

Gordon Institute of Business Science

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The Determination of a Viable Mechanism for Delivering Effective Maintenance of Infrastructure Assets in Emerging Markets – A South African Case Study

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ABSTRACT

The aim of the research was to determine a viable mechanism of delivering effective maintenance of infrastructure assets in emerging markets. Infrastructure assets are one of the prerequisites to meet the economic and social growth aspirations in emerging economies. The upkeep of infrastructure assets to perform at their optimal levels is therefore paramount to achieving these growth objectives. The research emanated from a need to address the growing challenge of the deterioration of infrastructure due to a lack of maintenance. This phenomenon is hampering the growth in emerging economies, including South Africa. The author intends for the learnings of this report to be used by asset owners and practitioners to address this growing concern.

The research commenced to investigate the extent of the problem of deficiencies in maintenance of infrastructure assets across the African continent, and the impact this is having on those economies. The literature review also honed in on the state of infrastructure and maintenance in South Africa. It was found that there was a wide-spread problem of deteriorating strategic infrastructure due to a lack of maintenance. The literature attributed the lack of maintenance of infrastructure in South Africa due to a lack of funding, lack of reliable data on existing infrastructure stock, uncoordinated efforts by maintenance departments in government agencies, and a lack of life cycle costing at the procurement stage (South African Institution of Civil Engineers, 2011). The literature also attributed a lack of maintenance of infrastructure in emerging markets to a lack of funding due to inadequate billing and collection procedures, low purchase power by users, insufficient attention to operations and maintenance, a lack of experienced personnel to execute maintenance, and weak political will (Alm, 2013).

The case study method was adopted as a research methodology. Five cases were selected in total. Semi-structured interviews were used to collect data. The questionnaire for the interviews was based on the themes and detailed findings from the literature review. Qualitative Content Analysis (QCA) was used to analyse the transcriptions developed from the semi-structured interviews. The single and multiple case study methods were utilised. The feedback from the cross-case analysis was used as a basis for the key findings to address the research questions.

The cross-case analysis revealed factors that lead to a lack of infrastructure maintenance, and determined potential viable mechanisms to deliver effective maintenance of infrastructure assets. The factors that were found to be the most influential in the delivery of effective maintenance of infrastructure were as follows:

- 1) Ensuring mechanisms are in place to make maintenance a core business function or activity
- 2) Use of a combination of maintenance techniques, including run-to-failure, preventative or planned maintenance, and condition based maintenance.
- 3) The use of strategic maintenance guidelines by the maintenance department.
- 4) Keeping most of the maintenance work in-house and limiting outsourcing to specialist equipment.
- 5) The use of MPIs to track the effectiveness and quality of maintenance, and its impact on the overall performance of infrastructure assets.
- 6) Use of technologies to supplement human personnel in the form of maintenance software solutions and automation for monitoring the performance of equipment and other related assets.
- 7) Continuous investment in training of maintenance personnel, including technicians and artisans.
- 8) Initiatives should be put in place to retain critical skills.
- 9) A culture of maintenance should be developed in the organisation, starting from top management structures.
- 10) An asset management division should be put in place to work closely with the maintenance department.

The study is concluded with recommendations for future research. The author believes that the key findings of the research will help advance further research in the field of infrastructure maintenance in emerging markets.

Keywords: Infrastructure, Maintenance, Asset Management, Emerging Markets, South Africa.

DECLARATION

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

Student Name and Surname: _____

Student Signature of Participant: _____

Date: _____

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1 INTRODUCTION TO RESEARCH PROBLEM

1.1 Research Introduction and Background

According to a report prepared on behalf of the European Parliamentary Research Service, up until 2015 and over the past 15 years preceding, a large majority of countries on the African continent had been on an impressive economic growth trajectory with rates often exceeding 5% per year (Zamfir, 2016, p. 1). This growth was largely attributable to favourable external factors which supported high net profits in oil and commodities exports; large inflows of investment capital looking for new opportunities, and to some degree relatively improved domestic macroeconomic conditions.

In 2015, however, Africa's stellar economic growth path was slowed down by many political, economic and social events that took place. Included amongst these was the depreciation of major African currencies by an average of 40% vis-à-vis the US dollar; the end of the commodity price super cycle (significantly affecting oil, copper and iron ore), the slowdown of the Chinese economy and tightening global financial conditions (Zamfir, 2016; p. 8). To reflect this, the African Economic Outlook (AEO) for 2016 reported that Africa's real GDP grew by an average of 3.6% in 2015 which was below the 5% average of the last decade (African Development Bank, 2016, p. 6). This was still higher, however, than the global average growth of 3.1% and more than double that of the Euro area; which is a reflection of the slowdown of the overall global economy in the past couple of years.

