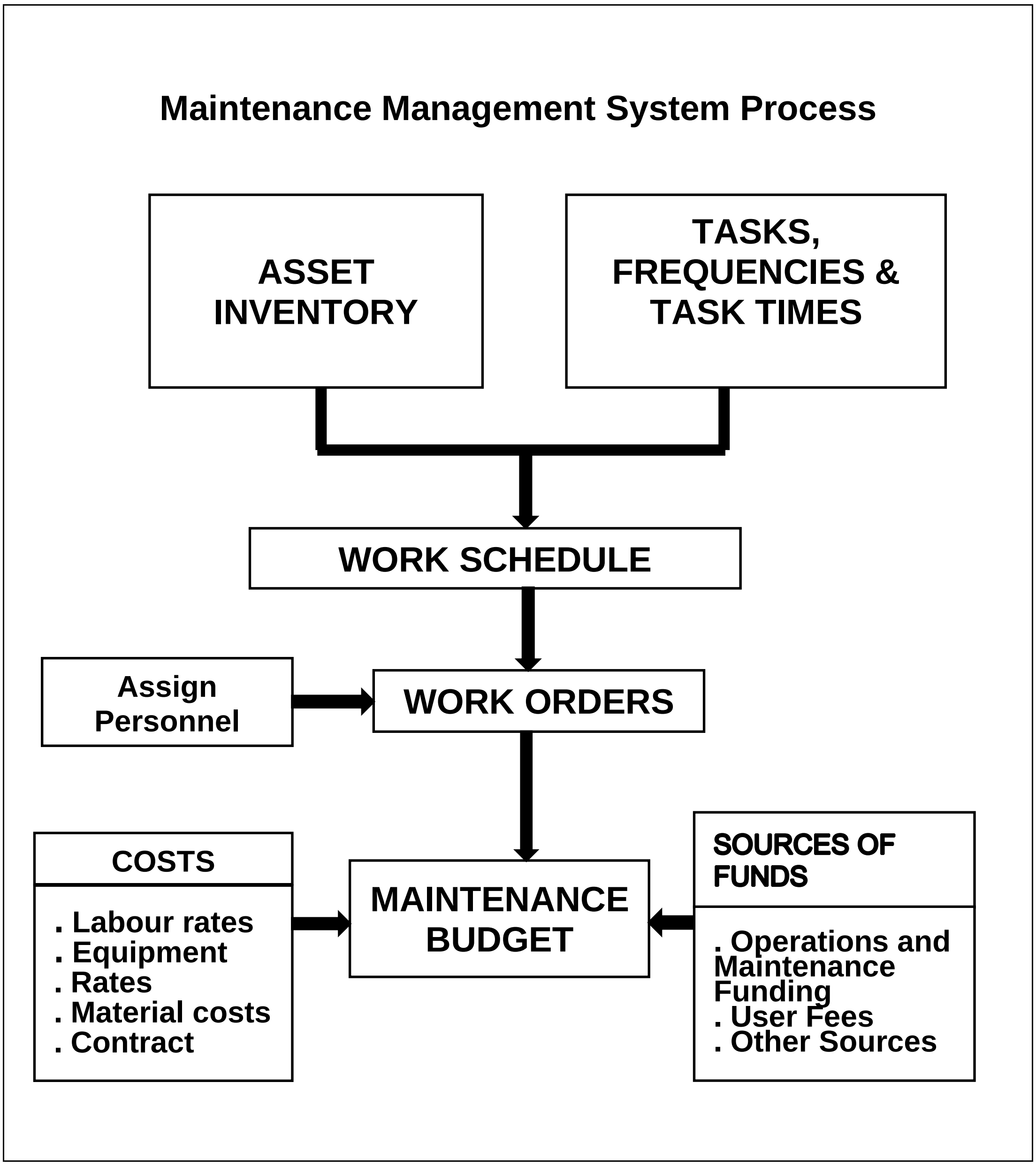

Figure 2.1: Maintenance management system process

Source: Anderson, (1984).

In addition, Márquez (2007) defines maintenance management as the management of all assets owned by a firm to increase the asset's return on investment. Marquez and Gupta (2006) define maintenance management as all management activities that determine maintenance objectives or priorities, strategies, and responsibilities, and then implement them through methods such as maintenance planning, maintenance control, and supervision, and other methods that improve the organisation's economic aspects. Figure 2.2 depicts the seven subject categories and related subject elements of the maintenance management process.

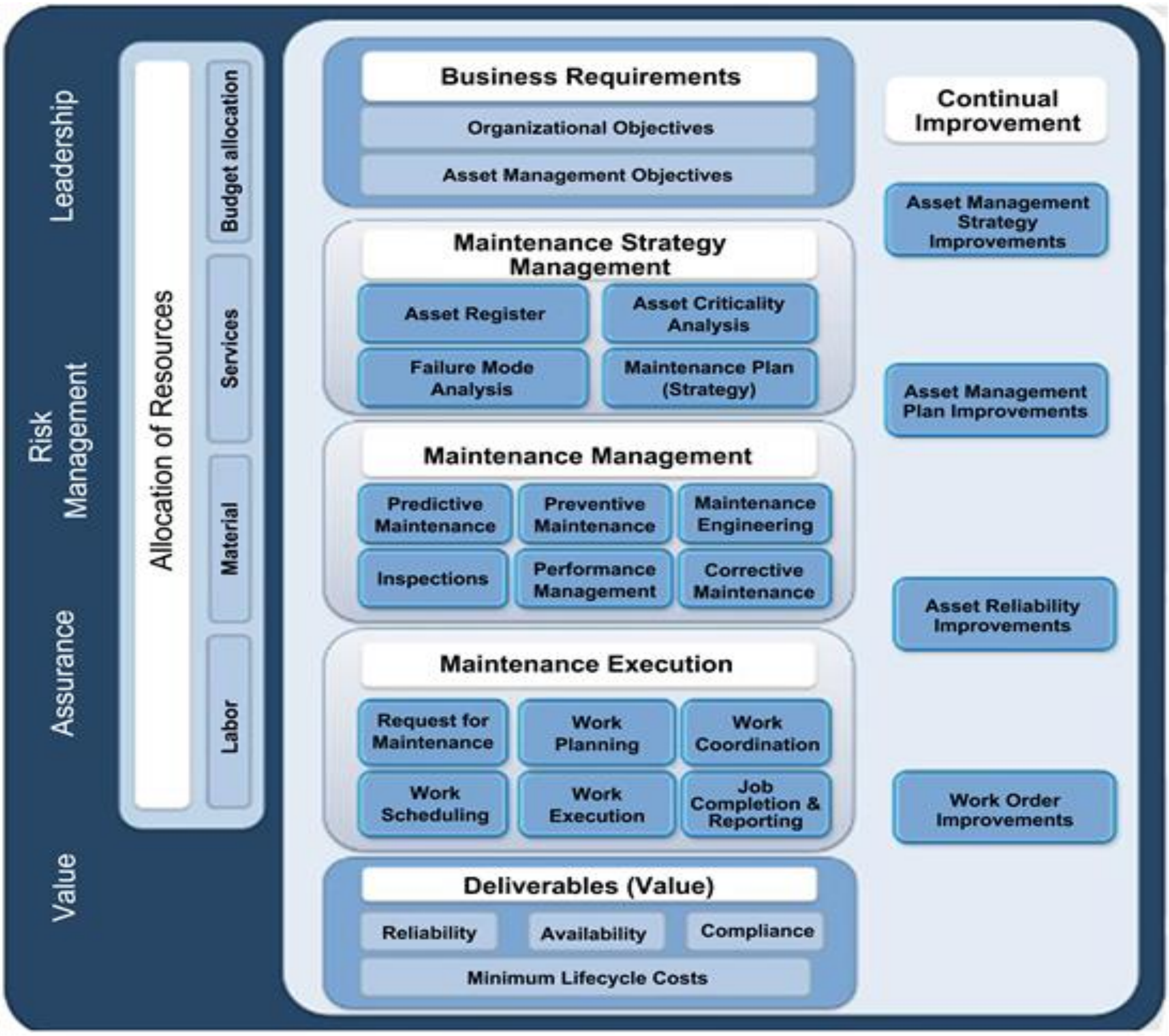

Figure 2.2 Maintenance Management Framework

Source: Keat, al et.,(2021).

2.4 Maintenance management system review

This section explores the maintenance management system as defined in the existing literature. No organisation is immune to internal and external economic factors. The fact to be considered is that no matter how well the organisation is resourced, no organisation can have a perfect maintenance and management system. Maintenance management involves making maintenance-related decisions at the strategic, tactical, and operational levels (for example, hiring trained labour, allocating resources, and scheduling resources, among other things) and then taking action to put those decisions into action (Ben et al., 2016).

A maintenance system is made up of three basic components: risk assessment, maintenance strategy selection and maintenance task interval determination. To have a safe and reliable system at a fair cost, these elements must be done optimally in the maintenance management of a plant system. Different maintenance strategies such as Reliability Centred Maintenance (RCM) are used to optimise maintenance components (Emovon et al., 2016).

2.4.1 Risk assessment

In the RCM process, risk assessment entails determining the likelihood of equipment failure and recommending a suitable maintenance strategy based on the risk assessment. Data sources, human variables, methodologies, instruments for doing the analysis, and the analyst's ability and experience are all aspects that influence the quality of the risk analysis result (Emovon et al., 2016). According to Pacaiova and Glatz (2015), in the asset management framework, there is a tool for risk assessment. The notion of risk management, in general, entails adhering to the following key steps: a) Risk analysis and risk assessment b) Object boundary determination, threats, and hazards are identified, and the likelihood and consequences are calculated. c) Probability and consequences are used to estimate risks. d) Risk assessment is conducted to determine acceptability and tolerability. According to Rimington, (1992), risk assessment allows one risk to be weighed against another to make a safe investment. Again, the underlying premise is that risk assessment can help prioritise actions because resources are limited, and various incidents must be tolerated and controlled.

2.5 Maintenance strategy selection

Various maintenance strategies can be implemented to reduce many failure modes of a plant system. Selecting the appropriate maintenance strategy for the system assists in maintaining a balance between system availability and maintenance cost. The run-to-failure, preventive, and condition-based maintenance strategies are used to determine the best strategy for each component/failure mode of the system (Emovon et al., 2016). According to Velmurugan and Dhingra (2015), in every industry, selecting a maintenance strategy for a specific equipment/system is a typical multiple criterion decision making challenge (Ahmadi et al., 2010). Authors employed analytic hierarchy processes, fuzzy analytic hierarchy processes, and other techniques to solve such problems.

2.5.1 Maintenance interval determination

According to Emovon et al., (2016), the fundamental premise for determining the interval is to strike a balance between the expense of obtaining maximum reliability and the cost of unexpected failure. Different models, such as scheduled replacement and scheduled on-condition tasks, are used to establish inspection intervals. Woohyun et al. (2009) explain that corrective maintenance (CM) and preventative maintenance (PM) are two types of maintenance and that unscheduled CM actions are designed to recover a system from a broken state to a working condition by repairing or replacing faulty components. PM, on the other hand, is a scheduled active procedure that can be used to either lessen the risk of a failure or improve the system's availability. As the PM cost rises, the CM cost falls. Because the overall cost of PM and CM actions drops first, the cost climbs as PM effort increases. There is an optimal amount of PM effort that will reduce total maintenance costs. Therefore, reduction of the entire cost is one strategy to determine optimal maintenance actions. Meng and Wang (2015) explain that to determine the best maintenance interval, the outcome is established according to a connected decision-making target. Maximisation of operational readiness; minimisation of loss, which may include integration of Preventive Maintenance (PM) spending, failure loss, and maintenance cost, among other things, are general optimal principles chosen depending on the characteristics of equipment and corresponding missions.

2.6 Benefits of an effective maintenance management system

Pacaiova and Glatz (2015) define a management system as a set of interconnected processes that improves the organisation's efficiency and effectiveness in reaching stated goals. Karaa (1989) indicates that effective maintenance offers organisations benefits if implemented correctly as indicated below:

- The organisation can keep the infrastructure intact

- Maintenance cost saving by taking the right decision on selecting the type of design, technology, and material needed at the planning stage of infrastructure construction.

- The organisation can preserve the heritage of infrastructure for future generations by implementing the correct maintenance strategy.

- Critical infrastructure like nuclear plants, national assembly complex, and airports can be protected from dilapidating prematurely (Karaa, 1989).

Effective maintenance decisions must be made within a framework that considers technical, commercial, social, and management challenges in the context of the entire business. An effective maintenance system includes decision-making approaches, models, and methodologies, as well as the ability for maintenance people to use them to keep overall production costs low and assure excellent levels of customer service. As a result, successful maintenance management requires quantitative business models that combine maintenance with other decisions, such as production, and so on (Ben et al., 2016). As the demand for services grows, infrastructure needs to be in a good state to provide uninterrupted production and services. Therefore, proper maintenance of an engineering object, including periodic in-service inspections, has a beneficial impact on the object's technical status and can significantly extend its lifetime Ben et al., (2016). Maintenance management systems need to align with company goals to support management objectives (Pacaiova and Glatz, 2015).

2.7 Maintenance strategy management

To determine the appropriate maintenance strategy for the maintenance of physical assets such as water pumps, electric motors, water main pipelines, electrical transformers, and several approaches exist in asset management. Andrawus et al. (2006) explain that total productive maintenance traces the root cause of asset failure, risk-based inspection identifies the appropriate condition monitoring method to investigate the causes of equipment failure, and reliability-centered maintenance identifies the appropriate maintenance strategy for effective equipment maintenance.

2.7.1 Reliability Centred Maintenance (RCM)

Reliability Centred Maintenance (RCM) is a philosophy that is used to determine the performance of a system so that a decision can be taken to determine the relevant and effective maintenance strategy that can be deployed on that system and ensure it performs to the required operational reliability, safety, readiness, environmental safety, and cost-effectiveness (Okwuobi et al., 2018). Organisations can utilise the Reliability Centred Maintenance (RCM) strategy to determine an effective maintenance strategy or philosophy that can enable them to maintain their infrastructure. As ageing water infrastructure can affect the supply of water services, attention needs to be paid to address the challenges of reactive maintenance by implementing an effective maintenance strategy.

Andrawus et al. (2016) point out that, to implement the RCM strategy, the organisation should ask the following questions:

- What is the function and standard of the current operating system?
- What are its functional failures?
- What causes the system to fail?
- What are the failure consequences?
- How failures can be prevented?
- What should be done to prevent failures and what should be done if there is no alternative system?

Sullivan et al. (2010) explain the hierarchy of RCM as follows the first maintenance strategy is reactive maintenance whereby equipment is allowed to run to failure, the second is preventive maintenance that is applied at predetermined time intervals in maintaining infrastructure, while the third strategy is predictive, whereby the scheduling pattern depends on the operations condition of the infrastructure. These maintenance strategies are illustrated in Figure 2.3

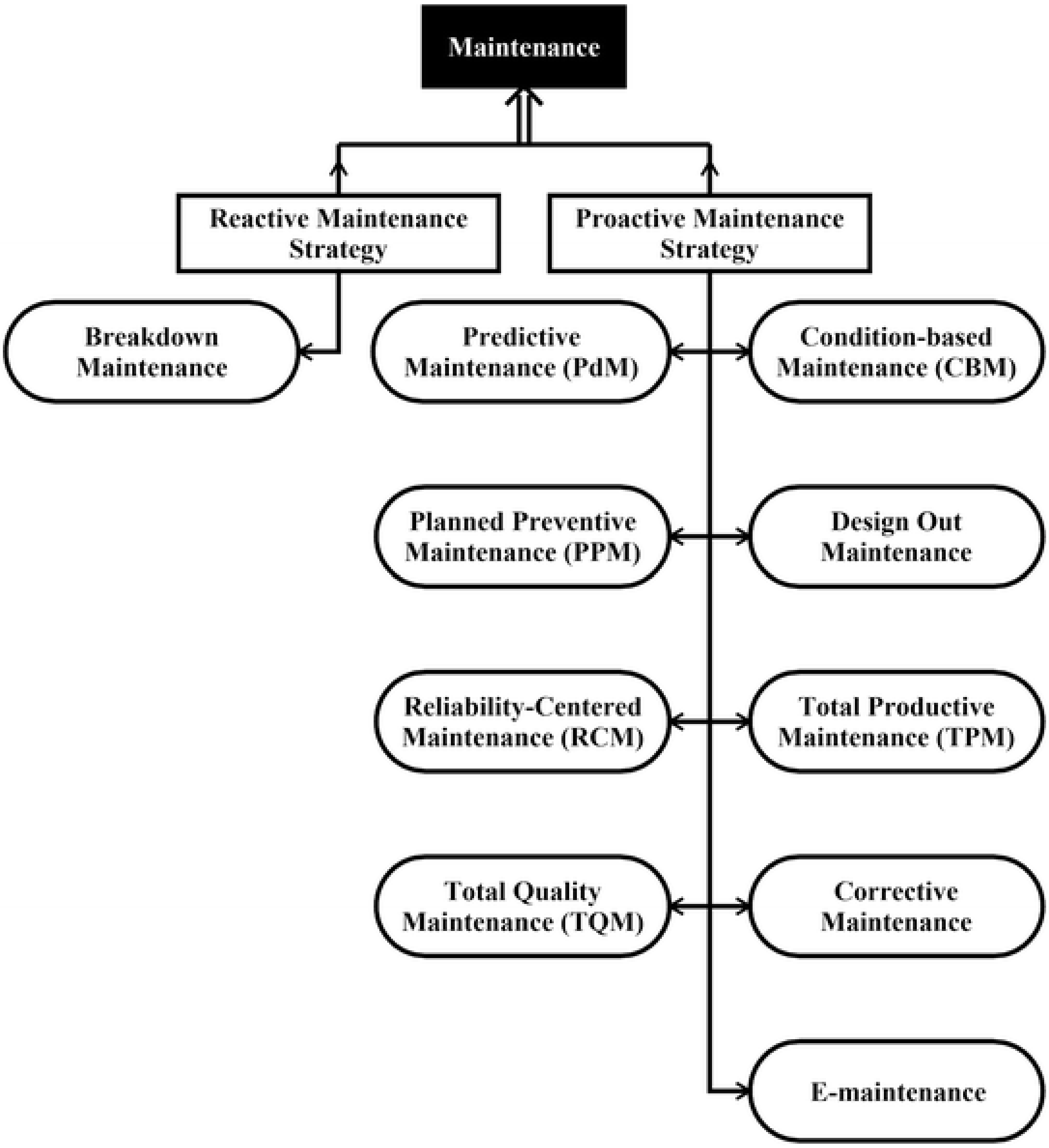

Figure 2.3: Maintenance Strategies

Source: Xing and Marwala, (2018)

Figure 2.4 indicates the three maintenance strategies and their impact on the maintenance of infrastructure.