It is this vulnerability to external shocks that raises a major challenge for the African continent because it leads to uncertainty that results in high costs of doing business and thus hampers economic productivity and growth. From the above background, there is a clear need to address these sources of vulnerability and to build resilience in order to achieve economic prosperity on the African continent.

It is against this background that Mbu (2006), advocates that this 'elusive' economic prosperity can be achieved through sound economic policies that have a particular focus on targeted investments in the areas of infrastructure development and not only through exports of oil and commodities. This in turn has created a continued dialogue calling on African countries to increase the infrastructure spending component of their capital expenditure budgets. The findings of a 2010 report, commissioned by the World Bank, titled "*Africa's infrastructure: A time for transformation*," further supports this drive, showing estimates that proved at the time, that infrastructure was responsible for more than half of Africa's economic

performance (Foster & Brinceno-Garmendia, 2010,). The author of this research therefore aims to expand on this idea and to advocate that having proper maintenance plans of infrastructure assets once they are in place; is instrumental in ensuring sustained economic growth. The research will therefore strive to endorse that a critical part of the solution to solving Africa's economic woes into economic fortunes is through the proper implementation of appropriate infrastructure across all sectors of the economy and to ensure that they are properly maintained to achieve sustained levels of economic growth, with a particular focus on South Africa.

Despite being relatively more advanced in relation to the majority of other African countries, South Africa still faces infrastructure challenges similar to those of other emerging economies. Notwithstanding the bleak legacy of apartheid; pre-1994, whereby adequate services were accessed only by a select few, the country has made considerable strides in its quest to deliver services to the millions of people that were previously disadvantaged by the system. In its second publication dated 2011, the authors of the SAICE (South African Institution of Civil Engineering) Infrastructure Report Card (IRC); warned that; "even though the country had improved on key infrastructure areas since the previous report dated 2006, the quality and reliability of basic infrastructure serving the majority of the country's citizens was primarily poor and deteriorating in certain sectors" (South African Institution of Civil Engineering, 2011, p. 2).

There is a need to raise awareness in emerging economies, including South Africa, about the importance of providing for adequate maintenance of both existing and new infrastructure assets so they deliver social and economic benefits to their respective populations. Mechanisms of maintaining these assets need careful planning and execution; which normally starts with the interrogation of the main attributes and reasons for poor maintenance, and thereafter developing mechanisms to ameliorate apparent deficiencies.

1.2 Research Problem

The importance of providing for adequate maintenance of infrastructure to prolong its life span and to ensure that it delivers the required services to those in need cannot be overemphasised. Given the large investment that is made in current and future expansion of infrastructure and the social and economic benefit these assets contribute to developing countries, it is imperative to ensure their preservation over the planned life-span of the asset. In the case of South Africa, the government has recognised the need to ensure maintenance of its existing and new infrastructure "as a strategic tool to promote improved service delivery,

to unlock funding to extend infrastructure to historically disadvantaged communities, and to support the nation's economy" (Construction Industry Development Board, 2007, p.5).

Notwithstanding the impressive policy guidelines related to the implementation and maintenance of infrastructure that have been drafted by many developing countries, the challenge becomes the 'how' of implementing these strategies effectively in practice. There are various reasons that have been cited for the state of poor maintenance of existing and new infrastructure in emerging economies, more specifically in Africa. Firstly, one of the typical challenges is that the high demand for new infrastructure tends to put pressure on funding resources needed for maintenance. Secondly, a lack of capacity at local government level to maintain new and existing infrastructure has also been identified as a challenge (National Planning Commission, 2011, p. 24). Thirdly, while infrastructure services in low-income economies are relatively high, the costs to construct infrastructure remains even higher which leads to lack of cost recovery to cover operating and maintenance costs over the life of the asset (Foster & Briceno-Garmendia, 2010, p. 23). Furthermore, other reasons that attribute to inadequate maintenance of infrastructure assets relate to a lack of up-to-date database information on existing assets in many low-income countries, additional pressure on state resources due to an existing backlog of capital maintenance, a reactive culture of dealing with maintenance only when failure happens, and little incentive for service providers to set funds aside before failure takes place (Fonseca, Nyarko, & Franceys, 2013, pp. 23-24).

This research sets out to outline the root causes of the prevailing trend of poor maintenance of infrastructure in South Africa and to develop viable alternatives to address this problem. It is the intention of the author to avail the findings from the research study to be adopted by other developing countries.

1.3 Research Objectives

The research paper seeks to investigate the root causes of the culture of the lack of maintenance of new and existing infrastructure in South Africa. The objective of the research is therefore to develop effective and viable maintenance mechanisms for South Africa's infrastructure assets. These mechanisms will not only be limited to the planning and implementation of maintenance plans, but will also seek to investigate viable financing mechanisms for infrastructure maintenance in South Africa.

It is the intention of the author to share lessons learnt so they can be adopted in other emerging economies with dynamics similar to South Africa.

The first section of this research paper will cover theory and literature review to determine the current state of infrastructure and its maintenance on the African continent, with a specific focus on South Africa. The research will further unpack the reasons behind the lack of maintenance that has been reported by both researchers and practitioners. The second section outlines the proposed research methodology and design to be adopted to address the research questions. This will include the method of data analysis to be adopted following the data collection stage.

2 LITERATURE REVIEW

2.1 Infrastructure and Economic Growth

There appears to be a consensus amongst researchers and practitioners on the positive correlation between infrastructure development and economic growth; as proven in numerous research papers on the topic, published in the last few decades. A panel dynamic model employed by Batuo (2015) which takes into account the correlation between previous and subsequent values of growth on a panel data set of 44 African countries, showed results suggesting that real GDP per capita will rise by the range of 0.5% to 0.8% following an increase in teledensity by 10 people per 100 inhabitants (p. 319). Teledensity relates to the number of telephone connections for every hundred individuals living within an area. Another study done in India using a data set spanning from 1970 to 2010 showed that an increase in transport infrastructure (road and rail) and gross capital formation will lead to pervasive economic growth (Pradhan & Bagchi, 2013, p. 147). Sahoo and Dash (2012) on the other hand used a general production function framework which examined the effect of infrastructure stock on economic growth in four South Asian countries and found that infrastructure development in these countries had a positive contribution towards growth, results of which suggested “that a 1% increase in the infrastructure index is likely to increase income by about 0.26%” (p. 234).

2.2 The State of Infrastructure in the Developing World

The African continent lags behind the rest of the world in terms of adequate infrastructure development and this has negatively affected Africa’s “international competitiveness, the cost of doing business, impeded foreign direct investment (FDI) and trade, and retarded its overall economic performance” (Luiz, 2010, p. 515). In their report, Foster & Briceno-Garmendia (2010) estimated that the continent requires approximately \$93 billion a year (15% of region’s GDP) to address its infrastructure backlog, “two-thirds of this total relates to capital expenditure, and the remaining one-third to operations and maintenance requirements” (p. 6).

2.3 Infrastructure Funding Requirements per Sector

The World Bank report on the state of Africa's infrastructure, highlights Africa's infrastructure funding gaps per sector; stating that the majority of Africa's 60 % funding gap, is associated with power, followed by water and irrigation, and the balance to ICT and transport (Foster & Briceno-Garmendia, 2010, p. 11). In the same report, it was estimated that the continent delivers only a fraction of its power needs in terms of generation capacity, electricity consumption, or security of supply. To put this into context, it is estimated that 45 Sub-Saharan countries with a population of approximately 800 million people generate the same amount of power as Spain; which has a population of approximately 45 million people (Foster & Briceno-Garmendia, 2010, p. 5).

Another sector which is in dire need of investment is water supply and sanitation, with a funding gap estimated at approximately \$22 billion dollars annually, which equates to about 2.58 percent of GDP (Rodriguez, van den & McMahan., 2012, p. 8). Rodriguez et al. (2012) further explain that a third of the shortfall is required for capital expenditure (\$15 billion), while the balance is required for operational and maintenance expenditures (p. 8). This large capital expenditure involved in infrastructure investment is evidence that it is important to have proper maintenance mechanisms in place in African countries, in order to preserve and prolong the life-span of these important assets.

2.4 State of Infrastructure in South Africa

South Africa still bears the brunt of its unequal past, which has denied the majority of South Africans access to adequate infrastructure and services rendered thereof. A report commissioned by the National Planning Commission (2011) states that public investment "in both new and existing infrastructure falls far short of what is needed to meet the country's economic and social requirements" (p. 16). This means that not enough funding was allocated for the maintenance of existing infrastructure assets in the past, leading to a deterioration which could have otherwise been avoided. This deterioration varies per sector, with water infrastructure, particularly wastewater treatment plants, water treatment works, water and sewer reticulation, and on-site sanitation being highlighted to be of particular concern (Construction Industry Development Board, 2007). Ruiters (2013) reviewed research related to water infrastructure done by various organisations, and established that infrastructure maintenance budgets are the first to be cut for purposes of cost savings when spending budgets are tight in many public organisations.