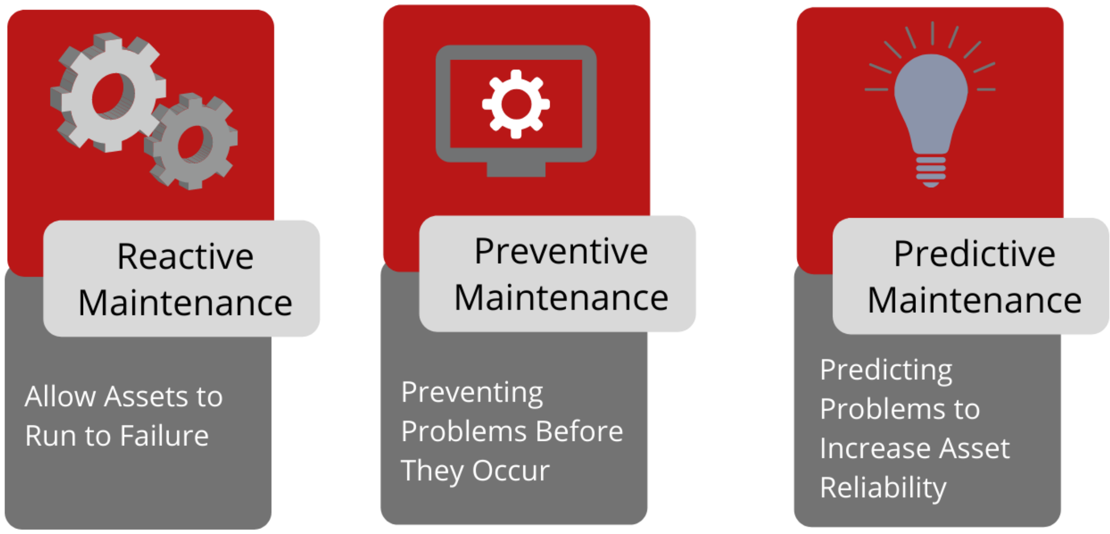

Figure 2.4: Three maintenance strategies

Source: Prometheus group, (2020)

2.7.2 Preventive maintenance

Preventive maintenance is a pre-planned activity undertaken on a time-based schedule to point out or lessen system failures before they occur intending to extend its useful life by controlling its degradation (Sullivan et al., 2002). With challenges of poor maintenance affecting the life span of infrastructure, preventive maintenance can be a solution to organisations. The preventive maintenance strategy can increase the reliability of water infrastructure. According to Mobley (2011), an approach to improving maintenance of infrastructure can be done by establishing standards in advance so that inspection or automatic detection can determine the threshold limit to give notifications before failures occur. The need for maintenance spares can be anticipated in advance and only the required spares are procured on an as-needed basis. With the implementation of preventive maintenance, organisations could reduce the inventory of their maintenance spares. Unscheduled downtime and premature failures or damages could be prevented, and reactive maintenance is reduced. Improvement in maintenance and preventive maintenance can reduce corrective maintenance.

Daya et al. (2016) explain that preventive maintenance strategies control the failure of an engineered object by taking actions in advance.

According to Levitt (2003), preventive maintenance has the following benefits,

- Increases public safety, maintenance mechanic, and operation.
- Reduces downtime while increasing uptime.
- Increases equipment availability when needed.
- Lowers operational cost.
- Allows time for equipment to be taken out of operation and for corrective maintenance to be performed.
- Reduces damage to parts of equipment.
- Reduces the period and number of repairs.
- Increases business opportunities due to customer satisfaction.
- Increases equipment expected useful life.
- Improves output quality.
- Improves output quality.
- Reduces the number of emergency breakdowns and overtime.
- Improves cash accountability
- Reduces the risk of liability.
- Reduces inventory levels and ensures better control of spare parts.

2.7.3 Predictive maintenance

Mobley (2002) defines predictive maintenance as a philosophy or attitude that is used to determine the actual operating condition of plant equipment and systems to optimise total plant operation. Water problems are aggravated by the implementation of an ineffective maintenance strategy. When problems are identified before they can cause a huge financial loss, organisations may be able to collect revenue. Predictive maintenance gives an early indication before the system or infrastructure fails. The author further explains that predictive maintenance is implemented as a maintenance management tool, a plant optimisation tool, or as a reliability tool to prevent catastrophic failures and corrective maintenance tasks while it ensures that the useful life of the equipment is extended.

2.7.3.1 Benefits of predictive maintenance

Mobley (2011) identified the following benefits of Predictive Maintenance.

- Regular monitoring of equipment reduces the interval between repairs and the cost of unplanned outages.
- It improves productivity, product quality, profitability, and effectiveness of production.
- It uses tools such as vibration monitoring, process parameter monitoring, thermography, tribology, and visual inspection that does not cause disturbance in the operation of machines.
- The actual operating condition of critical equipment is recorded by the cost-effective tools and the data is used for maintenance schedules.
- The comprehensive maintenance management program provides the capability to improve the availability of machinery and reduce the cost of maintenance.
- It minimises unplanned maintenance and ensures equipment is in a good condition
- Failures are detected before they become serious

Swanson (2001) explains that predictive maintenance reduces the probability of equipment breakdown because the equipment is only taken out of service when it is evident that deterioration has taken place. A company called Predictive Maintenance Solutions (2021) identifies the following benefits of predictive maintenance; the equipment is monitored in real-time 24/7 to detect problems before the equipment fail, it reduces the frequency of inspections, resolves labour shortages, reduces excess part replacement, and unskilled maintenance engineers can provide similar services as skilled maintenance engineers.

2.7.3.2 The challenges of implementing predictive maintenance successfully

According to Davis (2019), organisations find it difficult to successfully implement predictive maintenance strategies due to the following factors:

- Unskilled technicians

Unskilled maintenance technicians struggle to adapt to new technology and find it difficult to understand certain machine operational parameters.

- Unbalanced scheduling

Overloading technicians with work confuse them and they end up spending a lot of time searching for spares and tools to start working on a piece of equipment. An unbalanced maintenance schedule causes delays and results in an ineffective maintenance program. A maintenance schedule should allow technicians enough time to plan their work in a simple way and avoid delays.

- Lack of buy-in from top management

Lack of support and resistance by top management affects the implementation of the maintenance program and the reason is attributed to the unavailability of data required for preventive maintenance activities.

- Incomplete task descriptions

Lack of knowledge of the equipment results in a poor maintenance plan and incomplete task description. An incomplete maintenance plan causes unavailability of required spare parts, unreliable and incomplete data, and longer maintenance time.

Blanche (2021) observed that implementation of predictive maintenance is hampered by undefined financial benefits, undefined operational benefits, poor programme execution, and lack of executive support.

The organisation's performance is dependent on the support from its leadership and supervision. The senior executive, as well as the entire workforce, contribute to the organisation's functional activities (Daya et al., 2009).

2.7.4 Reactive maintenance

Sullivan et al. (2002) defines reactive maintenance as a strategy that allows the equipment to run until it fails. The design life of infrastructure or assets is not reached as no effort is made to save the equipment from failing. The implementation of reactive maintenance does not require any additional manpower or capital cost because no maintenance is done on the new infrastructure. New infrastructure is operated until it fails and there are no concerns about its design life. If the decision is taken to repair infrastructure that was allowed to run until it fails, labour cost will be high because spares will be expensive as infrastructure was never maintained. Daya et al. (2016) explain that reactive maintenance is a strategy whereby equipment or infrastructure is restored to its operational state after it has failed by implementing corrective measures.

Toxopeus (2019) points out that the water infrastructure assessment report done by the Helen Suzman Foundation shows that poor maintenance and ageing contribute to the deterioration of infrastructure. The report further indicates that the reduction in the functional life span of infrastructure raises costs of repair as the approach of infrastructure maintenance by South Africa gives the idea of being reactive as opposed to preventive. The Helen Suzman Foundation report establishes that municipalities face several challenges in effectively maintaining infrastructure due to a lack of engineering capacity and the mismanagement of water infrastructure. There is a lack of capacity and skills amongst maintenance technicians, communities experience no running water, and the challenge is exacerbated by the unavailability of resources to do maintenance and repairs. Training or skills development is sometimes also not in place.

According to Sullivan et al. (2004), maintenance, overtime costs can be experienced when infrastructure fails after normal working hours because maintenance technicians will have to be called in to come and repair the failed infrastructure. Reactive maintenance is accompanied by many risks as the effects drive up insurance costs, poor return on investments, and poor service delivery. Implementation of an effective maintenance strategy is critical and can minimise maintenance costs, and the organisation can save on operational costs.

Burnett and Vlok (2014) affirm that reactive maintenance can be performed after failure has occurred and the decision can be taken to either do the repairs immediately or be postponed to another date. The authors further explain that for organisations to accomplish maintenance excellence, maintenance activities should be properly planned and coordinated.

The objective of maintenance strategies is to ensure that the total cost of inspections, repair, and equipment downtime is minimised, and production is not affected. The investment cost on reactive maintenance is low but high maintenance costs can be realised when the equipment fails while still in operation. To minimise equipment downtime which affects production, preventive maintenance can be introduced as an alternative strategy. Preventive maintenance is executed at predetermined time intervals to avoid unexpected failures (Jin et al., 2016).

2.7.4.1 Advantages and Disadvantages of a reactive maintenance strategy

Given the meaning of reactive maintenance, the strategy has several advantages. Foremost, a reactive maintenance strategy can be used effectively based on the outcome of the Reliability Centred Maintenance (RCM) analysis in comparing the risk of equipment failure and the cost of maintenance required to alleviate the risk and cost of failure (NASA, 2008).

When an organisation has adopted a reactive maintenance strategy, the equipment is operated until it fails and no manpower and capital cost is incurred, minimal failure incidents are expected, no spending on capital costs, therefore the approach has benefits related to low cost and less staff (Sullivan et al., 2010). The same view is shared by Swanson (2001) that reactive maintenance allows the organisation to operate the plant with minimal maintenance staff while money will be saved to keep equipment operational. The author further indicates that temporary repairs can be made to keep the equipment running until permanent repairs can be done at a later stage.

While reactive maintenance has obvious benefits, there are a lot of disadvantages that can make the benefits difficult to be realised. The downside of reactive maintenance is that while it is believed that there is cost-saving, costs are incurred during unplanned downtime of equipment as production is interrupted, labour cost increases when the equipment is not functional because overtime will be paid to maintenance staff to get the equipment back to operation, there is a cost involved to repair or replace the broken equipment, the life span of equipment is shorted while waiting for the equipment to fail and be taken out of the system, the broken equipment can affect the secondary components during a breakdown and inefficient use of staff resources due to idling time and not performing maintenance (Sullivan et al., 2010).

Swanson (2001) points out that, the disadvantage of reactive maintenance is that the approach is unpredictable and affects production, it creates scrap output and increases overall maintenance costs to repair fatal failures.

2.7.4.2 Characteristics of reactive maintenance

Maintenance strategies have different traits, qualities that distinguish them from each other. The characteristics of the strategies make it easier for organisations to understand which one is relevant to their operations. The provision of water is an essential service that needs a clear and effective strategy. According to Swanson, (2001), reactive maintenance strategy has the following characteristics:

- Reactive maintenance helps a company to save time and money by reducing the number of maintenance workers required to keep equipment working.
- It is unpredictably variable, resulting in fluctuating production capacity, greater out-of-tolerance and scrap output, and higher overall maintenance expenditures to repair catastrophic failures.
- Reactive maintenance, on the other hand, has a moderately negative connection with the dependent variable.

2.7.4.3 Challenges of reactive maintenance

In the water supply environment, the challenges of non-supply or interruption do not only affect water utilities financially or their reputation but also affects the life and health of communities. If the maintenance strategies fail to protect infrastructure, decisions need to be taken to resolve the challenges. According to Prometheus (2020) organisations that use reactive maintenance strategy frequently treat the symptom of the asset rather than the problem that is producing the symptom. The following challenges are indicated by Prometheus (2020).

- **Chronic failures**

  Due to the need to get the plant back into production, reactive maintenance only does the absolute minimum to get the system up and running again. The problem recurs and causes more downtime if not corrected appropriately. When this happens and again, production is lost, and services are interrupted.

- **Sporadic equipment downtime**

  Unplanned repairs happen at any time with a reactive maintenance strategy, whereas planned maintenance can be written into the maintenance schedule. It is not known when will the equipment fail and cause production delay. The confidence between maintenance, production, and stakeholders is eroded when equipment goes down frequently or sporadically.

- **Interferes with planned preventive work**

  The maintenance death spiral occurs when emergency repairs are frequently prioritised over planned preventive maintenance. Planned work may be pushed back or altogether cancelled, resulting in future unanticipated breakdowns, resulting in more unplanned work and the omission of future preventive work.

- **Collateral damage**

  A small maintenance problem becomes a massive system repair that affects the entire operational system. When the whole system is disrupted, maintenance staff are expected to work overtime which increases spending, there is a loss of revenue, and stakeholders start to question the ability of the organisation to provide services.

- **Safety issues**

  When technicians are working on reactive maintenance, they are under extra pressure to get systems up and running as soon as possible. Occupational, Health, and Safety requirements or guidelines are not followed, accidents occur, and the strategic goal of the system is contradicted.

2.7.4.4 What contributes to reactive maintenance

In the environment of water supply, there is a need for continuous maintenance and management of infrastructure. Therefore, when a particular maintenance strategy is used for effective operation, the process brings the consequences of that strategy to the fore. Mothetha et al. (2013) identify the following aspects as the causes of reactive maintenance:

- Lack of capacity and skills by maintenance staff and no development programmes.
- Insufficient budgets to repair or replace dilapidated infrastructure and the implementation of wrong maintenance strategies.
- Illegal water connections due to lack of reticulation.
- Political interferences as water infrastructure projects funds are redirected to other projects.

According to Mothetha et al., (2013), the delivery of services in the South African water sector is affected or delayed by political interference as funds are redirected to other projects or funds are misused and institutions fail to achieve service delivery. Krar (2015) highlights the following challenges in the maintenance of infrastructure:

- Unavailability of written objectives and policy
- Inability or failure to manage budget
- Failure to control work order and service requests
- Non-usage of standards

- Failure to control maintenance work
- Unavailability of maintenance history reports that include, costs, control systems, and maintenance planning
- Unavailability of maintenance spares

The inefficient use of resources or lack of proper control is indicated by Prometheus (2020) as another factor that causes reactive maintenance. Maintenance technicians spend a lot of time looking for the right manuals and schematics, buying the necessary parts, and diagnosing and fixing problems.

2.7.4.5 The impact of reactive maintenance in the organisation

Reactive maintenance is a strategy that is implemented after a breakdown has been identified to restore a broken device to full functionality, either through repair or replacement. This application of strategy results in either a major waste of time or an unreasonably high inventory cost. Sukma et al. (2019). When infrastructure fails to perform its functions, services are disrupted, the production is reduced or stopped, and in turn, the organisation loses revenue. Poor maintenance of infrastructure can cause infrastructure to break down during start-ups or after normal working hours creating shutdowns and overtimes (Gulati and Smith, 2009). Velmurugan and Dhingra (2015) indicate that failure to maintain infrastructure timeously disrupts services.

Costa and Balduino (2018) explain that reactive maintenance is typically performed when equipment becomes malfunctioning and ceases to operate, which can be hazardous to production because it is unable to be programmed, and it occurs in conjunction with a production stoppage. Primero et al. (2015) stipulates that organisations experience high repair costs when the equipment is repaired in the remedial stage than when they are in the preventive stage.

2.7.4.6 The benefits of reactive maintenance in the organisation

For the maintenance to contribute positively to the total output of the organisation, maintenance staff need to know that they are part of the larger production strategy. Physical assets must be maintained to ensure that they are reliable and available to offer products or services. Both direct costs that include, labour, material, spares, tools, information, and contractors, and indirect costs such as lost revenue due to downtime, lost reputation, customer compensation, and fines expenses should be considered when calculating the financial impact of maintenance (Mungani and Visser, 2013).

Costa and Balduino (2018) point out that for organisations to avoid production loss and reputational embarrassment due to infrastructure failures, it is necessary for the company to implement a system of preventive and corrective maintenance, to repair or correct the wearing process of its infrastructure, to maintain the environment in perfect condition, and leaving it with a safety aspect to benefit its users. It is further indicated by Swanson (2001) that reactive maintenance helps a company to save time and money by reducing the number of maintenance workers required to keep equipment working.

2.7.4.7 Linking reactive maintenance strategy to performance

Performance measurement is based on the notion of management. Performance measurement is critical because it identifies existing performance gaps between current and desired performance, as well as progress toward closing those gaps (Velmurugan and Dhingra, 2015). To give relevant information for making effective decisions and promoting desirable outcomes, performance measures should be related to an organization's strategy (Tsang et al., 1999).

Swanson (2001) explains that:

- Many businesses rely on reactive maintenance as it extends the life of equipment, increases its availability, and keeps it in good working condition.
- Poorly maintained equipment because of reactive maintenance may result in more frequent equipment breakdowns, lower equipment usage, and postponed production schedules.
- Reactive maintenance results in decreased production performance.
- The performance measurements of other strategies, such as proactive and aggressive maintenance, have a marginally significant positive output compared to the reactive strategy.

2.8 Effective strategy defined

Businesses rely heavily on maintenance activities that are supported by effective strategies to produce goods and services. Zafar (2018) explains that there is no common framework that meets the needs of all businesses in terms of maintenance. Traditional maintenance strategies are founded on the assumption that maintenance is all about protecting an equipment's inherent reliability of built-in capability. This paradigm leads to preventative maintenance procedures to avoid breakdowns and failures. An effective strategy comprises processes and actions that must be designed and implemented to allow maintenance to concentrate its attention on the most profitable equipment in the business. It ensures that resources and hazards are efficiently managed, and that asset maintenance corresponds with business objectives, by covering all areas of maintenance management. Onawoga and Akinyemi (2010) identify components of effective maintenance strategy as:

- Increased production levels
- Rigid production schedules
- Increased equipment uses, and
- Market competition

And the author also indicates that an organisation that lacks an effective maintenance strategy has some negative repercussions as listed below that contribute to high production costs and loss of revenue.

- Machine breakdowns regularly
- Emergency maintenance work regularly
- The asset life expectancy has been shortened.
- Maintenance personnel are underutilised
- Products of lower grade
- An excessive amount of money is spent on spare parts and maintenance materials.
- Excessive overtime costs for both maintenance and production staff

Effective maintenance strategy entails performing the proper maintenance to increase equipment reliability and reduce operating risks (Mbohwa and Mwanza, 2016).

2.9 Maintenance execution

According to Staub (2012), maintenance can be classified into two types: preventive and corrective. Preventive maintenance is performed at predetermined intervals (e.g., time-based, or use-based) or according to other prescribed criteria (e.g., defects and conditions) to reduce the chances of an item failing to achieve an acceptable condition. Any maintenance action that is required to remedy a failure that has occurred or is in the process of occurring is referred to as corrective maintenance. The types of maintenance activities can be identified as cleaning, repair, and replacement. Maintenance activities can be planned and calculated using standardised performance levels, such as the minimum condition of equipment after performing maintenance work, which can be achieved by setting a lower limit in a condition rating scale and thus establishing norms for the maximum performance loss.

2.10 Management of resources for maintenance management

Tools for maintenance management include Computerised Maintenance Management System (CMMS), Gantt chart, labour, budget, maintenance spares, material, and services (Cahyo, et al., 2014). According to Levitt (2010), the Computerised Maintenance Management System (CMMS) is the hub of information about asset maintenance and reliability. To maintain an asset functioning, systems with good databases have a complete set of information relating to expenses, frequencies, tasks, time spent, and materials. In short, having all the information in one place has some advantages. The Total Productive Maintenance (TPM) operators would capture their maintenance time on the CMMS through the Material Requirement Planning (MRP) system. The CMMS would store the maintenance task lists. TPM operators would store instructions in the CMMS's structures, as well as any external systems used by maintenance employees for task justification, task engineering, and drafting. Cato and Mobley (2002) explain that CMMSs assist organisations in better managing maintenance by organising and recording the plethora of data needed to run effective maintenance operations. Work schedules and backlogs, preventative maintenance plans and timetables, labour use, and maintenance cost distribution are examples of such data. Materials utilised, as well as quantities and costs, are tracked by computer-controlled maintenance systems. It can manage stocks and keep them at optimal, cost-effective levels. It can also provide both summary and detailed information on the past, present, and future.

Labib (2008) indicates that Computerised Maintenance Management Systems (CMMS's) are critical for coordinating all tasks connected to complex system's availability, productivity, and maintainability. Maintenance, for example, has seen a tremendous increase in effectiveness and efficiency because of modern computing facilities. Crain (2003) concludes that Computerised Maintenance Management Systems should be set up to deliver the most user-friendly interface possible.

Gantt chart is another tool identified by Levitt (2010), that is used by maintenance teams, and it is explained that reading and understanding the meaning of a display or chart is faster and more accurate than reading and understanding the meaning of a written report. The method is thought to be the foundation of the visual workplace. The Gantt chart has benefits such as a simplified operator-based care training, more consistency of tasks, faster detection of operating abnormalities, quicker troubleshooting, and root cause analysis, reduced store inventory and fewer mistakes, fewer unplanned Maintenance, Repair, and Operations (MRO) purchases, and improved safety and employee morale.

Mong et al. (2018) explain that human resources, spare parts, tools, and knowledge are among the resources required for maintenance. The author indicates that the quality of human resources is determined by the company's environment, including its training system and the availability of skilled and knowledgeable personnel in the specific scope of maintenance work. Maintenance knowledge may be gained through training, and jobs can be completed successfully and efficiently. In the event of a skills shortage, the company might outsource the task. However, the business cannot simply explain the cost decrease for maintenance tasks since they have paid to increase performance by outsourcing and providing training to the personnel. Maintenance spare parts must be able to strike the best possible balance between price and quality. Furthermore, the setting should be categorised and recorded in the inventories to manage the spare part.

Koumanakos (2008) indicate that in general, inventory management efficiency or inefficiency is merely one element that might affect a company's performance. The author further explains that the purpose of an inventory manager is to minimise cost or maximise profit while meeting client expectations. These two criteria result in the same optimal replenishment policy if inventory decisions do not affect income streams. Wild (2017) asserts that the basic idea behind Just in Time (JIT) is that we have items when they're needed and none when they're not. JIT is the product of a high-quality supply chain.

2.11 Continual improvement

South Africa is a water-scarce country with uncertain yearly rainfall. The country also experiences droughts and floods which are a result of extreme weather conditions (Omotayo et al., 2021).

The response to the challenges of water and availability of infrastructure is for governments to implement the Sustainable Development Goals (SDG). Sustainable Development Goal 6 (SDG6) intends to ensure the availability and sustainable management of water and sanitation. To achieve these SDGs, funds need to be available to construct and upgrade water infrastructure. The new infrastructure will address issues of water availability, water loss, and water quality. SDG 9 supports SDG 6 as it intends to build resilient infrastructure that promotes sustainable industrialisation and fosters innovation. The goal is to support economic development and human wellbeing because people will have access to clean drinking water (Desa, (2016).

Initiatives should be taken to teach and alert communities or consumers on the importance of saving water. Incentives can be provided to customers to use water more efficiently and charge fewer tariffs. Reduction or affordable tariffs can provide quality services and encourage consumers to take responsibility for water usage. While implementing low tariffs, it should be noted that this can result in unsustainable levels of water consumption because consumers can use more water and future production costs can rise (Rodriguez, 2012).

To respond to reactive maintenance of water infrastructure, the availability and reliability of the equipment should be maximised to achieve business objectives

(Velmurugan and Dhingra 2015).

According to Karaa (1989), infrastructure maintenance management system can be implemented as a support system of maintenance versus the decisions of replacement and rehabilitation. The system is used in the organisation for planning, scheduling the maintenance and capital projects, and organising services and operational capabilities of the organisation. Maser (1988) shares the same viewpoint, stating that maintenance and capital improvement decisions can be classified into three levels at which they take place in the organisational structure. The levels are explained as follows:

- **Level 1**

This level deals with the strategic planning of budget allocations and prioritises the needs of the organisation. The budget is split into long-term projections, selection of projects and their evaluations, manpower, and resource programming. Sources of financing are identified to enable project funding. The organisation takes decisions about the required data on the level.

- **Level 2**

At this level, decisions are made regarding the implementation of methodologies in inspections, operational control of the organisation, capital improvement, maintenance contracts for the repairs, replacement, and rehabilitation. The process and the need for in-house and contracting external contracts are defined and unpacked.

- **Level 3**

Tactical decisions are taken at this level. Management looks at how frequently should the inspections on the infrastructure system be conducted, at what level should the details be captured, and the implementation of maintenance plans.

Maintenance of system theory looks at operations and maintenance of water infrastructure as a critical component to the production of the final product. Maintenance is a combination of a set of organised activities that are performed to keep a piece of equipment in its best operational condition without incurring high maintenance costs (Saxena et al., 2013). The statement is supported by Krar (2015), indicating that when equipment is regularly maintained, it will operate 100% efficiently and always give the required production.

Good operations and maintenance of water infrastructure are critical for uninterrupted services. With sufficient capital investment, infrastructure can deliver services as required. When the water infrastructure system is not taken care of, it will fail and there will be no benefits. Capital investment contributes to making infrastructure productive and infrastructure investment can expand. Efficient operation and maintenance of infrastructure lower private user's costs and make infrastructure accessible (Fox and Murray, 2015).

There has been a shift in trying to make infrastructure climate resilient. Infrastructure needs to be designed in a way that it can adapt to climate change and be fit for its purpose. Investment in water infrastructure is required and effective champions in leading the process should be identified. The water service provider needs to align its business models and budget methods with the changing technologies. Water infrastructure needs to be ready to provide services to the unexpected changes and be more efficient and less wasteful (World Water Council, 2016). The resilience of infrastructure to climate change can provide opportunities for socio-economic growth as many stakeholders receive water services(Frone and Frone, 2012).

The objective of general maintenance is to ensure that the production level is kept at its optimum while operational cost is low without compromising health, safety, and the environment (Aker Solutions, 2010). According to Velmurugan and Dhingra (2015), to effectively utilise assets and achieve key objectives of maintenance, there is a need for technical skills, techniques, and methods from technicians.

To address the challenges of maintenance, a sufficient budget should be formulated to cover short-term and long-term objectives of maintenance. The budget should cover items such as the cost of an internal manpower contract and material that will be needed for maintenance (Velmurugan and Dhingra, 2015).

An approach to improving infrastructure maintenance, achieving high equipment availability and optimum reliability while complying with safety and other regulations, can be achieved by setting up and implementing a proper maintenance management process. Continuous improvement requires effective planning and scheduling of maintenance job cards. Feedback collected by maintenance personnel in the job cards provides a history that can be implemented for the next time when maintenance is done on the same equipment. Effective and maximum utilisation of internal resources minimise the use of contracts and outside resources (Admin, 2018). Figure 2.5 illustrates the maintenance management process that promotes continuous improvement of maintenance.

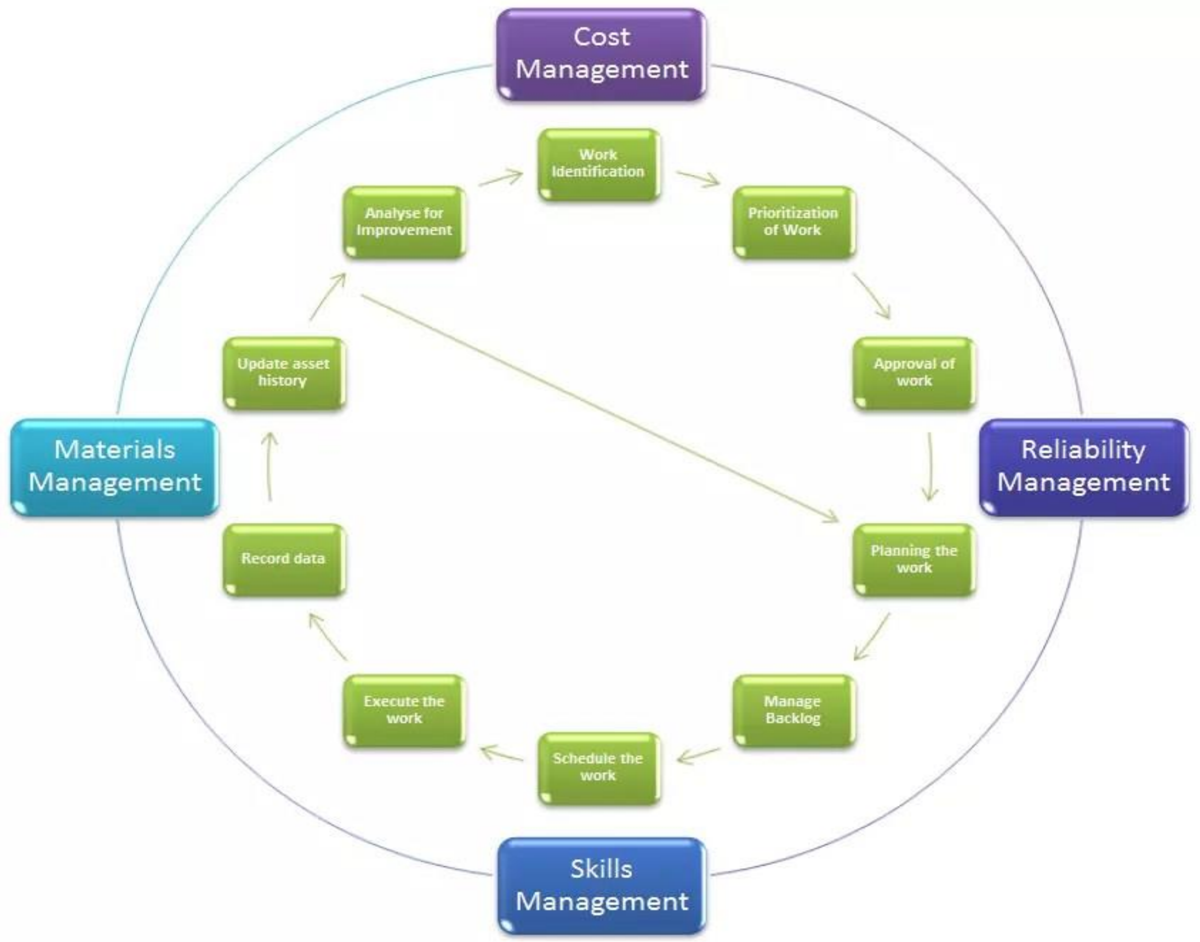

Figure 2.5: Maintenance Management process

Source: Admin, (2018)

2.12 Organisational support for maintenance

To ensure the success of a good maintenance programme, it must be supported by everyone in the organisation from top executives to the lower-level employees (Krar, 2015). Furthermore, lack of funding by organisational leadership in water infrastructure is compromising the provision of water services. With that said, water services provide economic, health, and environmental benefits to communities. The global financial crisis has made funding for infrastructure inadequate to meet the demand of the increasing population. Taxpayers have taken the brunt of paying for water infrastructure through taxes while the private sector contributes through private debt or credit financing. Water infrastructure has become an unfavourable area to investors because of its 20-year built period while the upfront costs are large and repayment periods are long (Rodriguez et al., 2012).

According to Oyedele (2015), the budget for infrastructure is not readily available as the government waits until the last minute to fund infrastructure maintenance, hence, the government fails to provide services. Mobley (2011) indicates that according to the normal plant accounting procedures, maintenance costs are regarded to be a major portion of the total operating costs in most plants. Lack of understanding by management that budget development should be designed in a way that it must contribute to organisational mission, affects the very same mission that the organisation intends to achieve (Daya et al., 2009).

Effective implementation of planned maintenance jobs does not only require top management to give support on the availability of spare parts and maintenance labour, but it also requires support services in the areas of design, works order scheduling, dispatching, and investigations on quality assurance (Daya et al., 2009). Lack of commitment by management is largely a familiar reason for the organisation to fail in achieving the expected results. However, for the organisation to achieve its objectives, management must be fully committed to change, be dedicated, and allow space for the change to take place. Furthermore, management must set achievable maintenance performance targets concerning equipment uptime, maintenance costs, overtime, workforce productivity, and time spent by supervisors onsite (Smith and Hawkins, 2004).

Insufficient budget, insufficient time, lack of management support, and poor maintenance management contribute to maintenance failure. Furthermore, failure by management to control relationships between production which controls the downtime for keeping maintenance going, procurement and materials management, which ensure the proper parts and materials are available, engineering, which ensures the system is properly configured and operational, and human resources, which provides the skilled technicians, forces the entire organisation to become reactive (Mobley, 2021).

With limited budgets and staffing, maintenance of critical tasks falls behind and the team fails to implement proactive maintenance while in the process the team experiences burnout, and production is affected (Comstock, 2021). Having a reactive maintenance strategy affects production levels, and the required quantities are not achieved while with proactive maintenance, the strategy that prevents downtime, the required production capacity is produced and the business is sustained (Smith and Hawkins, 2004). Reactive maintenance affects organisations business needs while preventive maintenance assists the business in realising its investment target (Comstock, 2021). Preventive and predictive maintenance strategies are effective, and they maintain planned maintenance goals (Levitt, 2003).

2.13 Conclusion

This chapter presented literature relevant to the maintenance of water infrastructure. Maintenance is critical in ensuring infrastructure performs its function with minimum disruptions and at a lower cost. Organisations adopt different maintenance strategies to ensure their business objectives are achieved. Firstly, I discussed maintenance and followed by maintenance management framework, maintenance management system review, maintenance strategies to understand their benefits and contribution to the existence of infrastructure, while in the last section I discussed organisational support to maintenance. The following chapter will discuss the methodology used to conduct this research.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the research design and methodology which particularly outlines the interpretive paradigm as an appropriate framework for the study. The study adopted a qualitative approach to data collection which included, documents analysis, structured interviews, and questionnaires that were employed to investigate the challenges in the reactive maintenance of water infrastructure in Lepelle Northern Water. The chapter also provides details on the case study area, ethical considerations, and limitations of the study.

3.2 Research Methodology

3.2.1 Research Paradigm: Interpretive

A paradigm is defined by Kivunja and Kuyini (2017) as an idea formed in the mind of researchers to scrutinise their project method's effects and decide on the research method that they can use for the research and how the data will be analysed.

Paradigms are accepted by everyone in that they provide solutions to scientists or a group of people who share a common concern to model problems (Sandhya, 2020). Paradigm can be used for the institutionalisation of intellectual activity, a wide range of certain approaches and perspectives to the study of any subject, and the description of approaches to research like the positivist or interpretive paradigms (Grix, 2010). The interpretivist approach strives to understand values, beliefs, and behaviour, and draw out any insight of participants' social activities and experiences (Smith and Heshsius, 1986). Interpretive research is an emergent process that is time and context-specific while it pursues to describe and identify unknown realities (Hudson and Ozanne, 1988). According to Nieuwenhuis (2015), interpretive attempts to determine how people are impacted by the social world as human behaviour is influenced by the environment. This approach is interested in the subjective point of view and the explanations by participants on the scope of investigation instead of the objective of an observer of the action (Ponelis, 2015). According to Mackenzie and Knipe (2006), there are three components of a paradigm: nature of knowledge, criteria for validity, and research methodology.

Ontology is concerned with the nature of reality and explains how systematically things can be presented. The relationship between the describable set of objects is deliberated in the representational language in a form of a focused philosophy (Gruber and Olsen, 1994). Social science generates ontological hypotheses about the nature of reality and social beings (Hudson and Ozanne, 1988). Ontology concentrates on the nature and structure of things in consideration of their independence and existence (Guarino et al., 2009).

Epistemological assumptions deal with the theory of knowledge and the interpretivism approach is to establish motives, meanings, reasons, and other subjective experiences on situations that have restricted periods (Hudson and Ozanne, 1988). Epistemology asks questions such as: "What is the relationship between the knower and what is known? How do we know what we know? What counts as knowledge" (Tuli, 2010). It deals with knowledge as a species of belief, justified true beliefs, perhaps, or justified true beliefs that meet some further conditions. It differentiates the epistemic uses by bridging concepts in question to knowledge by the suitable goal of accomplishing the truth and avoiding error (McGlynn, 2013).

The methodology is a system of guidelines or principles that can be customised and be used to a specific approach, templates, forms, and even checklists of a situation or case. The methodology is a process that documents a series of steps, processes, and procedures to deliver the successful completion of a project to an end (Charvat, 2003). The methodology brings together the philosophical standpoint on ontology, epistemology, and methodology (Nieuwenhuis, 2015). A methodology is informed by the philosophical beliefs that guide how the researcher should proceed after combining different methods and theories of research (Leavy, 2014). According to Warren (2020), research methodology is about how a researcher orderly designs a study to achieve trustworthy results that address the research aims and objectives. A similar explanation was given by Kothari (2004), by indicating that research methodology is a process that solves the research problems in an orderly manner.

Therefore, through the methodological design of this study, I was able to gain insight from participants on how the challenges of reactive maintenance on water infrastructure are impacting the mandate of Lepelle Northern Water of providing uninterrupted bulk water services.

3.2.2 Research Design: Qualitative Approach

The study followed the qualitative approach to collect data to address the aims and objectives of the study. Qualitative research uses an orderly predefined set of procedures to investigate and collect evidence to answer questions. Qualitative research aims to comprehend a given study problem or topic through the eyes of the people who live in the area. Qualitative research is particularly useful for acquiring culturally relevant information on a population's beliefs, attitudes, behaviours, and social circumstances (Mack, 2005). According to Vanderstoep and Johnson (2008), a qualitative approach believes that knowledge from individuals can be formulated through communication but not by analysing the parts of the organisation. The author explains the purpose of qualitative research as being more descriptive than predictive and aims to understand in detail the viewpoint of a research participant. Qualitative research is influenced by technological developments and acquiring information relies on engaging and observing human beings (Leavy, 2014). In this study, the qualitative approach helped provide an understanding of how participants react and share their experiences on the issues of water infrastructure maintenance.

According to Creswell and Creswell (2017), the qualitative approach allows the researcher to collect open-ended information directly from participants intending to develop themes from the collected data. Mack (2005) further points out that documents provide information that was previously not known, and that the same information can be used in future studies. A qualitative approach is concerned with the subjective assessment of participants attitudes, opinions, and behaviour (Kothari, 2004). The process of qualitative research includes new questions and procedures, data collection from participants environments, analysing data inductively, building from particulars to general themes, and making interpretations of the meaning of the data, and the final written report that has a flexible writing structure (Creswell and Creswell, 2017).

The study is largely descriptive, as the questions posed to the participants were structured around answering questions about who, what, where, when, and to what extent (Loeb et al., 2017). Participants answered the questions and explained their understanding of water infrastructure maintenance, the situations they are operating under, and the challenges they are experiencing in their daily work activities (Loeb et al., 2017). The author further presents arguments to emphasise that descriptive analysis can be used on its own as a research product as it can identify important concepts that have not previously been identified.

Lans and van der Voordt (2002) highlight the characteristics of descriptive research as follows:

- It is confined to factual recording, so there is no need to try to figure out why reality is presenting itself the way it is.
- It does not try to establish hypotheses or construct theories. It is objective or neutral.
- It describes how reality is.
- It differs from prescriptive research that is primarily concerned with the question of how the reality should be.
- It makes inventories while prescriptive research is normative.

3.3 Research design: Case study

Yin (1984:23) defines the case study as "real research that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are not evident, and in which multiple sources of evidence are used". Zainal, (2007) explains that a case study method allows a researcher an opportunity to closely scrutinise the data of a chosen unit within a specific context. While Gerring (2004), indicates that a case study should be described as an intensive study of a single unit to bring together all larger sets of units and that it must be understood to be a way of defining cases rather than analysing them.

For this study, I applied the interpretive research approach because of the small number of participants that were selected purposefully from the single case study (Holloway, 1997), and the interpretive approach provided a suitable framework (Sileyew, 2019).

To achieve the objectives of this study, a strategy was adopted to obtain information, collect, and analyse data and draw conclusions and recommendations regarding the research problem. Figure 3.1 shows the steps I followed in conducting this research.