2.4.1 Public Infrastructure spend per Sector

The table below illustrates South Africa's public infrastructure expenditure estimates per sector over the period, 2011/2012 to 2017/2018. It will then be followed by an explanation of the criteria used to categorise infrastructure assets that are prioritised for investment as well as maintenance.

R billion	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	MTEF Total
	Outcomes			Estimates				
Energy	67.1	75.1	69.5	69.2	71.1	56.0	39.2	166.3
Water and sanitation	19.2	22.6	26.2	34.8	37.3	39.8	40.3	117.4
Transport and logistics	70.1	69.5	76.4	93.7	104.3	113.5	121.3	339.2
Other economic services	11.5	8.9	11.8	17.5	15.4	15.5	14.7	45.6
Health	7.7	9.7	10.6	9.7	9.3	9.9	10.3	29.5
Education	7.8	9.8	12.3	13.5	14.5	14.5	14.8	43.7
Other social services	15.7	10.7	10.3	11.5	10.6	11.3	11.6	33.5
Justice and protection services	2.8	4.4	4.0	3.9	4.5	5.2	5.5	15.2
Central government, administration services and financial services	6.5	6.9	5.8	8.6	6.9	7.7	8.2	22.7
Total	208.3	217.7	226.9	262.4	274.0	273.3	265.8	813.1
National departments	6.6	9.6	10.6	11.2	13.8	16.0	15.4	45.3
Provincial departments	43.4	36.4	39.5	44.0	45.0	47.7	47.4	140.1
Local government	33.2	41.7	47.1	58.3	55.9	59.0	62.0	177.0
Public entities ¹	15.4	14.1	13.0	27.5	26.1	26.0	26.9	79.0
Public private partnerships	10.7	2.6	3.0	3.1	2.9	3.3	3.4	9.7
State-owned companies ¹	98.9	113.4	113.7	118.3	130.1	121.3	110.7	362.2
Total	208.3	217.7	226.9	262.4	274.0	273.3	265.8	813.1

1. Public entities are financed by capital transfers from the fiscus and state-owned companies are financed from a combination of own revenue, borrowings and private funding

Table 2.1: South Africa's public infrastructure expenditure estimates per sector over the period 2011/2012 to 2017/2018

Source: National Treasury (2015 Budget Review)

In its 2015 budget review, the National Treasury (2015) estimated that the Energy subsector will spend a total of R166.3 billion over a 3 year period which would translate to approximately 20% of the total public-sector infrastructure budget (p. 123). The lion's share of this amount is attributable to Eskom, the national power supplier, accounting for 83% of the energy spend amount.

2.4.2 Strategic Infrastructure

The criteria used for selecting infrastructure projects that need to be prioritised for investment, is amongst others, to ascertain which ones fall into the category of strategic or critical infrastructure assets and embark on these in order of priority. In the United States of America, critical infrastructure is defined as; “those systems and assets—both physical and cyber—so vital to the Nation that their incapacity or destruction would have a debilitating impact on national security, economic security, and/or public health and safety” (Moteff, Copeland & Fischer, 2003, p. 5).

South Africa on the other hand, uses the National Infrastructure Maintenance Strategy (NIMS) to provide budgeting guidelines for maintenance of public sector infrastructure assets and to help in the move towards effective infrastructure asset management (Construction Industry Development Board (CIDB), 2007). The NIMS has been ratified by cabinet and is currently under the responsibility of the Department of Public Works, and supported by the Construction Industry Development Board (CIDB) for implementation purposes (CIDB, 2006, p. 1). The NIMS has identified strategic infrastructure as that “which, if it fails, has the largest impact on service delivery” (CIDB, 2006a, p. 2) and “that most pertinent to supporting government's growth and poverty eradication objectives” (CIDB, 2006b, p. 17). These are further classified into the following categories:

“ ...