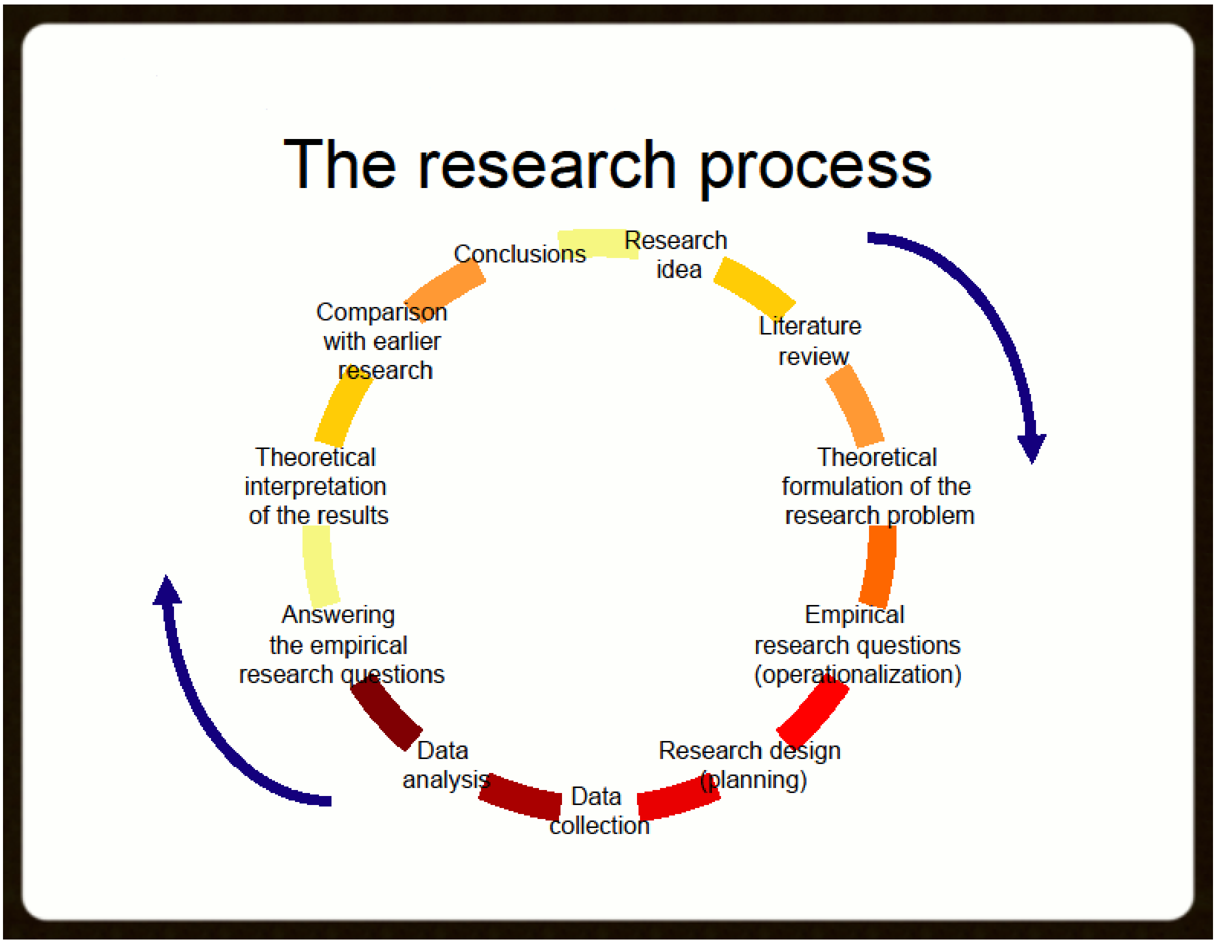

Figure 3.1: Research design process

Source: Creswell and Poth, (2016)

3.3.1 Case study area

The purpose of this subsection is to provide the background of the case study area and generate the rationale for the selection of the study site. I selected Lepelle Northern Water because it is the major bulk water supplier in the Limpopo province and the study is focussed on investigating the challenges of the reactive maintenance of water infrastructure.

South Africa is a dry country with varied water availability and an average rainfall of 450 mm per annum. South Africa is also faced with growing challenges around managing its existing water supply particularly in terms of qualified staff in water infrastructure for both capital and maintenance projects (Wall, 2010). According to stats SA (2019), the national population is estimated at 58 775 022. South Africa's water infrastructure has an average age of 39 years and lack of maintenance and capital renewal further aggravate the condition of the infrastructure. There are nine (9) provinces in South Africa, and each province has Water Service Authorities (WSA) and water boards that are responsible to provide bulk potable and wastewater services (Government Communication and Information System, 2013). According to Masindi and Duncker (2016), the water sector in South Africa is regulated by the Department of Water and Sanitation (DWS) and it is responsible to develop policies and strategies around water management. The nine (9) South African provinces and water boards are indicated in Figure 3.2 and the study area is shaded with a light blue colour.

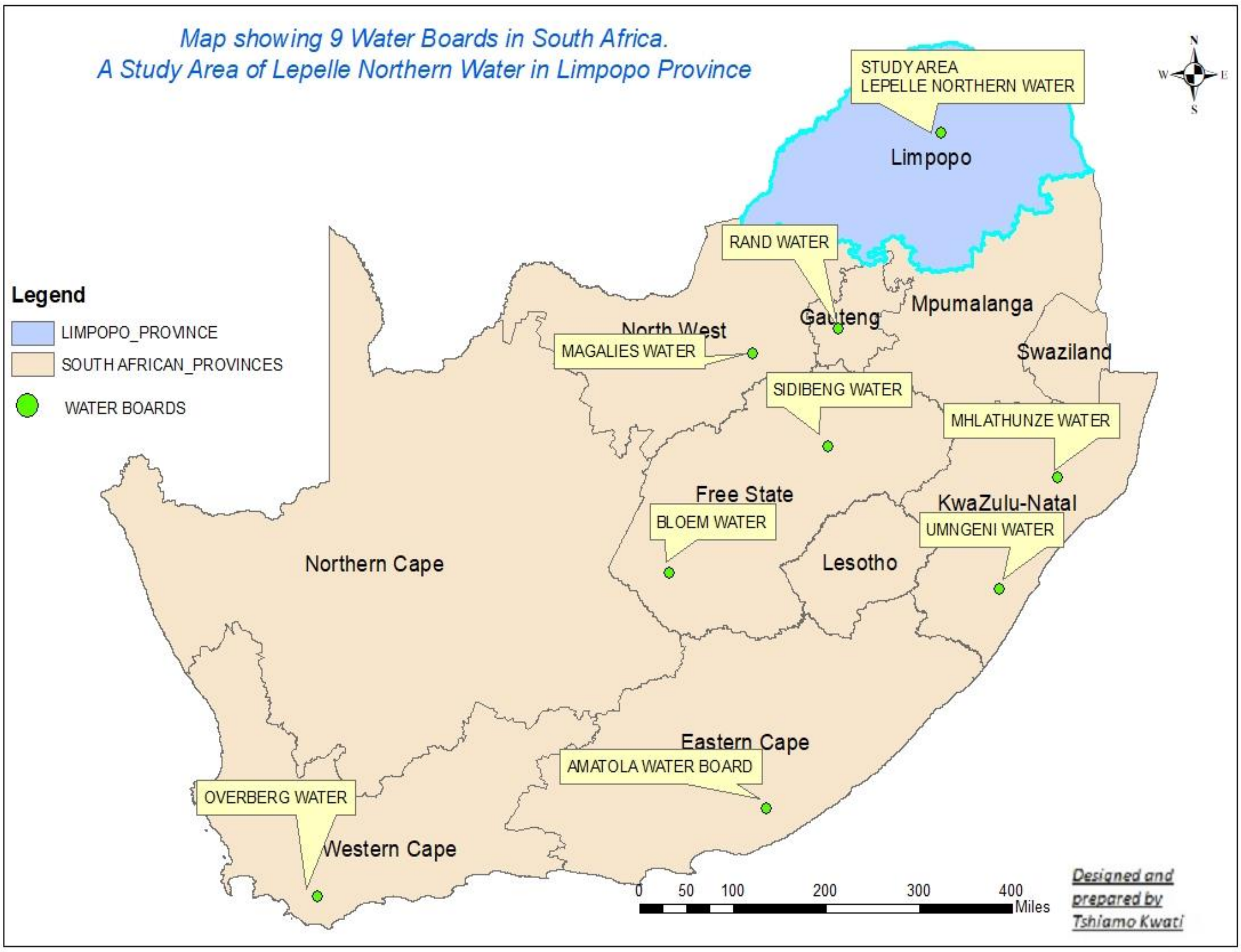

Figure 3.2: South African provinces and Water Boards

Source: LNW GIS unit

3.3.2 Research site selection

The study was conducted in Lepelle Northern Water (LNW) in the Limpopo province, South Africa. Limpopo province is one of the nine (9) provinces in South Africa, and it has an estimated population of 5 982 584 (stats SA, 2019). Lepelle Northern Water is the main water board in Limpopo province. According to Lepelle Northern Water, 2019 report, LNW was established in terms of the Water Services Act, Act No. 108 of 1997 and the Board of LNW is accountable to the Minister of Water and Sanitation. Lepelle Northern Water operates twenty-two (22) water treatment plants ranging in size from 0.1 to 175 megalitres per day as well as four (4) wastewater treatment plants spread across the Capricorn, Sekhukhune, Waterberg, Mopani, and Vhembe districts in the Limpopo Province (Lepelle Northern Water, 2017). The primary mandate of Lepelle Northern Water (LNW) is to provide bulk water to water services authorities, mines, industries, and businesses in Limpopo province. LNW is mandated to cover 80 000 square kilometres of Limpopo province's surface area of 125 754 square kilometres which includes, rural and urban areas. Currently, LNW is serving bulk water to 3 001 323 of the population which is 42% of its mandated 80 000 square kilometres (Lepelle Northern Water, 2019). The head office of Lepelle Northern Water is situated in the city of Polokwane, and it has regional offices in the three districts of Limpopo province (Lepelle Northern Water, 2017).

Figure 3.3 shows the districts and WTP in Limpopo province where Lepelle Northern Water provides bulk water services.

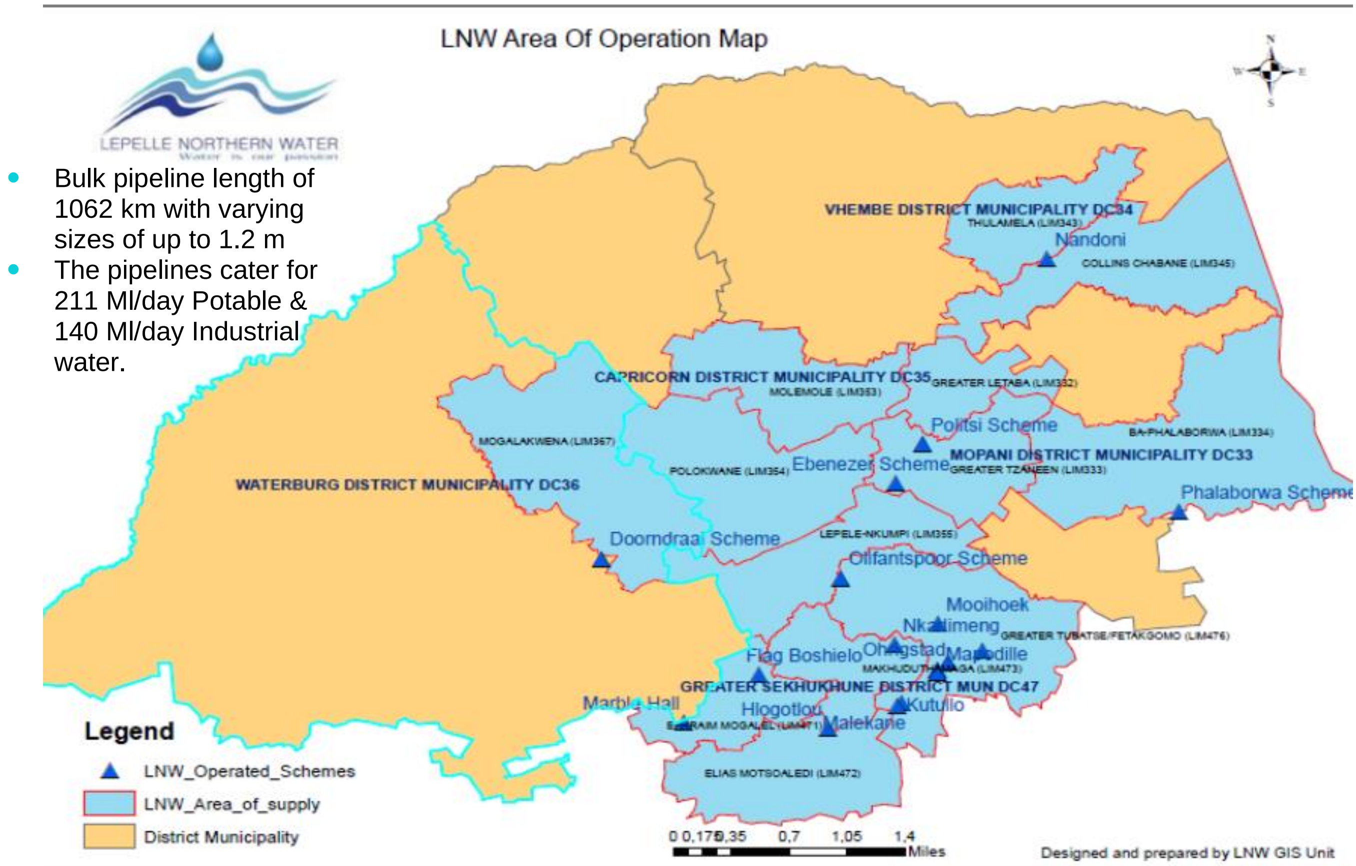

Figure 3.3: Lepelle Northern Water operations area

Source: LNW GIS unit

The chapter will now discuss how participant selection took place from LNW and what tools were used to gather information from these participants.

3.3.3 Selection of participants

For this study, purposive sampling was used in selecting the participants involved in the maintenance and operation of water infrastructure. Participants were selected from the four regions of Capricorn, Sekhukhune, Mopani, and Vhembe where LNW operates and maintains water infrastructure. The purposive sampling method was selected for the study because it allows for participants to be chosen on their knowledge and skills about the subject of interest (Etikan et al., 2016).

Participants were selected and grouped according to the research questions taking into consideration their experience and how they will contribute to the study (Mack, 2005). Participants were expected to meet the following characteristics to be part of the study; to be the employees of LNW, working under operations and maintenance department, have a technical background which is either on mechanical, electrical, civil, or instrumentation, know WTP operations and maintenance, and working or have previously worked at the Water Treatment Plants. Those who did not meet the characteristics required were then excluded from the study (Bezuidenhout et al., 2014). Of the thirty-five (35) participants who participated in the study, five (5) were managers, ten (10) supervisors, and twenty (20) maintenance technicians. All participants were expected to contribute as much as possible to the study by sharing their ideas and experience in the environment of water infrastructure maintenance. The sample size was determined when it was found that sampling more will not produce any new information that is related to the study (Mack, 2005).

The participants provided the researcher with information that can support the aims and objective of the study. A purposive sampling method gave a balanced understanding of the issues under investigation. The technique allowed the researcher to decide on the research problem he wanted to investigate, and the type of information needed for the research (Tongco, 2007).

3.4 Qualitative data collection tools

Data collection is a systematic way of collecting information about a specific research issue and the environment in which it occurs. Observation, interviews, questionnaires, and focus group discussions are some of the tools used for data collection in qualitative research (Chaleunvong, 2009). In this study, structured interviews, questionnaires, and documentation analysis were employed. Data collection allow the researcher to collect needed information from the participants (Abawi, 2017). Interviews enable the researcher to probe the views, feelings, and experiences of individual participants (Gill et al., 2008). The structured questionnaire provided a communication link between the researcher and the participants while the two were not in the same setting (Hague, et al., 2004). The documentation provided readily available information and tested the validity of data collected from different participants (Cath et al., 2017). These data collection methods were adopted to collect information and validate the data against one another and provide information to help understand and unpack the challenges of reactive maintenance of water infrastructure.

3.4.1 Documents

Documents from Lepelle Northern Water such as technical reports, business plans, annual reports, strategies, and policies were used for data collection. According to Bowen (2009), when analysing documents, the process of reviewing the printed and electronic documents is done systematically. The author further explains that each document in research should provide information to researchers, store historical information, give a background of events, provide researchers with the questions and situations that still need to be asked, and provide extra research data to the researcher to complete the research.

Each document provided background information on how it supports the mandate of LNW. Technical reports gave a historical performance in the maintenance of water infrastructure, business plans detailed the mandate of LNW, the annual report provided a yearly performance on the key performance indicators, strategies indicated how the targets will be approached to achieve the objectives, and the policies gave direction on how the organisation is supposed to function. Documentary analysis was important for this study because I needed historical information to find out what plans have been put in place for Lepelle Northern Water to achieve its mandate. The documentary analysis also provided insight into the context in which participants operated. Collaboration of qualitative methods strengthened the validity and the reliability of findings for this study.

3.4.2 Structured questionnaires

A questionnaire is a research tool with predetermined questions that assists researchers to gather information from participants (Keinath and Neuner, 2014). Michalos (2014) explains that a structured questionnaire is a standardised form used to collect information from participants in research and the questions are structured in the same order and wording. During this study, the purposefully identified participants were invited through emails, and follow-up was done by phone calls to confirm if they received the invite to participate in the study. Participants were then provided with the research explanatory statement, consent forms, and the questionnaire to respond to the questions if they agreed to what was indicated in the explanatory statement.

The questionnaires were structured in a way that they took no longer than ten minutes to be completed. Questionnaires are flexible tools in data collection, the cost involved in the research process is low and, they are simple to control (Phillips and Stawarski, 2008). The soft copy of questionnaires was sent by emails to participants so that they can be completed. Participants were requested to return questionnaires within ten (10) days. Some participants returned the questionnaires within the stipulated period of ten (10) days by email while other participants only returned the questionnaires after I followed-up with them.

3.4.3 Structured interviews

Interviews are used in descriptive research, and they involve verbal communication between the researcher and the participant (Mathers and Hunn, 1998). Interviews involve questions that need to be answered by the participants for the interviewer to be able to collect data (Rashidi et al., 2014).

For this study, interviews were structured since the study intended to determine the challenges of reactive maintenance of water infrastructure within a single research site. The structured questions allowed participants to be able to respond to all the questions and for the interviewer to understand the participants responses. The interview process took a long time because I had to ensure that preparations and the same process were consistent throughout the sessions (Phillips and Stawarski, 2008). The structured interview questions were developed to obtain the views and opinions of the participants (Creswell and Creswell, 2017).

Before data collection started, I visited all the four regions of Lepelle Northern Water, Capricorn, Sekhukhune, Mopani, and Vhembe. As an employee of Lepelle Northern Water, I had the advantage of access to WTP's in the regions without any difficulties since I am familiar with protocols that needed to be followed before visiting the sites. I ensured that though I am an employee of LNW, I engaged with gatekeepers openly and transparently to gain access to the sites. A gatekeeper is defined by Singh and Wassenaar (2016) as a person who has the authority to permit access to the organisation. I had meetings with plant and unit managers as gatekeepers and they assisted in identifying participants.

After participants were identified, they were notified telephonically about their selection to be part of the research study. I explained to the participants the reason why I needed to interview them and what would happen to the information they would be sharing with me and ensured them that their names would not be shared with anyone (Phillips and Stawarski, 2008).

All participants were sent the research explanatory statement and the consent forms so that they could prepare before agreeing on the interview date. The interview dates were set and before the start of the process, they were taken through the explanatory statement and the consent forms. Ten (10) participants were interviewed face-to-face while the other five (5) participants were interviewed telephonically due to Covid-19 lockdown and participants were not available to meet face to face. Participants responded to a series of pre-established questions and notes were taken while listening intensively to the participants. The interviews lasted between 10-15 minutes, and most were conducted inside the open workshops where it was quiet and cool. All face to face interviews were recorded.

3.5 Data analysis

According to Flick (2013), data analysis is the primary step in qualitative research.