- a) *Arterial roads which are key transport routes - as these provide the backbone for economic growth and employment;*
- b) *Bulk water storage and bulk water reticulation -as these provide the water supply to regions, municipalities and communities which they serve;*
- c) *Water purification works - as the correct functioning of these have a direct impact on the health of entire communities which they service;*
- d) *Sewage treatment works - as the functioning of these have a direct and serious impact on the health of entire communities and the environment downstream from them;*
- e) *Electricity generation facilities - as these provide the power supply for the entire nation which is the backbone for all development;*
- f) *Major electricity supply lines and transformers - as these provide the power supply for the entire nation;*
- g) *Hospital critical care and emergency facilities - which are needed for critical hospital services;*

h) *Structural integrity, roofing and weather proofing of schools – as without safe, weatherproof classrooms schools cannot function adequately”*

(CIDB, 2006, p. 2)

The NIMS report prepared CIDB (2007) categorises public infrastructure assets in terms of the level of maintenance upkeep they require as shown below (p. 8).

- a) **Category A** – These assets are those with sound asset management plans in place, and they have provision for funding, skills and capacity needed for implementation of maintenance plans, and their leadership has a strong maintenance ethic.
- b) **Category B** – These do not have asset management plans in place, maintenance budgets are not adequate, they lack capacity, and their leadership does not regard maintenance to be very important,

Category	Brief description	Institutions
A	Adequate and/or improving maintenance	SANRAL, national government public buildings, DWAF, ACSA, Eskom, Telkom, Transnet, some provincial roads, some provincial health and education, some municipalities, some water boards
B	Inadequate maintenance and/or deteriorating	Some provincial roads, some provincial health and education, most municipalities, some water boards

Table 2.2: Public sector institutions categorised by their state of maintenance priority

Source: Construction Industry Development Board (CIDB), 2007, p. 8

2.5 Definition of Maintenance

There are various definitions of maintenance found in the array of literature reviewed in this study. According to Gyamfi, Gutierrez, and Yepes (1992), maintenance is “that set of activities which enables systems to deliver efficiently the outputs for which they we defined” (p. i). In addition, Gyamfi, Gutierrez, and Yepes (1992) clarify that maintenance does not only refer to

the upkeep or preservation of physical infrastructure assets, but it is also concerned with the management systems and the institutional capacity necessary to obtain maximum benefits from this infrastructure.

Maintenance is key to any organisation or entity that owns and operates infrastructure assets or plant equipment. Khan and Haddar (2003), assert that one of the key objectives of maintenance plans is to minimise the possible hazards, to both humans and the environment that may be caused by any unexpected failure of mechanical equipment or plant belonging to any organisation. The starting point of any maintenance strategy should therefore be to ensure that the right mechanical equipment or assets are procured for company operations and put in place measures to control the rate at which these assets deteriorate. In addition it is also prudent to ensure that the equipment/assets chosen are environmentally safe and friendly, whilst at the same time striking a balance between minimising total operational costs against maximising returns on those assets (Maiti, 2007). Another key value add objective of putting optimal maintenance activities in place, is that they help to minimise the downtime of plant and equipment operations (Too, 2002).

2.6 Maintenance Approaches

Once constructed, every infrastructure asset is supposed to have maintenance plans in place which are meant to be implemented at different intervals throughout its life-cycle.

According to Salith, Edum-Fotwe, Price, (2016), these maintenance plans usually work as follows:

- 1) Routine maintenance - This comprises of all maintenance activities that need to be performed at least once a year,
- 2) Emergency maintenance or repairs - These comprise of all maintenance activities that have to be performed in cases of emergency to save lives or to prevent disastrous consequences in the case where infrastructure plants or equipment gets damaged, and
- 3) Periodic maintenance and reconstruction - This comprises of repairs which are less frequent than the above

2.7 Maintenance Techniques

Maintenance can be classified further into maintenance techniques. Garg and Deshmukh (2006) have proposed the following different ways of categorising different maintenance techniques. These have been summarised as follows:

Preventative Maintenance- Preventative maintenance is defined as “a series of tasks performed at a frequency dictated by the passage of time, the amount of production, and machine condition; that either extend the life of an asset or detect that an asset had critical wear and is going to fail or break down” (Garg and Deshmukh, 2006, p. 214). This type of maintenance is undertaken regularly at predetermined intervals while the asset is operating at satisfactory levels to reduce or eliminate accumulated deterioration (Chen & Trivedi, 2002).

Condition-based Maintenance - This is a subset of preventative maintenance, and comprises of a set of maintenance actions taken after each inspection. This may comprise of no action, or minimal maintenance with the intention of recovering to the previous stage of degradation, or major maintenance to bring the system to a state which is as good as new (Chen & Trivedi, 2002).