Lacey and Luff (2001) explain that with qualitative data analysis, a large amount of collected data during the interviews or observations needs to be defined and be presented in a precise manner. Questions posed to the participants during interviews then require the researcher to determine the relationships between the different themes that have been identified.

Stages in qualitative data analysis include transcription which involves the use of electronically recorded interviews, focus groups, video recordings, or handwritten field notes. The second stage involves organising data and the process is done after transcription of data into easily retrievable sections. The third stage is familiarisation where the researcher listens to the recorded material repeatedly so that all relevant data can be summarised. The fourth step of qualitative data analysis is data coding while the last step is organising themes which assists in developing an adequately formalised category (Lacey and Luff, 2001).

The collected data from the questionnaires and interviews were grouped according to their similarities or differences so that variables and themes can be analysed separately. The grouping of data assisted in logically answering the research aims and objectives. Analysing numbers, characters, and images separately gave the researcher clear information that can be used to enhance understanding and new knowledge (Start, 2006). Since the data was in a text format, content analysis and narrative methods were used to analyse qualitative data. The two stages of data analysis are discussed below.

3.5.1 Organising the data

After returning from the interview sites, the first step was to organise the collected data. I listened to the audio recording for those interviews where permission had been given by the participants to record (not all participants agreed to this). While listening to the audio, I used pen and paper to write the verbal content of interactions I had with the participant without using any specific symbols. When transcribing the data, I was guided by the aim and objective of the study because not all the data was relevant (Moore and Llompart, 2017). The audio recording assisted in ensuring that I did not miss critical information and that I was able to go back and listen later and verify what I have captured (Berazneva, 2014).

I read the transcripts several times to become familiar with the data and thereafter started with the coding process. I ensured that the data was related to the research aim and objective so that I would be able to develop a storyline within the data (Stuckey, 2015). Participants were allocated identification codes after a process of analysing the data in text form (Moore and Llompart, 2017).

3.5.2 Coding

According to Baralt (2012), coding is a method of organising and sorting data. The process allows data to be compiled and arranged in a way that makes data easily understood. The author also indicates that coding includes attaching a word to a phrase, number, or symbol to each coding group. Coding is defined by Creswell and Creswell (2017) as a way of putting together the material into pieces of text to elaborate a definition of each piece. A code in qualitative research is a word that attributes a collective, noticeable, and capturing of visual data, and the data can comprise of interview transcripts, participant observation field notes, journals, documents, open-ended survey responses, drawings, artifacts, photographs, video, Internet sites, e-mail correspondence, academic and fictional literature (Saldaña, 2021).

For this study, I transcribed the raw data that I had collected into written text before I could start with the analysis. I read the transcripts line by line and highlighted words, and phrases that were relevant to the key concepts underpinning this study. To help identify phrases and words that were relevant to the aim and objective of the study, I wrote down the main critical words and phrases in a bullet format on a piece of paper. Words and phrases like, maintenance, infrastructure, and water were highlighted. The process of organising data in words and phrases assisted in ensuring that data can be easily managed. According to Mathers et al. (1998), wherever possible, each possible answer in qualitative research needs to be allocated with a numeric code. Transcripts were labelled according to their similarities and groups. To ensure that key concepts of the study are also included during coding, words and phrases that had to do with the challenges and interventions on reactive maintenance of water infrastructure were then grouped according to their categories. I then organised data from all the transcripts. Direct quotes from participants were used in this study to ensure the credibility of the data.

3.6 Limitations of the study

Limitations are possible and uncontrollable weaknesses that are encountered by the researcher (Simon, 2011). According to Theofanidis and Fountouki (2018), limitations in the study can be a consequence of a chosen research design, statistical model constraints, funding constraints, or other factors and the researcher is unable to control.

Participants in this study were in different regions of the province and based at different water treatment works which were also in remote areas. These factors meant more traveling time and financial spending. The sampling strategy deployed in this research as described in the preceding sections was designed to minimise these limitations that are related to the geographical spread of the participants. The sample size can also be a limitation of this study because of the scattered location of participants. Participants were located across different sites. However, in qualitative research, the focus is not on the size of the sample, but rather on the quality and depth of the information collected from the participants. The number of participants was influenced by the repetitive information that was provided by the participants (Mack, 2005).

This study was conducted during the period of Covid-19 and the government of South Africa had imposed Covid-19 regulations that needed to be observed by everyone. The lockdown and the third wave delayed the face-to-face meeting with participants. Therefore, Covid-19 was another limitation in this study. However, with protocols and guidelines that were available to mitigate the spread of the virus, I was able to arrange with participants to meet in an open area that had enough ventilation or outside where it was safe. I ensured that during the interviews that Covid-19 regulations are observed, and we did not spend a lot of time together unnecessarily. Five (5) participants were interviewed telephonically because they were not available for the face-to-face meetings due to the strict Covid-19 regulations.

3.7 Trustworthiness in the study

Maher et al. (2018) explain that trustworthiness is regarded as a more suitable principle for evaluating qualitative studies. Trustworthiness comprises credibility, transferability, dependability, and conformability while the rigorous process results in a trustworthy finding.

3.7.1 Credibility

Lincoln and Guba, (1985) explain that the credibility of research is based on the agreement between the participants and the researcher to be believable and appropriate. The authors further point out the five ways that can determine the credibility of research, prolonged engagement, persistent observation, triangulation, peer debriefing, and negative case analysis. Ahmad and Jan (2018) suggested several processes to be considered when using credibility to evaluate the quality of information including its believability, reliability, accuracy, and truthfulness. Credibility is used to evaluate the quality of information by determining its believability, reliability, accuracy, and truthfulness (Ahmad and Jan 2018).

To ensure the credibility of the research, positive and negative findings were equally reported. Participants were purposefully chosen and interviewed with the same structured questionnaires, interviews, and observation. Enough time was spent with the participants during the interviews.

3.7.2 Transferability

Korstjens and Moser (2018) indicate that transferability looks at the applicability of information provided by the researcher to enable the reader to determine whether the findings are transferable to their setup. Transferability is the number of research findings that can be applied from one study to another (Shenton, 2004).

Qualitative methods were used to assist the researcher in transferring a large amount of data to other contexts and different setups. Collected data was from the operations and maintenance department and the water treatment plants that have been identified in the study. The manageable sampling size enabled the researcher to transfer all the information on the report.

3.7.3 Dependability

Kennedy-Clark (2012) states that, if the same work with uniform methods is repeated by the same participants, the output of that work will the same. Dependability involves an element of consistency, and the process of analysing data should conform to the design standard of that process (Korstjens and Moser, 2018).

The dependability of the trustworthiness of the data was addressed by the research design. The process that was followed to recruit participants convinced the researcher that the data can be trusted. Shenton (2004) points out that to address the dependability issue more directly, the processes within the study should be reported in detail, thereby enabling a future researcher to repeat the work, if not necessarily to gain the same results.

3.7.4 Confirmability

Kennedy-Clark, (2012) explains that confirmability gives assurance to the findings of the research to be the outcome of the ideas and experiences of the participants and not what the researcher chose to report on. Interpretation of the data should depend on findings made on the ground and not be centred on the views or preferences of the researcher.

In this study, the researcher took steps in confirming the objectivity of the data by ensuring that the findings are the ideas of the participants, and the information is not altered. Not all findings or data collected were taken as accurate without confirming its credibility.

3.8 Ethical considerations

Jennings (2014) explains that ethical standards are not standards of law, but they are higher standards. Ethical standards are the rules of conduct that govern society and are the expectations of an individual's behaviour. The author further explains that ethics is honesty, fairness, and justice. In research, ethics play a critical role, participants should be protected from any harm, not be exploited, it should be explained to them what the nature of the study is and how the findings will be used. Participants should voluntarily take part in the research and their information should be confidential (Leavy, 2014). Fleming and Zegwaard (2018) point out that before the start of data collection from participants, the research ethics committee must approve the data collection process as approval cannot be given after data collection has already started.

To avoid challenges and considering the IIEMSA research requirements, ethical matters were addressed during the proposal defence. Ethical clearance was requested from IIEMSA and Lepelle Northern Water before the data collection process could commence, and clearance was approved (see attached Appendix C and D).

Participants were informed of their right to participate or refuse to be part of the study and gave consent for their participation. The participants were assured that their participation and names will remain confidential, and their privacy will not be violated during the interviews. The purpose of the study was explained and their rights to ask questions during the interviews were respected. I asked participants permission to record interviews and some participants agreed and some did not, so I respected their rights and recorded only those participants who agreed.

Permission to interview maintenance staff was requested from scheme managers and the participants were protected against any physical, psychological, moral, and reputational harm. The research was conducted with openness, transparency, and truthfulness.

3.9 Conclusion

This chapter presented the research design, methodology, , data collection tools, data analysis, limitations of the study, and trustworthiness. The research adhered to all ethical considerations as prescribed by IIEMSA. The aim and objectives of the study were addressed by the responses given by the participants. A qualitative approach was used in conducting the study. The case study approach was used to explore, describe, and validate the data collection methods for this study including documentation analysis, structured questionnaires, and structured interviews. The trustworthiness of the study considered the credibility, transferability, dependability, and confirmability of the data. The next chapter will present the detailed findings from the study.

CHAPTER FOUR

RESEARCH FINDINGS

4.1 Introduction

This chapter presents the findings of the research and analyses these findings in relation to the aims and objectives of the study. The study aimed to explore the maintenance and management process in water infrastructure and recommend a better or more effective maintenance strategy that can be used to address water challenges. The data was collected through structured questionnaires, structured interviews, and documentation. Lepelle Northern Water (LNW) documents were analysed to understand what exists, what should exist, and what plans, and policies indicate regarding the business operations of the organisation. The chapter has been divided into two sections.

The first section provides a brief background on the data analysed from the existing documentation in Lepelle Northern Water to gain an understanding of its mandate in the water sector. Some of these documents included budget management policy, business plans, human resource policy, information technology strategy, and maintenance strategy. Other documents like security management, operations and maintenance procedure manuals, and infrastructure maintenance records were not available during the investigations. The second section is subdivided into themes that deal with the strategic role of maintenance.

4.2 Section 1: Documentation

The Lepelle Northern Water, (2020) report, explains that Lepelle Northern Water is a public water entity that was established in terms of the Water Services Act, Act No. 108 of 1997, and its board reports directly to the Minister of the Department of Water and Sanitation. The mandate of Lepelle Northern Water is “to provide bulk water services and sanitation to other water institutions in the Limpopo province”

4.2.1 Existing documents

4.2.1.1 Budget Management Policy

Through the analysis of the LNW budget management policy document, the study found that annual budgets should be prepared following the budget guidelines and that a draft budget should be submitted to all relevant stakeholders in LNW as prescribed in the procedures. The approval of the budget is done in line with the Public Finance Management Act. Each year budget owners prepare their budgets as a zero-based budget for their departments and unit (Participant LI04, 04 April, 2021).

4.2.1.2 Business Plan

Lepelle Northern Water, (2020)document shows that for Lepelle Northern Water to accomplish its strategic objectives, the following key issues should be addressed, mitigated, and managed.

- Negative effects and consequences of climate change with drought currently impacting the availability of water resources.
- Ageing infrastructure
- Deteriorating raw water quality
- Non-payment by the water service authorities for bulk water services
- High operational costs
- Changes in municipal leadership (administratively and politically), and
- Water demand that exceeds available raw water allocation (over-abstraction)

Lepelle Northern Water, (2020) indicated that LNW views maintenance management as a proactive way of avoiding interruptions in the supply of services. Maintaining assets through their entire life cycle is critical to optimising return on assets. The report further stated that LNW is continuously making sufficient budget allocation towards the maintenance of its assets and that sufficient depreciation on equipment has also been provided for.

The plan continues to indicate that potential scope for cost savings exist in the following areas:

- Reduction of breakdowns and damage to equipment through the training and development of maintenance personnel.
- Introduction of roaming maintenance teams performing specialised duties i.e., laser alignment, vibration analysis, and thermal imaging. Greater economies of scale when acquiring spare parts and stock items.

- Costing of any repair work and computerised capturing and cost allocation to each element of the system allowing for the early detection of trouble making equipment or installation and replacement thereof,
- Most probable cost savings due to outsourcing of specialised equipment or facilities.
- Reduction of sewage pump maintenance costs because of reducing the volume of rainwater and grit entering the sewer system.

4.2.1.3 The Human Resource Policy

LNW human resources policy manual indicates that LNW encourages self-development amongst its employees. The organisation grants employees leave days for attending classes and preparation for examinations. Employees are also given a bursary when a specific course of study is considered by LNW to be beneficial to the organisation (Lepelle Northern Water, 2017).

4.2.1.4 Information Technology Strategy

The strategy explains that it intends to bring solutions over systems. It further indicates that it considers the fit between updated/re-engineered business processes and supporting technologies. The strategy aims to identify and prioritise areas for improvement, and potential effectiveness across business processes and systems to create solutions (Lepelle Northern Water, 2019).

4.2.1.5 Maintenance Strategy

According to the Lepelle Northern Water, (2020)document, the strategic objectives of the maintenance strategy were changed but the study found that the existing strategy document was still referring to the old objectives of the 2017 financial year. The document further shows that the maintenance strategy should be reviewed annually. Lepelle Northern Water, (2020)document listed reliability-centred maintenance, preventive, reactive, and predictive maintenance approaches as the adopted maintenance strategies by Lepelle Northern Water. The maintenance planning resources included budget, tools, labour, enterprise asset management system, spares, and training. The strategy covered some of the information that was shared by the participants during the interviews and in the questionnaires. During the process of data collection, the participants indicated that:

> "*LNW has adopted 4 types of maintenance strategies, corrective, preventive,*

condition-based, and risk-based maintenance" (Participant LI01).

"*The maintenance strategy informs the maintenance plans and LNW has adopted the Reliability Centred Maintenance (RCM) strategy*" (Participant LI02).

"*It is a plan that is used to maintain the infrastructure and Lepelle Northern Water has adopted RCM strategy"* (Participant LI05).

4.4.2 Progress reports

4.4.2.1 Infrastructure utilisation report

The analysis of the Lepelle Northern Water, (2017)document shows that the set target for the water infrastructure utilisation for Lepelle Northern Water is 95%. This study found that the key performance indicator (KPI) was not included in the Lepelle Northern Water, (2019), but LNW still reported on the target.

The Figure 4.1 indicates how LNW performed in the last three financial years on the water infrastructure utilisation. The figure shows that in the financial year 2017/2018, LNW achieved 97% while the lowest was 95% which was in the financial year 2019/2020. The analysis of the figure shows that performance in the utilisation of water infrastructure was declining overall, while it is noted that 95% is still an achievement.

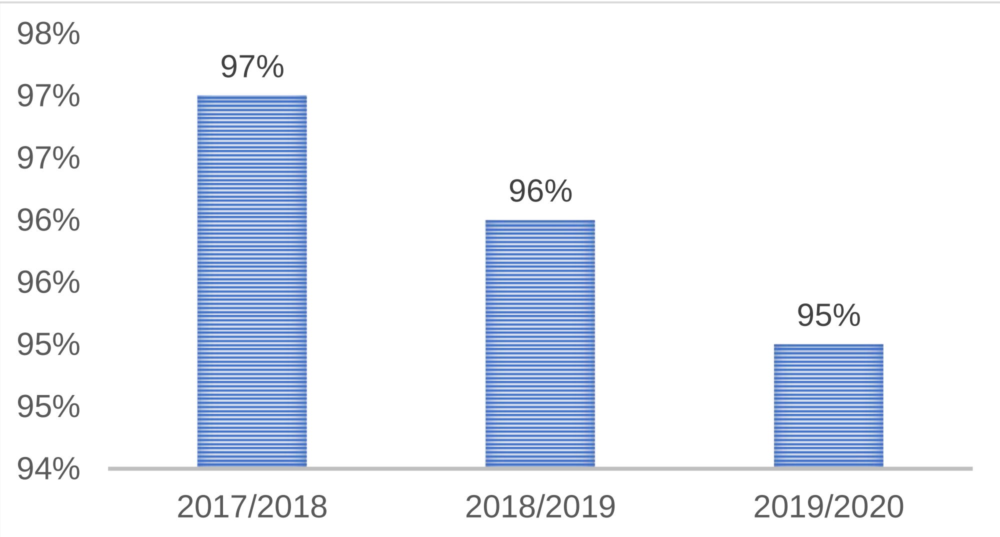

Figure 4.1: Water Infrastructure utilisation 2017/2018 – 2019/2020

Source: Lepelle Northern Water, (2017)

4.4.2.2 Supply interruption

The analysis of documentation established that performance targets were set for LNW to achieve business objectives which included water supply interruptions. Key performance indicators on water supply interruption (which is described as the number of unplanned interruptions to bulk supply each exceeding 24 hours) is 2%.

Lepelle Northern Water, (2017)document indicates that LNW aims to maintain infrastructure through its entire life cycle and to optimise return on assets. The study found that in the last three years, 2017/2018, 2018/2019, and 2019/2020 LNW achieved, 0.77%, 0.33%, and 0.48% which is below the target of 2%. The results show that LNW has achieved its objective of ensuring that interruptions do not go beyond 24 hours. Lepelle Northern Water, (2017)document also indicated that LNW is continuously making sufficient budget allocation towards the maintenance of its assets to mitigate water supply interruptions, and this was also pointed out by the participants during the interviews.

4.4.2.3 Annual performance report – non-revenue/water loss

According to the Lepelle Northern Water, (2019) water loss was reported to be at 7%, 8.66%, and 3.69% respectively.

Lepelle Northern Water, (2017)document indicates that the annual water loss target for LNW is 5%. The figures indicated that in 2019/2020, the water loss has come down. During the interviews , the participants indicated that unavailability of spares, poor maintenance, a ‘no care attitude’, and lack of training are some of the causes of reactive maintenance and that these have an impact on water loss. The reported figures for 2017/2018, 2018/2019, and 2019/2020 indicate fluctuations in water loss and that the target was only achieved in the 2019/2020 financial year when LNW achieved 3.69%. Therefore, it could be suggested that water loss fluctuations were probably due to the challenges that were indicated by the participants during the interviews.

4.4.2.4 Infrastructure assessment reports

- The water infrastructure conditional assessment report included the 32-year refurbishment plan, and the plan was analysed together with the internal monthly infrastructure assessments report. The analysis of the Water Infrastructure assessment report recommended the use of a competent Computerised Maintenance Management System (CMMS) to assist the Operations and

Maintenance department to effectively maintain infrastructure. The assessment report indicated that LNW had implemented SAP's Plant Maintenance module, but the use of the systems had been limited.

The report further clarified that the limited use of the SAP system could not be established conclusively but may include the perceived complexity of the system. The report indicated that stakeholders felt that they were left out of the initial implementation and decision-making process, limited reporting was initially set up for users, there was ineffective training on the use of the system, and there was a skewed focus on the other "core" modules. The assessment report suggests that there was no accompanying maintenance strategy document to give support to the maintenance schedules and no maintenance management plans to show how the process of managing maintenance, particularly concerning how feedback on maintenance is carried out and if its effectiveness was considered.

The documentary analysis additionally suggested that while the preventative maintenance schedules were available, there was little evidence that these schedules were always implemented and were overwhelmed by the sheer volume of reactive maintenance. From the Abaziyo Consulting Engineers (2020) report, the study found that there were no procedures in place during the implementation of the SAP system for LNW. The report indicated that LNW's departments worked in silo's hence the system was found to be ineffective by the operations and maintenance department. Most participants who were interviewed shared the same view with the consultants, as they complained about the ineffectiveness of the SAP Planned Maintenance module.

- The analysis of the LNW Maintenance Unit Report (2019), identifies several challenges and made recommendations for the maintenance of infrastructure. Some of the identified challenges include; extensive rust and corrosion on pipelines, makeshift maintenance practices, water leaks, equipment unavailability, poor and unsafe operation procedure by the maintenance teams, poor housekeeping, health and safety protocols not followed, a continuation of poor maintenance culture spreading across the WTP, disregard of maintenance codes and procedures, compromised availability standard as set by the organisation, water losses, wastage of organisational resources and the reactive maintenance approach practice been preferred over preventative maintenance.

  During the interviews, participants complained about many things which were also identified in the assessment report. The internal assessment report shows that, while it agrees with the participants, there is an issue of attitude that contributes to poor maintenance, maintenance codes, and maintenance procedures are disregarded. However, the documents indicate that LNW is continuously making sufficient budget allocation available towards the maintenance of infrastructure.

The section below presents some of the background data collected from fifteen participants who participated in a short, structured questionnaire.

4.3 Section 2: Strategic function of maintenance

4.3.1 Introduction

This section is a crucial component of the research, it explores participant's views around the maintenance activities and processes that are undertaken to achieve the business strategic objectives of Lepelle Northern Water. The section has been divided into five themes.

4.3.2 What maintenance strategy exists in Lepelle Northern Water?

As stated in Chapter One, the study sought to explore the challenges of water infrastructure maintenance and management and recommend a more effective maintenance strategy that can be used to address water infrastructure challenges. The benefits of the preventive maintenance strategy are outlined in Chapter Two. Participants were encouraged to share their views and experience concerning what they know about maintenance strategies.

When asked what strategy LNW had implemented participants stated different strategies such as corrective maintenance, preventive maintenance, condition-based maintenance, and risk-based maintenance as maintenance strategies adopted by Lepelle Northern Water (LNW) while some were not sure what strategy had been implemented by Lepelle Northern Water (LNW). All participants indicated that they have seen water infrastructure maintenance plans placed on the notice boards in the technical workshops and that the maintenance plans are developed from planned maintenance systems but the non-compliance to scheduling results in backlogs and ineffective maintenance. In explaining their understanding of maintenance strategies and how it works in LNW, participants stated that:

“Reliability Centred Maintenance - LNW has adopted the Reliable Centred Maintenance (RCM) approach which focuses on maintaining the critical items of infrastructure. The method employs Planned Preventive Maintenance (PPM), Condition Maintenance (also called Predictive Maintenance), and Reactive Maintenance techniques in an integrated manner to increase the probability that equipment will function in the required manner over its design life-cycle” (Participant LQ03).

Another participant indicated that:

“Maintenance strategy is the process of deciding what maintenance to do, when, and how often. These strategies range from optimisation of existing maintenance routines to eliminating the root causes of failures, to minimise maintenance requirements. Ultimately, the focus should be on improving equipment reliability while reducing the cost of ownership. There are 3 main types of strategies, namely design out, preventive maintenance, and corrective maintenance. LNW has adopted corrective maintenance, reactive and Adhoc maintenance to be precise which cost the organisation a lot of maintenance costs, loss of production due to unnecessary downtime, however, there is still a bit of preventive maintenance (predictive maintenance)” (Participant LQ11).

While the above participants define maintenance strategies, the below participant explained how the strategy is implemented.

“LNW has adopted the Reliability Centred Maintenance that is implemented to optimise the maintenance program. My understanding of this maintenance program is the implementation of a specific maintenance strategy on each of the assets of the Organisation. i.e., we combine Preventative and Predictive maintenance strategy at the certain pump station, while we prefer to use Reactive Maintenance on submersible pumps” (Participant LQ08).

The comments by the three participants highlight that they understand the consequences of non-compliance to maintenance strategies. They all acknowledged the existence of the maintenance strategies in LNW. Participants further explained that if planning is not correctly and realistically done, then the effects will be costly because of the damages or after-effects caused to the infrastructure. The non-adherence to the implementation of maintenance strategies can be costly to the organisation as infrastructure can fail prematurely and cause water supply disruptions.

4.3.3 Challenges of the reactive maintenance

From the participant's perspective, the factors indicated below illustrate the problems that LNW faces in achieving its strategic objectives. The planned maintenance unit of Lepelle Northern Water oversees developing maintenance plans, uploading them to the SAP system, and issuing job cards to the maintenance teams according to the planned timetable. The planned maintenance unit will analyse data and generate reports for management after receiving job cards from the maintenance team. With all the necessary resources provided, participants are faced with different challenges when executing their duties. The research participants were asked to list challenges that have an impact on water infrastructure maintenance and management. The section will address nine (9) challenges such as ineffective computerised maintenance management system (CMMS), lack of compliance to maintenance practices, insufficient budget, unavailability of maintenance spares, lack of training, attitude problems, theft and vandalism, illegal connections, and ageing infrastructure.

4.3.3.1 Ineffective computerised maintenance management system (CMMS)

A majority (two-thirds) of participants confirmed the availability and functionality of the asset management system and they described it differently as some mentioned the use of ISO 55000 while others mentioned the SAP system. A quarter of participants confirmed the availability of the system, but they raised their concerns on the limited utilisation and function of SAP. Participants pointed out that the system is expensive due to operating licenses and that the SAP system feedback is not well configured to give well-structured reports. Participants further indicated the inability of the system in enabling the tracking of all assets.

One participant expressed how they view the function of the maintenance system by indicating that:

> *"The results of the maintenance organisation are dependent upon the proper execution of the maintenance plan and general performance (quality, timeliness, and efficiency) of the workforce. This necessitated the implementation of a proper maintenance operational system, to answer the*

question, yes there is SAP in place, but it is underutilised, or it was not well executed. It is a core function from the finance side but to the Planned Maintenance it malfunctions. It is currently utilised to plan, schedule work orders and to capture them into the system" (Participant LQ02).

Another participant echoed the same sentiment as the above by indicating that:

> *"Yes, there is. The system is not always fully functional as sometimes we prioritise on production because of the demand"* (Participant LQ14).

Adding to what the other participants explained, the third participant commented:

> *"Yes, we have SAP system in place and is not well utilised because of limitations of very expensive operating licenses and feedback is not well configured to give well structure reports. We use Excel to report while we have a system"* (Participant LQ05).

With the same views expressed by participants regarding the maintenance system, the study found that the LNW Information Technology (IT) strategy is aware of the need to reconfigure the SAP system and enhance the efficiency of the Plant Maintenance module. The same challenge of an ineffective SAP system was raised by the consultant for the infrastructure assessment. When designing an enterprise asset management system, organisations often lose focus and concentrate on the technology which lead the organisation to forget about the key business objectives of emphasised by the consultant report.

4.3.3.2 Lack of compliance to maintenance practices

The following participants were concerned about the lack of compliance with maintenance standards.

> *"Inspections are not done properly, checking if the equipment is running normally, oils, gland packings are not checked and not having a checklist"* (Participant LQ12).

> *“If Planning is not correctly and realistically done and the effects thereof are costly because of the damages or after-effects caused to the infrastructure”* (Participant LQ07).

Participants indicated issues of non-availability of guidelines such as checklists and poor planning as contributors to lack of compliance to maintenance standards. The analysis of the infrastructure assessment report indicated that while the preventative maintenance schedules were available, there was little evidence that these schedules were always implemented and were overwhelmed by the sheer volume of reactive maintenance. Poor maintenance and lack of compliance with maintenance standards pose a risk for the infrastructure to fail prematurely. With a lack of qualified personnel and funding, the system is put under pressure, and eventually, it fails to supply water.

4.3.3.3 Insufficient budget

The absence of adequate operations and maintenance and refurbishment budget was overwhelmingly indicated by two-thirds of the participants as a cause for reactive maintenance. The other third of participants indicated different contributors and they further mentioned that heads of units are responsible for preparing their budgets. Participants indicated that water treatment plant managers as end-users, use information from the assessments done by the maintenance unit to prepare their unit's budgets. With most participants showing their dissatisfaction with how the budget is handled by the finance department, one participant commented:

> *“No, the WTP budget draft does not get approved as submitted, resulting in finance cutting the budget, which then affects the maintenance needs”* (Participant LQ09).

The same sentiment was echoed by another participant who indicated that:

> *“The budget is sent to different WTP Managers for implementation and the defect that do not require budget gets done however that requires refurbishment budgets but does not get the attention required as the WTP’s do not get refurbishment budget as planned”*

In support of the two previous participants, and pointing out the results of lack of budget in maintenance the other two participants confirms:

> *"No, in most cases some of the equipment is not fixed/refurbished or maintained due to budget constraints"* (Participant LQ05)

> *" We have a planned maintenance strategy however we lack the resources to mitigate the reactive approach with the proactive approach. We need refurbishment budget"* (Participant LQ09).

The insufficient allocation of operations and maintenance, and infrastructure replacement budget can contribute to the continuous challenges of reactive maintenance in water infrastructure, and this is because the benefits of maintenance are long-term, and decision-makers have minimal incentives to boost maintenance spending. To avoid or minimise non-performance of maintenance that can cause deterioration of asset performance, the maintenance process should be adequately funded. Through the analysis of the budget management policy document, this study found that it is indicated in the document that end-users shall prepare their annual budget following budget guidelines and they will be done in line with the Public Finance Management Act. The analysis of the conditional assessment report indicated that there is a 30-year horizon refurbishment plan that the end-users must refer to when preparing their annual budgets (Abaziyo Consulting Engineers, 2020). LNW_19BP document shows that Lepelle Northern Water (LNW) is allocating sufficient budget towards the maintenance of its infrastructure.

4.3.3.4 Unavailability of maintenance spares

Spares are critical during breakdowns, their availability reduces the downtime of machinery. When the spares are readily available, the machine can be returned to production within a short period.

The majority (two-thirds) of participants agreed that maintenance spares are unavailable, and they are only procured when required. They further indicated that even if the spares are available, they are insufficient due to the ineffectiveness of the current system and they are unable to manage them. Participants expressed their views as follows:

“Yes, we do keep critical maintenance spares in our storerooms, and we buy additional spares when the number of remaining ones reach the ordering limit” (Participant LQ08).

“Insufficient due to the ineffectiveness of the current system we are unable to manage this aspect” (Participant LQ03).

“We do not have maintenance spares on-site. We normally buy when is required due to our financial situation” (Participant LQ05).

The comments by participants indicate mixed views about the management of spares which have an impact on how they attend to the maintenance of infrastructure. The analysis of the Lepelle Northern Water, (2019)document indicates the intention of LNW in ensuring greater economies of scale when acquiring spare parts and stock items. The study also notes that during the interviews, participants complained about the unavailability of critical spares in their stores. The control and positioning of spare parts are critical in a time of emergencies so that downtime can be reduced.

4.3.3.5 Lack of training

LNW developed an onsite technical training centre for employees to attend annual refresher courses and the aim is for the employees to perform their duties effectively. Technical training included, laser alignment, steel pipe welding, bearing removals and installations, water pump repairs, and gearboxes overhauling (Participant LI06,16 April, 2021).

The non-existence of technical training was cited by half of the participants. A quarter of participants indicated that they had done the root cause analysis training while the remaining quarter of participants attended different training such as cable joint, pump and valve maintenance, steel, and fiberglass pipe repairs. The concern with the lack of training by participants is that it affects their work performance because when a new system or infrastructure is brought in, they are unable to maintain it according to the required standards. Participants expressed their concern in this way:

“In, 2020 no training was done, however in 1999 all necessary safety training was done” (Participant LQ07).

The response indicates that while training is taking place, it is not related to technical training. These views were supported by another participant by indicating that:

> *"The organisation has stopped financing training. I have only attended health and safety training e.g., incident investigation and SHE rep"* (Participant LQ01).

The view by this participant suggests that the organisation is not considering technical training as a priority while it prioritises health and safety training. Another participant indicated that:

> *"I attended a root cause analysis course and Maintenance Planner course from March 2020 to date until September 2021"* (Participant LQ05).

From what participants indicated, there is a lack of technical training on pump efficiency testing and electrical high voltage maintenance. The participant's concern is that LNW is more interested in safety training. Documentary analysis of Lepelle Northern Water, (2017) indicated that employees are given a bursary when a specific course of study is considered by LNW to be beneficial to the organisation. This shows that LNW presented employees with an opportunity to improve their skills as lack or non-existence of relevant training can negatively affect the maintenance of infrastructure.

4.3.3.6 Attitude problem

Attitude, motivation, and empowerment of employees benefit the organisation as these outcomes can be achieved through the training of employees. The unfriendly and uncooperative behaviour of a co-worker with an attitude problem does not only affect other colleagues but also affects the output and finances of the organisation. The participants were of the view that:

> *"The laziness and incapacity of the maintenance team are affecting the organisation as the water supply is continuously disrupted while the material is wasted during maintenance"* (Participant LQ04).

The frustration is shown by the below participant as he commented that:

> *"No care attitude of workers fails us"* (Participant LQ06).

Considering what attitude problems can do to teamwork, one participant indicated that:

> *"Employees should be assessed annually to determine the state of their wellbeing because unhappy employees can be unsafe"* (Participant LQ14).

The study found that employees 'no care attitude' affected operations and maintenance processes, limiting proactive approaches to maintenance, and encouraging reactive approaches. The LNW Maintenance unit report (2019) indicated that there is a continuation of poor maintenance culture spreading across the WTP, with employees disregarding maintenance codes and procedures. The report further indicated that a 'no care attitude' does not only affect the operations and maintenance department but stakeholders are affected when resources are not properly and effectively utilised.

Attitude problems can go as far as affecting stakeholder relations as services are interrupted due to poor or lack of maintenance. Lack of maintenance brings challenges to services and production, and it cost organisations a lot of money. The challenge also makes it difficult for Lepelle Northern Water to perform and achieve its mandate of supplying uninterrupted water services. Participants indicated that reactive maintenance has the potential to disrupt the operation of the organisation and can result in revenue loss. The study found that the participants acknowledge that preventive maintenance plans are available, and the emergency response team has been established with relevant skills to ensure the availability of the equipment and to conduct the root cause analysis on critical infrastructure failures.

4.3.3.7 Theft and Vandalism

Theft and vandalism of water infrastructure causes interruptions to the supply of water to communities and businesses. There was concern expressed by all participants about the high incidents of theft and vandalism at the booster pump stations and reservoirs. Many cases have been reported to the South African Police Services and the Water Service Authorities (WSA). Participants also indicated that due to these challenges, water supply is interrupted, and maintenance costs go up.

> *"Our main pipelines go through villages and some of the settlements are*

illegal so communities will do their connections and cause leaks on the pipelines. Valve chambers are vandalized as they try to do connections and they close some valve chambers with cement concrete so that we must not remove the illegal connections. Some components at the reservoirs and pump stations are stolen. The community vandalises the CCTV cameras so that they can gain entry at the pump stations since there is no warm body security" (Participant LQ07).

"We are experiencing high water losses and supply interruption due to theft and vandalism. The teams work overtime to repair the vandalised pipelines and the integrity of the infrastructure is affected while our infrastructure is also ageing. When electrical cables are stolen at the outside pump stations, we stop pumping and it takes a long time to replace the cables because the spares are not readily available at the stores. Communities will then complain about not receiving water while their members are stealing the cables" (Participant LQ10).

"Theft and vandalism impact negatively on operations and maintenance. Communities steal telemetry systems at the reservoirs including the solar panels and this results in reservoirs overflowing and water being wasted. Criminal cases are opened with the South African Policy Services, but the incidents do not stop" (Participant LQ15).

The study indicates that security monitoring systems at the booster pump stations and reservoirs are not sufficient as perpetrators can gain access to the stations. The unavailability of LNW security strategy documents makes it difficult for the WTP's to implement standard monitoring systems in the organisation. Systems that can deter, detect, delay, and give indications before the attack on the system, can effectively protect pump stations and infrastructure. Paying customers are mostly affected when infrastructure is vandalised, parts are stripped, and pump stations become dysfunctional and non-operational. When some communities realise that they are not receiving services they believe that they are been deprived of their constitutional rights to receive basic services.

4.3.3.8 Illegal connections

Illegal connections on the main pipeline are cited by most participants as one of the major problems affecting the lifespan of infrastructure. Participants indicated that due to large settlements on the servitude of LNW and with no reticulated water system, communities tamper with infrastructure and that results in high water loss and frequent pipe bursts. Some participants pointed out that, if proper maintenance could be done, Lepelle Northern Water would benefit financially with limited infrastructure breakdowns and stakeholder relations would be healthy because the water supply would not be interrupted. The concern on this challenge is evident from the following responses:

> *"Due to large settlements which are not reticulated, we are encountering a high number of illegal connections and vandalism of infrastructure"* (Participant LQ01).

The participant further suggested to LNW how illegal connections can be resolved:

> *"Identifying the critical points or more affected areas and replacing the infrastructure"* (Participant LQ01).

Collaboration in dealing with illegal connections is emphasised by the third participant:

> *"I think illegal connections need all stakeholders to play their part, WSA's, communities, and LNW needs to do community awareness campaigns on the importance of protecting infrastructure. Illegal connections affect everyone as paying customers are not getting water as expected and businesses are also affected. Infrastructure life span if negatively affected because doing repairs now and then affects its integrity and it will fail more often"* (Participant LQ07).

The result of this study suggests that while there is a challenge of poor maintenance, communities settle illegally within the servitude of LNW and start to make illegal water connections along the pipeline. The results also suggest the decline in the life span of infrastructure due to the unauthorised connections and repetitive repairs of the failing pipelines.

4.3.3.9 Ageing infrastructure

Most of the infrastructure has passed its expected lifespan of 20 years although WTP's are still able to maintain and repair what is still available and supply water (Abaziyo Consulting Engineers, 2020). With the comments made by the participants on the lack of funds and the non-implementation of the refurbishment plan by LNW, challenges of breakdowns and supply interruptions will continue to exist. While pipelines are continuously bursting and wasting water, revenue collection is negatively affected, and communities' resort to illegal connections so that they can have drinking water. The view by most participants on ageing infrastructure is that:

> *"Ageing infrastructure creates unpredictable failures as emergency work results in more corrective approach"* (Participant LQ03).
>
> *Some major factors of reactive maintenance are ageing infrastructure and vandalism and the effects are, water supply interruptions that lead to negative customer satisfaction, deteriorating water quality, and high maintenance cost"* (Participant LQ08)

The below participant advised that:

> *"LNW need to implement the 30-year refurbishment plan to address backlog on infrastructure"* (Participant LQ05)

The challenge of ageing infrastructure is affecting the business of LNW because services are affected when infrastructure fails. Corruption and poor financial management have resulted in infrastructure not being maintained. The South African government has tried to bail out State-Owned Enterprises (SOE) through government guarantees so that SOE's would be able to provide essential services. The global financial crisis has also forced the government to rely on the private sector for financing infrastructure through the Infrastructure Fund (Marimuthu, 2020).

4.3.4 Impacts of reactive maintenance in water supply

4.3.4.1 Revenue loss

From the perspective of participants, loss of revenue is caused by many factors such as water loss, vandalism, and interruption in the water supply. While there is a challenge regarding the lack of funding for maintenance, it will be difficult for LNW to replace vandalised infrastructure that results in the loss of millions of Rands if there is no revenue collection. These views are expressed in a response from one participant:

> *"It is seriously affected if equipment maintenance is not properly done. Loss of revenue and water supply interruption is experienced"* (Participant LQ11)

Lack of infrastructure maintenance comes out in the below response as one of the reasons why LNW is failing to collect revenue:

> *"Literally without maintaining the infrastructure, we cannot purify and pump clean water to consumers, and currently LNW is heading towards that direction because of the financial situation. Some of the infrastructures are ignored and left for failure so revenue collection will be a problem"* (Participant LQ07).

This finding highlights the possibility that the organisation can lose revenue because of unrepaired infrastructure, as high-water loss can have an impact on water supply and the organisation fails to collect revenue from customers. Some of the interviewed participants also raised concerns about the failure of LNW to collect revenue due to unresolved infrastructure challenges. Organisations lose revenue when infrastructure breaks down because the technician will be paid overtime to repair the failed infrastructure while production is lost.

4.3.4.2 Water loss

Considering the challenges of low dam levels in South Africa, participants believe that illegal water connections on the main pipelines, vandalism, and poor maintenance cause high water loss. Through the analysis of documents, the study found that LNW has set a target of 5% for the organisation that needs to be achieved annually by the WTP and the organisation. With the concern raised by the participants on poor maintenance, to achieve the 5% water loss will need effective maintenance to be in place.

"South Africa is a water-scarce country so if LNW is not prioritizing maintenance and availing budgets, it will be difficult for us to achieve the 5% target. Finance always cut the budgets and we struggle to fix infrastructure" (Participant LQ10).

One participant suggests a solution for LNW to address water loss issues by indicating that:

"The effect of reactive maintenance is this high-water loss which we are experiencing daily from our Plants. Infrastructure is ageing and communities are making unauthorised connections on the main pipelines. I think Lepelle must stop with projects and concentrate on maintenance" (Participant LQ07).

In supporting the above participants in proposing solutions to LNW. The below participant is of the view that:

"Aging infrastructure creates unpredictable failures as a lot of emergency work result in more corrective approach while more water will be lost if nothing is done urgently" (Participant LQ03)

The three responses by the participants indicate that they are aware of their role to ensure that the 5% water loss is achieved and water loss should be addressed. High water loss or nonrevenue water has a significant impact on the water supply.

4.3.4.3 Breakdowns

An analysis of the responses by participants in this study shows that breakdowns are due to ageing infrastructure and poor maintenance. These breakdowns are observed by participants to be occurring at different time intervals as indicated below:

"Too often especially after Covid 19 due to poor maintenance, vandalism and high-water demand not allowing maintenance shutdown to happen" (Participant LQ05).

Indicating the interval and the cause for the breakdown the participants commented:

"Quarterly due to changes in operational needs or demand which result in more stress to the infrastructure" (Participant LQ03).

In brief, the third participant indicated:

"Every second week mainly due to ageing infrastructure" (Participant LQ01).

Breakdowns occur at different time intervals from most WTP's, and the common cause is found to be the ageing infrastructure and poor maintenance. The analysis of the Lepelle Northern Water, (2020)document shows that for LNW to accomplish its strategic objectives, key issues like ageing infrastructure should be addressed, mitigated, and managed. If infrastructure is not well managed and is neglected, the life span of the infrastructure will decline, and operating maintenance costs will increase. To prolong the life span of infrastructure, the system should be maintained according to the original manufacturers standards.

4.3.4.4 Water supply interruptions

The analysis of the LNW corporate plan indicates that LNW has set a target for the water treatment plants not to exceed 24 hours of water supply interruptions during their operations. While the organisation is working towards achieving the set targets, participants believe that:

"Ageing of water infrastructure make it too difficult for the organisation to perform and achieve its mandate" (Participant LQ04)

A majority (two-thirds) of participants indicate that a Service Level Agreement between Lepelle Northern Water and stakeholders is at risk because the water supply is not as per both party's contract of service.

"It gets affected as it can result on the core business disruptions. Unable to honour the contracts with our stakeholders resulting on reputation risk" (Participant LQ09)

One way in which LNW can ensure that stakeholders are satisfied with the services of water supply is by doing proper maintenance:

> *"If we do proper maintenance Lepelle Northern Water is benefitting financially with limited infrastructure breakdowns and Stakeholder relation will be healthy because the water supply will not be interrupted"* (Participant LQ05).

Through the implementation of operations and maintenance instructions as provided in the maintenance manuals when performing maintenance, supply interruption can be minimised or prevented. Consumers expect high-quality services that are cost-effective and when infrastructure is operated according to manufacturer instructions, the organisation will benefit from a preventive maintenance approach, and unplanned failures will be kept to a minimum.

4.3.5 Proposed solutions to the challenges of reactive maintenance

This study argues that the "reactive maintenance strategy" can be beneficial to the organisation for a short period, however, the organisations cannot rely on it for effective operations and for the organisations to achieve their objectives. Participants provided ideas on what can be done or what is already in place to resolve challenges of reactive maintenance in Lepelle Northern Water.

4.3.5.1 Infrastructure condition assessment

Half of the participants indicated that LNW appointed a consultant to conduct a conditional water infrastructure assessment to develop new plans to assist in addressing the ageing infrastructure. While the other half of the participants indicated that the assessment of infrastructure assists in preparing for the implementation of new water projects. The plans included the 30-year refurbishment plan and recommend the appropriate maintenance strategy and Enterprise Asset Management System that can be adopted by LNW to effectively maintain and manage infrastructure. The participants indicated that:

> *"LNW is now implementing Focused Improvement procedure in pursuit of sustainable performance improvement and achievement of LNW' s asset management objectives. This will improve asset performance, reduce asset-related costs and mitigate risks in all aspects of asset management".* (Participant LQ08).

Intending to improve the effectiveness and reliability of infrastructure in meeting the objectives of LNW, participants believed that LNW is putting a process in place as mentioned below:

> *"LNW has adopted the Reliability Centred Maintenance that is implemented to optimise the maintenance program. My understanding of this maintenance program is the implementation of a specific maintenance strategy on each of the assets of the Organisation. i.e., We combine Preventative and Predictive maintenance strategies at certain pump stations, while we prefer to use Reactive Maintenance on submersible pumps*" (Participant LQ08).

The same understanding is indicated by the below participant:

> *"Preventative maintenance strategies which deal with the critical infrastructure that enables the WTP to perform its primary mandate of pumping bulk water to the stakeholders with less interruption. Reactive maintenance strategies deal with the infrastructure that does not affect production. e.g., electrical lights plug".*(Participant LQ09).

Explaining further on the maintenance strategies, the participant commented:

> *"Maintenance strategy is the process of deciding what maintenance to do, when, and how often. These strategies range from optimisation of existing maintenance routines to eliminating the root causes of failures, to minimise maintenance requirements. Ultimately, the focus should be on improving equipment reliability while reducing the cost of ownership. There are 3 main types of strategies, namely design out, preventive maintenance, and corrective maintenance. LNW has adopted corrective maintenance, reactive and Adhoc maintenance to be precise and that affects the organisation negatively with high maintenance costs. There is a loss of production due to unnecessary downtime, however, there is still a bit of preventive maintenance (predictive maintenance)"* (Participant LQ06).

Participants explained that there is a refurbishment budget allocated to resolve challenges of infrastructure, and one indicated that:

> *"There is a yearly refurbishment budget however that depends on the asset that needs to be refurbished as they drop inefficiency"* (Participant LQ04).

4.3.5.2 Budget and Training

A majority (two-thirds) of participants pointed out that budget owners are allowed to submit their operations and capital budget needs. Internally, the Maintenance Unit was supporting Water Treatment Plant (WTP) by assessing pumps, motors, and pipelines and reviewing the maintenance plans for the information to be used by Water Treatment Plant Managers during budgeting.

According to human resources policy, LNW offers employees a bursary to develop their skills and for the employees to be able to perform their duties diligently.
A quarter of participants appreciated the opportunity presented to them by LNW to further their studies by offering them a bursary so that they can perform their duties effectively with minimal production interruption. On training and development, participants indicated,

> *"Planning Unit is busy identifying gaps in the maintenance team that can be sent to training"* (Participant LQ04).

Another participant added:

> *"I have presented an equipment maintenance training six times"* (Participant LQ06).

The proposed solutions indicated by the participants in resolving water infrastructure challenges are in support of what is indicated in the Lepelle Northern Water, (2020) document.

The study shows that participants are willing to be part of the solutions to the challenges of infrastructure maintenance that Lepelle Northern Water is trying to resolve.

4.3.5.3 Management of maintenance job cards

The Planned Maintenance Unit creates job cards from the SAP system and assigns them to maintenance technicians. The job cards detail the description of work that must be performed by maintenance technicians and provides instructions on how the work should be carried out. LNW's maintenance strategy outlines the step-by-step guide to completing the job cards and prioritisation of work.

All participants indicated that job cards are issued by the Maintenance Planning Technicians. They further indicated that job cards are not issued as per the schedule and sometimes they do not get them, and they end up using job requests. The completed job cards are either submitted to the WTP Manager or the Maintenance Officer or the Planning Technician. While participants confirmed that they do receive job cards, some of the participants were not aware of the maintenance strategy adopted by LNW and what maintenance system is used to generate job cards and reports.

Planned job cards are issued as per the maintenance plans and are used by participants to execute the maintenance. Some of the maintenance plans are pasted on the workshops notice boards for ease of reference by the maintenance team. This was indicated by the participants:

> *"Job cards are received weekly and yes we are aware of the maintenance plans and that they are posted on the notice board and get reviewed annually"* (Participant LI02).

Supporting what the first participant indicated above, another participant explained further that:

“Sometimes job cards are received once a month for the whole month and in case the job cards are not available, we use job request forms” (Participant LI05). After we have completed the job cards, we submit them to the maintenance officer for approval then to regional planning technician for final approval” (Participant LI05).

Another participant indicated that:

“We sign the job card and hazard identification risk assessment form and send it back to Planning for recording. We capture hours worked and submit them to the Maintenance Officer for signature” (Participant LI15)

The responses by most participants suggest that while job cards are available, the issuing schedule is not the same for all the Water Treatment Plants hence the maintenance team will use job request forms when the planned job cards are not available. The study established that the process of managing job cards is not standardised as participants indicated different intervals of receiving planned job cards.

4.3.5.4 Proper projects handover

Projects completed by the Technical Services Unit (TSU) are maintained by Water Treatment Plants maintenance teams after they have passed their warranty period. Participants raised their dissatisfaction with how projects are managed and indicated how the challenges can be resolved.

“Not informed about the new contractors/projects, not given chance to attend the meeting and understand what is going to happen. We do not know; they tell us only when it is the hand over” (Participant LI03).

The below participants proposed that:

“Projects should be handed over immediately after the warranty period has lapsed and all information should be shared with the maintenance team. Specifications, drawings, and maintenance manuals to be safely stored” (Participant LI12).

> *“Training on the operation and maintenance of the completed project should include all maintenance staff”* (Participant LI09).

The study found that there is a communication gap between the technical services unit and the Water Treatment Plants which are the end-users of the completed projects. Units are not integrated, and they operate in silo's which is a remedy for failure. The result of poor handover of completed projects will result in the new system failing from the start and that will cause financial losses to the organisation. Lack of internal communication within the organisation delays the implementation of strategies and the organisation fails to achieve its objectives. Services are delayed and there is a cost involved as customers are not receiving expected services.

4.4 Conclusion

This chapter presented the findings of the research in the context of the aims and objectives of the study. The data was collected through structured questionnaires, structured interviews, and documentation. Documentation was used to determine the mandate of Lepelle Northern Water and investigated strategies, plans, policies, and procedures that exist in LNW. Five (5) documents that included, budget management policy, corporate plan, human resource policy, information technology strategy, and maintenance strategy were analysed to get a picture of the current operations of LNW.

The structured questionnaire probed the level of positions held by the participants as per the functional structure and the period of service the participants have been in the employment of Lepelle Northern Water.

Participants expressed differing views on the strategic function of maintenance. Some were not quite sure about the strategy that was adopted by LNW. However, it was clear from their response that there is a maintenance strategy in the organisation but because of internal and external challenges, Water Treatment Works were forced to use the approach of being reactive to maintenance.

To conclude, a lack of maintenance did play a role in the challenges of reactive maintenance, and this was also indicated by participants. There is a need by Lepelle Northern Water to ensure that infrastructure is well looked after by supporting the operations and maintenance department. Participants raised critical issues that need intervention by the LNW Executive Management to ensure that the mandate to provide water supply services is achieved, and stakeholders are satisfied with the services rendered. The next chapter will discuss the implications of the key findings.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This chapter discusses the implication of the results concerning the research aim and objectives of the study given in Chapter One. The chapter is divided into three sections. The first section discusses the strategic role of maintenance with specific reference to its impact on bulk water supply. The second section of the chapter discusses the impact of reactive maintenance on water supply. The third section discusses possible solutions to the challenges of reactive maintenance.

The overall aim of this study was to explore the challenges of reactive maintenance in water infrastructure maintenance and recommend a better or more effective maintenance strategy. Therefore, my argument is that while a reactive maintenance strategy has some benefits to the maintenance and management of infrastructure, the reactive maintenance strategy cannot satisfy the objectives of Lepelle Northern Water to provide uninterrupted bulk water services. To assess how these challenges affect infrastructure maintenance, I then consider the wider relevance of the findings.

5.2 The strategic function of maintenance

The strategic function of maintenance is to assist the organisation to achieve its goals and objectives by ensuring the availability and efficiency of resources (Velmurugan and Dhingra, 2015). As the population grows, demand for water services increases, hence the need for LNW to ensure infrastructure is effectively maintained. Thus, the primary function of a water utility is to provide safe, affordable, and high-quality water that is enough for its customers (Jordan, 2000).

The results of this study show that while Lepelle Northern Water (LNW) is experiencing challenges due to reactive maintenance, the organisation has put in place measures to ensure that infrastructure is adequately maintained, and employees are offered opportunities to study and gain relevant skills. In addition to the available resources, Lepelle Northern Water has adopted a preventive maintenance strategy to achieve the mandate of providing uninterrupted water supply services to customers, however, implementation of the systems remains a challenge (Lepelle Northern Water, 2020).

This study observed that different factors contributed to participants abandoning preventive maintenance for a reactive maintenance approach. Poor management of maintenance spares delayed the availability of equipment and affected production. If spares are not procured timeously and not available during infrastructure breakdown, stakeholders are affected and the organisation in turn losses revenue. Maintenance can only be carried out effectively if special tools and materials are readily available on site and are not too far away from the work. (Gulati and Smith, 2009).

The results of this study shows that when resources are not available, services and stakeholders will be affected.

As this study has shown, reactive maintenance negatively affects the performance of organisations. While participants showed concern regarding the impact of training in executing their duties, it is important to have feedback and progress on the undertaken training. When errors are not identified early, employees will be disadvantaged when gaps are realised in a later stage after the damage has been done (Kum et al., 2014). Technical training offered to participants needs to be aligned to their tasks and responsibilities. The ability to analyse the real causes of the problem will minimise the repetitive failure of equipment. Participants in this study indicated that they did training on root cause analysis to determine the cause of infrastructure failures. The process of root cause analysis (RCA) investigates the cause-and-effect trail from the end failure of equipment back to the root cause. The process helps to reduce the likelihood that the equipment will fail again and increases availability (Daya, et al., 2009). When critical equipment is available and operational, production increases, and stakeholders will receive uninterrupted water supply.

Reactive maintenance is a response to a crisis such as breakdowns or equipment failure during operation (Dillion, n.d.)). Arguably, reactive maintenance affects business profitability, services, and business sustainability in the long term. Water loss in LNW affects business objectives and participants feel hopeless when ageing infrastructure worsens the situation. Addressing water loss needs all necessary resources to be available and be well utilised by competent employees through various interventions such as;

- Implementation of new methodologies that quantify physical and commercial losses more accurately.

- Introduction of more effective technical approaches to manage leakage and reduce system pressure.
- New processes of engaging the private sector, such as performance-based contracts.

Managers who lack the autonomy, accountability, and technical and managerial skills to provide reliable services will start to understand and have acknowledged the challenges and make gradual improvements to current policies and practices (Farley et al., 2010).

With no proper plans put in place to deal with water losses and the inability to meet the demand due to the reactive maintenance, water utilities will be unable to address challenges such as fast urbanisation, decreasing water supply, environmental pollution, old infrastructure, poor maintenance, and maintenance policy, poor record-keeping systems, lack of skills and technology, poor revenue collection and lack of funds, political, cultural, and social interference and influence, and illegal water connections (Farley et al., 2010). In this regard, I argue that preventive maintenance provides solutions to deal with elements of ineffective maintenance. Ab-Samat et al. (2013) suggest that organisations should adopt a preventive maintenance strategy as it is a simple and basic strategy that includes all the maintenance activities that keep equipment in good operational condition.

5.3 Impact of reactive maintenance on water supply

The three maintenance approaches, which are; preventive (including predictive), corrective, and breakdown maintenance have different roles concerning the maintenance of equipment. Activities in preventive maintenance are performed according to the schedule to minimise unpredicted failures, while corrective maintenance activities can be planned or unplanned to repair the faulty equipment. Breakdown maintenance strategies differ from the two above indicated strategies as the equipment is only attended to after it has failed (Jordan, 2000). Using these definitions, it can be argued that, in pursuit of the long-term goals of uninterrupted water supply, the best practice and system would need to focus on preventing unexpected failures and adopt an effective strategy. Having resources available, an infrastructure rehabilitation plan should be developed and implemented to repair leaking pipes and the plans should be supported by using monitoring devices to examine pipe leaks before they become visible. When pipes are found to be unrepairable or costly to repair, then they can be replaced (Duffy, 2013).

It is further noted that participants identified funding as a factor in addressing reactive maintenance challenges. Lack of funding in the maintenance and upgrading of water infrastructure delays the implementation of the rehabilitation or refurbishment plan. Water treatment plants struggle to keep infrastructure in a good working condition due to lack of budget and this results in breakdowns, revenue loss, water loss, and water supply interruption. For effective utilisation of water infrastructure, proper planning and investment must be provided into supporting water infrastructure (Duffy, 2013). Therefore, it can be concluded that, with the availability of a sufficient budget, ageing infrastructure can be addressed and maintenance can be executed effectively.

The findings of this research show that while participants were not certain about the adopted maintenance strategy by Lepelle Northern Water, they were aware of different strategies that exist. The preventive maintenance strategy was indicated as one of the adopted strategies however the reactive maintenance strategy was utilised as a preferred strategy by Water Treatment Plants. In the three tables below, Sullivan et al. (2002) identifies the advantages and disadvantages of reactive, preventive, and predictive maintenance procedures

Table 5.1: Reactive maintenance strategy

Advantages	Disadvantages
It is associated with low costs	Costs rise because of equipment downtime that was not expected.
Requires less staff	Higher cost of labour, especially if overtime is required
	Equipment failure may result in secondary equipment or process damage.
	Ineffective utilisation of personnel resources

Table 5.2: Preventive maintenance strategy

Advantages	Disadvantages
In capital-intensive procedures, it is cost-effective.	Catastrophic failures are still a possibility.
It is adaptable, allowing for changes in maintenance schedules.	It requires a lot of effort.
Extending the component's useful life,	It also entails the performance of unwanted maintenance.
Reduces equipment failure or process failure	Has the potential to cause unintended component damage while performing unnecessary maintenance

Table 5.3: Predictive maintenance strategy

Advantages	Disadvantages
Can extend the life of a component	An increase in diagnostic equipment investment
Make it possible to take preventative remedial action	Greater spending on employee training
Decreases equipment or process stoppages	Management is not seeing the savings possibilities.
Reduction in the cost of parts and labour	
Product quality improvement	
Enhanced worker and environmental protection	
Employee morale has improved	
Savings on energy	

Reactive maintenance can be three to four times more expensive than the preventive strategy. A reactive maintenance strategy is unpredictable and costly while the budget for planned maintenance can be more accurately predicted (ABM, 2019). The participants in the study wanted to see an effective strategy implemented that would address reactive maintenance issues indicated in Chapter 4. While other strategies have their benefits to infrastructure maintenance, the predictive maintenance strategy intends to solve the challenges of both reactive and preventive maintenance and avoids running the equipment to failure or replacing an operational component. (Prometheus group, 2020).

The concerns by participants on the adoption of reactive maintenance are reflected by Ochieng and Ominde (2020), who observed that reactive maintenance or poor maintenance may not be visible for a long period until the asset starts to show signs of wear and tear. The author further explains that organisations that experience resource pressures, tend to prioritise immediate operational needs rather than being proactive. The results of budget cuts means that organisation will spend more time on reactive maintenance. When reactive maintenance is preferred over proactive maintenance, asset life span is reduced and the consequence of that is, an increase in corrective maintenance, service interruptions, and failures. The delay in fixing the problem while it is still small, leads to much higher repair costs when the asset is repaired at a later stage (Ochieng and Ominde, 2020). Poorly maintained infrastructure affects water supply as there will be high water loss on the system. As communities experience water shortages, they will resort to illegal water connections. With a lack of maintenance, infrastructure deteriorates more rapidly and negatively impacts water quality and reliability of water supply (Mothetha et al., 2013).

5.4 Solutions to the challenges of a reactive maintenance strategy

The challenges of water infrastructure are complicated. They, therefore, need a combination of strategies and collaboration between stakeholders to address them. Maintenance managers and personnel must be aware that structures and equipment need different approaches to achieve a well-organised maintenance system (Jordan 2000). These challenges as indicated in Chapter 4, include insufficient funding, illegal water connections and vandalism, skills transfer, and ineffective maintenance systems.

Some of the participants showed a positive attitude towards the improvement of water infrastructure maintenance through the implementation of CMMS. They, however, raised concern on the approach that needs to be taken when implementing the new system and that the needs of the organisation should be prioritised. Their concerns are reflected by Wienker et al. (2016), who point out that implementation of Computerised Maintenance Management Systems (CMMS) often fails because the maintenance organisation is not prepared to be supported by a sophisticated computer system. The failure to implement the system successfully is further disrupted by a lack of communication within the organisation which results in employees not supporting and eventually rejecting the system.

Also important with the CMMS is that it provides organisations with alternatives in addressing the effectiveness of maintenance and operations challenges. Activities by maintenance staff can be automated and reduce the use of paperwork. Failures can be detected before they occur, availability of spare parts can be maximised and shortages eliminated, downtime can be reduced, and the expected life span of the equipment can be prolonged. CMMS provides maintenance teams with more options and many advantages compared to manual tracking systems in operations (Sullivan et al., 2002). According to participants, the available system is not effective, and it compromises maintenance, therefore, from this statement, it can be argued that LNW's CMMS system is available however the organisation is not benefiting from its existence. Participants showed an understanding of how the system should operate and what is expected from the system especially on issues of maintenance. The implemented maintenance system was found to be ineffective and not properly configured to produce maintenance reports. While the organisation was looking at bringing in an effective system that can be easily integrated with other existing systems, the operations and maintenance department was using Excel and Word documents for reporting.

Wienker et al. (2016) advise that it is important that before an organisation adopts a CMMS, there is a need for an organisation to move from a reactive strategy to preventive strategy. The preventive strategy will need to be implemented across the organisation. It must be noted that CMMS is not a tool that will change reactive maintenance strategy as this concept can lead to poor usage of the available modules of the system.

Before providing training to the employees on the use of the system or for any work-related matters, the organisations must first conduct an assessment to identify the problem and decide if there is a need to provide training to the employees as sometimes the problem might be a lack of discipline and not a lack of training (Smith, 2003). The author further believes that before training can be considered as a solution to problems in maintenance, the organisation needs to find answers to the below questions:

- Will training resolve my problem?
- How much money will I save by implementing this training programme?
- How much will the training cost?
- Is there a payback on this training?

The findings of this study illustrate that a lack of training can frustrate participants and affect the maintenance of infrastructure. Aguinis and Kraiger (2009) point out that training can increase the performance of individuals and teams. The statement is supported by Govender (2019), who indicates that the deterioration of infrastructure is the result of the loss of skilled human resources. As highlighted in Chapter 4, participants raised concerns about the lack of training which affects their performance and eventually maintenance becomes affected. When maintenance is not executed effectively the organisation starts to feel the effects and water service delivery will be interrupted. Loss of institutional knowledge, experience, and competency results in poor performance by the water sector (Nkondo, 2012). It is important to note that, when operators, maintenance technicians, and support staff have the right skills, infrastructure will be effectively maintained (Gulati and Smith, 2009).

To emphasise the importance of training, the findings of the study suggest that, to improve the maintenance performance of personnel and to perform the job effectively and efficiently, employees should be skilled (Velmurugan and Dhingra, 2015). In the absence of effective training, it is difficult to achieve business objectives (Velmurugan and Dhingra, 2015).

Amongst its many plans in addressing maintenance challenges, Lepelle Northern Water supports the operations and maintenance department towards the maintenance of infrastructure. Continuous improvement of maintenance is another strategy applied by LNW in ensuring infrastructure is maintained and preventive maintenance is applied across WTP’s. Preventative and work management processes work as a chain that must not be broken. The two processes form a complete success in maintenance management. With preventive maintenance, problems are prevented by conducting regular inspections before infrastructure breaks (Idammar, 2020). Furthermore, to support effective maintenance, the adoption of preventive maintenance was found to be implemented in LNW, and plans were identified to achieve business objectives. Figure 5.1 shows the continuous improvement process of moving away from reactive or corrective maintenance towards a preventive maintenance strategy.

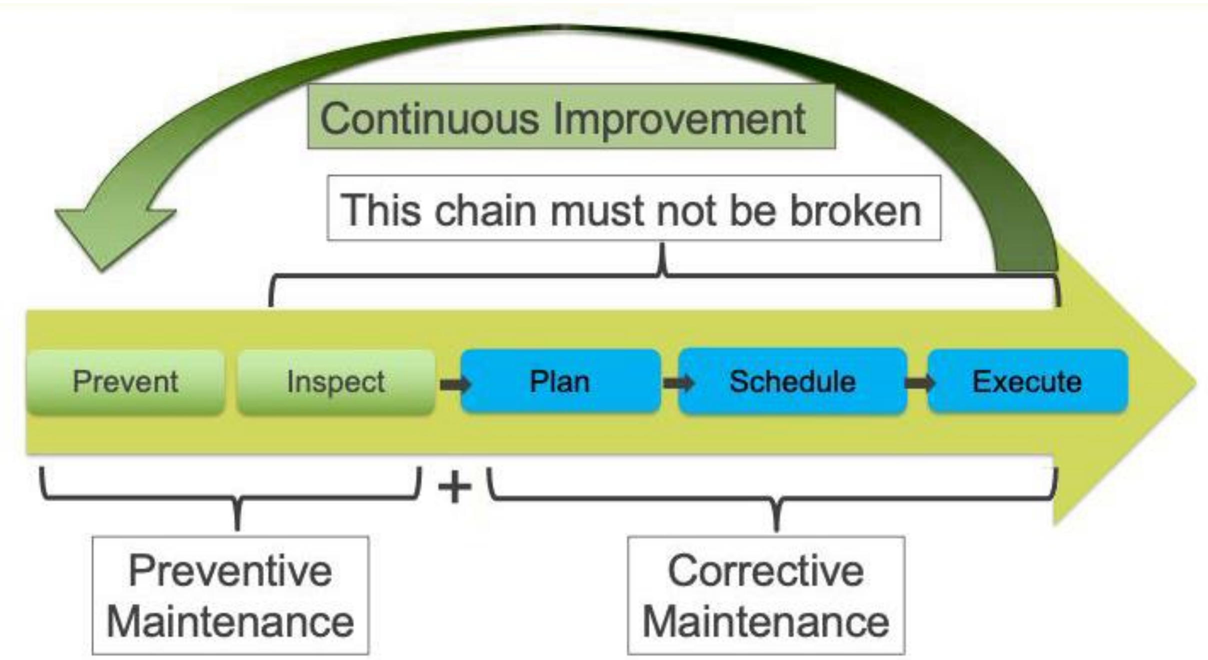

Figure 5.1 Continuous improvement

Source: Idammar, (2020)

Okoh et al. (2016) use examples drawn from other scholars to illustrate the influence of maintenance on the life-cycle phase of infrastructure.

Table 5.4: Influence of maintenance on infrastructure life cycle

Life-cycle phase	**Maintenance influence**
Needs/feasibility assessment	Maintenance workers should be included in the early stages of product development to identify and analyse what maintenance is required to keep the

	product in excellent working condition. Maintenance staff can learn what type of maintenance data to include, what type of maintenance method to recommend, how to do the maintenance, and how to incorporate maintenance into life cycle costing, etc.
Design	Maintenance staff must collaborate with design engineers to promote a product's design and maintainability.
Procurement/ development	Maintenance staff and procurement personnel can work together to maintain quality by evaluating and confirming the specifications of the assets and spare parts that are being delivered. Construction and installation for maintainability could also be promoted by maintenance workers.
Operation/ Utilisation	Maintenance and operations workers can work together to mitigate risk, for example, by agreeing on a shared agreement on potential trade-offs that will strike a balance between business and safety goals. Production staff, for example, may eliminate specific dangers in production-related, safety-critical systems prior to maintenance. (Okoh and Haugen, 2015).
Maintenance	Maintenance professionals have the technical expertise to guarantee that goods are kept or restored to a state

	where they can successfully execute their responsibilities.
Life extension (if applicable)	Service or system life extension, life cycle management, or life optimisation are all terms used to describe the process of extending the life of a product or service. The financial savings and the ability to postpone the disposal of older equipment are appealing. However, risk and cost-benefit analyses must be addressed; otherwise, short-term cost savings may be outweighed by higher long-term expenses, safety issues, or lower system performance. Maintenance employees can contribute significantly to the decision-making process.
Decommissioning	Assets become obsolete and non-competitive as technology progresses. Companies that do not align or adapt to new changes risk being outperformed by new monopoly-forming companies. Maintenance workers can assist in deciding whether to decommission.
Post decommissioning	Maintenance staff are required to assure the availability of equipment for site reinstatement or the removal of material that could hinder other site usage.

Source: Okoh et al., (2016)

Asset management and the maintenance strategy need to be the driving force behind companies and business operational needs (Nate et al., 2015). The view of Govender (2019) is that a preventative maintenance strategy implores better planning, prolongs infrastructure functionality, and reduces the possibility of infrastructure failure. Therefore, organisations need to adopt a preventative maintenance strategy to ensure infrastructure challenges are resolved.

Furthermore, as this study has shown, different maintenance processes are undertaken by LNW to ensure infrastructure is maintained, however, the issue of lack of funding always came up as a concern from the participants. If the water sector is to achieve its operational output, operations, maintenance, and refurbishment plans should be adequately funded and investment in water infrastructure doubled (Nkondo, 2012).

It should be noted that organisations adopt many tools and strategies such as Failure Mode and Effects Analysis (FMEA), Reliability Centred Maintenance (RCM), and predictive technologies to optimise maintenance work. These strategies require assets to be designed with high reliability and ease of maintenance features (Gulati and Smith, 2009). According to Daya et al. (2009), to establish an effective organisation, the following criteria should be considered:

- Roles and responsibilities are clearly defined and assigned.
- The organization puts maintenance in the right place in the organisation.
- The flow of information is both from top-down and bottom-up.
- A span of control is effective and supported with well-trained personal.
- Maintenance work is effectively controlled.
- Continuous improvement is built into the structure.
- Maintenance costs are minimised.
- Motivation and organisation culture.

To decide on an appropriate and effective strategy to maintain infrastructure, the organisation should ask these questions as indicated below:

- What are the functions and associated desired standards of performance of the asset in its present operating functions?

- What are the possible functional failures?
- What causes each functional failure (failure modes)?
- What happens when each failure occurs (failure effects)?
- In what way does each failure matter (failure consequences)?
- What should be done to predict or prevent each failure (proactive tasks and task intervals)?
- What should be done if a suitable proactive task cannot be found (Andrawus et al., 2006)?

While processes are unfolding in addressing challenges of reactive maintenance and water supply issues, it should be noted that employee's wellness should be looked after by the organisation. As this study showed, participants were happy to assist the organisation in achieving its objectives, however, attitude problems by some employees affected other team members. Attitude does not only affect employees, but it can cause damage to the reputation of the organisation. Customers will complain when not receiving services and view the organisation as failing in delivering its mandate and objectives. The attitude of employees plays an important part in a company achieving productivity. When employees are satisfied and have the skills and experience to do the job, they can perform and be productive (Offerbike et al., 2018).

The findings of this study have shown that LNW's operations serve a very large number of customers or stakeholders, all of whom are key. Figure 5.2 summarises the presentation of their composition.

Figure 5.2 LNW stakeholders

Source: Lepelle Northern Water, (2017)

Stakeholders are affected by the development of infrastructure projects hence their inputs in the development of the project are important. Infrastructure influences public development and social issues (Lim and Yang, 2008). Important in stakeholder involvement in water management, is that they bring solutions to water management situations. Stakeholders know what they want and need, their involvement in the planning and implementation of water infrastructure projects is critical (Morrison, 2003).

The findings of this study showed that in the context of revenue collection, illegal connections, vandalism, and water loss, stakeholders play a critical role. Stakeholders when participating in water infrastructure projects, bring in investments, communicate to media and take ownership of the infrastructure. Therefore, water infrastructure challenges can be eliminated if not minimised.

5.5 Conclusion

In this study, I suggest that the preventive maintenance strategy be considered by Lepelle Northern Water (LNW) as a better and more effective strategy than the reactive maintenance strategy. However, the success of the implementation of the preventive maintenance strategy will depend on the collaboration between stakeholders.

Lepelle Northern Water is the main bulk water supplier in Limpopo province, and it faces different challenges in the maintenance of infrastructure. There are maintenance issues that impact the mandate of LNW of providing uninterrupted water services. Participants are preferring a reactive maintenance strategy instead of the preventive strategy due to challenges indicated in Chapter 4. The reactive maintenance strategy affects the water supply as the organisation experiences, poor maintenance of infrastructure, illegal connections due to unavailability of water, supply interruptions because of infrastructure vandalism, and lack of budget to maintain infrastructure and procure maintenance spares.

Benefits of the implementation of a preventive maintenance strategy are outlined to address reactive maintenance challenges experienced by LNW. The evidence from the findings suggests that a preventive maintenance strategy could bring a good return on investment for LNW, and water challenge issues could be resolved.

The next chapter will provide the conclusions and recommendations of the study. The chapter will bring this investigation to conclusion.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

In this chapter, I present the conclusions and recommendations of the study. From the findings of the study, I bring up recommendations that can be implemented by Lepelle Northern Water to mitigate the challenges of reactive maintenance in maintaining water infrastructure and improve the process of water supply.

6.2 Conclusion

The purpose of this study was to investigate the challenges of reactive maintenance in water infrastructure maintenance in Lepelle Northern Water and recommend an effective maintenance strategy. The maintenance of water infrastructure is a critical activity in the existence of Lepelle Northern Water. South Africa is a country that has generally low rainfall and with long-term variation in rainfall and wasted water due to poor maintenance of water infrastructure can negatively affect industries and communities in an already stressed country (Wall, 2010). A reactive maintenance strategy can be used as a preferred strategy for infrastructure or assets that are underground or difficult to reach but generally the strategy is not effective.

From the findings of this study regarding the challenges of reactive maintenance in water infrastructure maintenance, my conclusions are:

- Regardless of what maintenance strategy was implemented by Lepelle Northern Water (LNW), participants performed their maintenance duties. Their approach to the daily activities depended on what was required on each specific day. The preventive maintenance strategy was implemented using the Computerised Maintenance Management System (CMMS) and the planned job cards were issued at different intervals while some work was done utilising job requests when planned job cards were not available. Participants did not follow or adhere to the preventive maintenance strategy due to the ineffective maintenance software system that was brought to the organisation without engaging all stakeholders. The configuration of the SAP system was not supporting the objective of the maintenance department because the system was unable to produce maintenance reports. It was found that in the absence of reports been generated by the SAP system, Microsoft programs such as

Word, and Excel were utilised to generate the reports.

- Inadequate operations and maintenance budget created delays in the procurement of spares and participants were not able to attend training for self-development. At the beginning of every financial year, budgets are submitted to finance, however the budget will get cut without engaging end-users. The inadequate budget and unavailability of maintenance spares affected the strategic objectives and the mandate of LNW of supplying uninterrupted bulk water services to the clients. Due to poor resources, participants were unable to attend to pipe bursts and breakdowns timeously. When breakdowns and pipe bursts occur, the organisation loses revenue and produces insufficient water. This study shows that, when participants are making alternative means to minimise the impact on water supply, they continued to ensure infrastructure is maintained even when the process is reactive. The attitude of participants showed resilience under the circumstances even while others felt unmotivated because they struggled to get resources to perform their duties.
- Theft and vandalism of water infrastructure is a thorny issue for Lepelle Northern Water. The participants in this study have the challenge of ensuring the water supply system is properly maintained, safe, and protected. Participants manage these risks to protect infrastructure from failing by ensuring monitoring protection systems are installed and there are security guards at the remote pump stations. Vandalism on the pipeline caused infrastructure to age prematurely as tampering with the live pipeline through illegal water connections creates breakdowns and water loss. Poor maintenance on the vandalised infrastructure results from spares not being available, and water continues to be wasted. From the findings of this study, arguably, participants strive for continual improvement and ensure infrastructure is protected and performs to its optimum.
- As a measure to address maintenance challenges, participants used job request cards when planned job cards were not available and monthly maintenance plans were posted on the notice boards in the technical workshops. The utilisation of job requests enabled participants to be flexible in rescheduling the non-critical tasks and to attend to breakdowns and outstanding jobs. As projects are completed and handed over to the maintenance team, the

maintenance unit creates maintenance plans for each component as per the original equipment manufacturer's operations manual. Participants were involved in training and skill transfer programmes so that they can be effective in their different fields of specialties.

6.3 Recommendations

Following the research results presented in Chapter 4 and the discussions in the preceding chapter, the study provides the following recommendations to improve the maintenance of water infrastructure in Lepelle Northern Water.

Reactive maintenance has been a thorny issue in Lepelle Northern Water (LNW) for a long period of time. Infrastructure failures, high maintenance costs, high overtimes, and insufficient water supply have brought unhappiness to stakeholders. Lepelle Northern Water as the bulk water service provider in the Limpopo province has been in the spotlight because of water service interruptions.

- Reactive maintenance is caused by different factors which have negative effects on the supply of bulk water. It is therefore recommended that Lepelle Northern Water (LNW): a) Implement an integrated enterprise asset management system (EAMS) and all departments to form part of the process. b) Make operations and maintenance budget sufficiently available. c) Conduct skills gap analysis and give employees training that is relevant to their duties.
- Lepelle Northern Water’s mandate is to provide bulk water services with minimum or no interruptions. As evidenced in this study, there are challenges of water loss in the system, revenue collection is also affected, infrastructure breaks down when least expected, and clients experience water supply interruptions due to the reactive maintenance approach. To address these effects created by reactive maintenance strategy, it is recommended that Lepelle Northern Water should: a) Implement a refurbishment and replacement plan for infrastructure that has reached its expected useful life span. b) prioritise maintenance over new projects that are not bringing in revenue and not increasing water supply. c) install leak detection devices on the main pipelines for monitoring purposes and d) make funds available for the renewal/refurbishment of critical infrastructure.
- Theft and vandalism will continue to disrupt bulk water services and cause

revenue loss. This study suggests that: a) Advanced security monitoring system be installed at all critical points within the water supply system and daily patrols are done by security personnel on the pipelines. b) Communities, municipalities, politicians, South African Policy Services (SAPS), and South African National Defence Force (SANDF) be involved in water committees. c) all Water Treatment Plants to be registered as National Key Points.

- Literature indicates that improving maintenance of infrastructure requires established standards to be in place so that failure can be detected before it can happen (Mobley, 2011). It is further indicated that the advancement and application of preventive maintenance programs are essential for improved management of infrastructure (Karaa, 1989). It is thus recommended that: a) condition monitoring systems be installed b) preventive maintenance strategy be implemented and integrated with other maintenance strategies to achieve desired results (Patidar, et al., 2017). c) focus improvement strategy be implemented across all the WTP’s. d) internal specialist is appointed as a reliability technician or condition monitoring technician.

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