Total Productive Maintenance (TPM) - Total productive maintenance originates from a Japanese philosophy and is an approach to maintenance that optimises equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators through day-to-day activities involving total the workforce (Ahuja & Khamba, 2008).

Computerised Maintenance Management Systems (CMMS) - CMMS has become an important tool that is used to support the maintenance management function. CMMS allows asset (maintenance) managers to store, retrieve and analyse information, whilst also allowing them to facilitate and coordinate maintenance activities (Swanson, 1997). A study by Swanson (1997) shows that CMMS is primarily used as a storehouse for equipment information, as a preventative maintenance tool, as well as a maintenance work planning tool. CMMS also plays a key role in assisting with the analysis of key performance measurements. This is done by assessing the current maintenance status against maintenance objective(s) (Cholasuke, Bhardwa & Antony, 2004).

Reliability Centred Maintenance (RCM) – RCM originated from aircraft maintenance in the 1960s and entails the process of directing maintenance efforts at those units and parts where reliability is critical (Garg and Deshmukh, 2006).

Predictive Maintenance - According to Garg and Deshmukh (2006), predictive maintenance entails deciding whether or not to maintain an asset or system depending on its state or

condition. It is recommended that asset managers utilise predictive maintenance in conjunction with traditional maintenance methods because when implemented correctly, predictive maintenance policies can help detect equipment problems early and reduce the possibility of premature periodic replacements and equipment failures (McKone & Weiss, 2002).

Maintenance Outsourcing – The rationale behind outsourcing the maintenance function (i.e. transferring workload to third parties) is based on the goal of getting the benefit of higher quality maintenance faster, safely and at lower costs (Garg and Deshmukh, 2006). Martin (1997) explains that the key considerations for outsourcing of a maintenance function include:

- Size of maintenance department – maintenance work might be too extensive or technical for small maintenance team.
- Rising maintenance costs based on increased training requirements for the maintenance workforce, due to rapid changes in technological advancements, as well as changing safety and environmental requirements that become more stringent with time.
- Outsourcing offers increased operational flexibility which can help the company deal with changing organisations requirements. No longer does a company have to change all companies' activities in detail, but it can rather concentrate efforts on updating contract with the outsourced contractor.
- Outsourcing can also provide organisations with financial flexibility in terms of the type of contract that can be agreed with the outsourced contractor.

An organisation would therefore have to conduct a cost-benefit analysis to weigh the pros and cons of adopting an outsourcing maintenance strategy.

Effective Centred Maintenance (ECM) – ECM is a maintenance technique that stresses “doing the right things” instead of “doing things right” (Pun, Chin, Chow & Lau, 2002, p. 346). According to Pun et al. (2002), ECM encompasses the core concepts of quality management, total productive maintenance, and reliability-centred maintenance. Pun et al. (2002) advise that the implementation of ECM entails four phases which include.

- 1) Employee participation,
- 2) Quality improvement,
- 3) Maintenance development, and
- 4) Performance measurement.

Strategic Maintenance Management (SMM) - SMM is a multi-disciplinary maintenance approach that views maintenance strategically from a holistic business perspective (Murthy,

Atrens & Eccleston, 2002). SMM is expanded upon further in the proceeding chapters of this research.

Risk-based Maintenance – The main purpose of a risk-based approach is to reduce the overall risk of unexpected failures of operating facilities (Arunraj & Maiti, 2007). The approach achieves this by utilising information obtained from the study of failure modes and their economic consequences, in order to conduct a risk analysis (Khan & Haddara, 2003). The risk-based maintenance framework comprises of two main phases being risk assessment and maintenance planning to reduce failure risk (Arunraj & Maiti, 2007). Khan and Haddara (2003) explain that continued risk analysis (or assessment) identifies, characterises, quantifies, and evaluates the loss that results from a risk event. This technique further integrates probability and consequence analysis at various stages of the analysis to assess the possibility of a risk event.

2.8 Selection of Appropriate Contractual Relationships

As discussed previously in this study, there are many benefits that warrant the outsourcing of certain maintenance tasks or responsibilities from an owner's perspective. These benefits offer owners "less hassle, reduced total-system costs, better and faster work done, exposure to outside specialists, greater flexibility to adopt new technologies and more focus on strategic asset management issues" (Tsang, 2002, p. 13). It is therefore important for the asset owner to understand the spread and technical details of maintenance management contracts as these may have varying implications on the expectation of maintenance outcomes. Martin (1997) makes a distinction between three maintenance contracts types in terms of contract complexity, client-contractor relationship and client maintenance knowledge base.

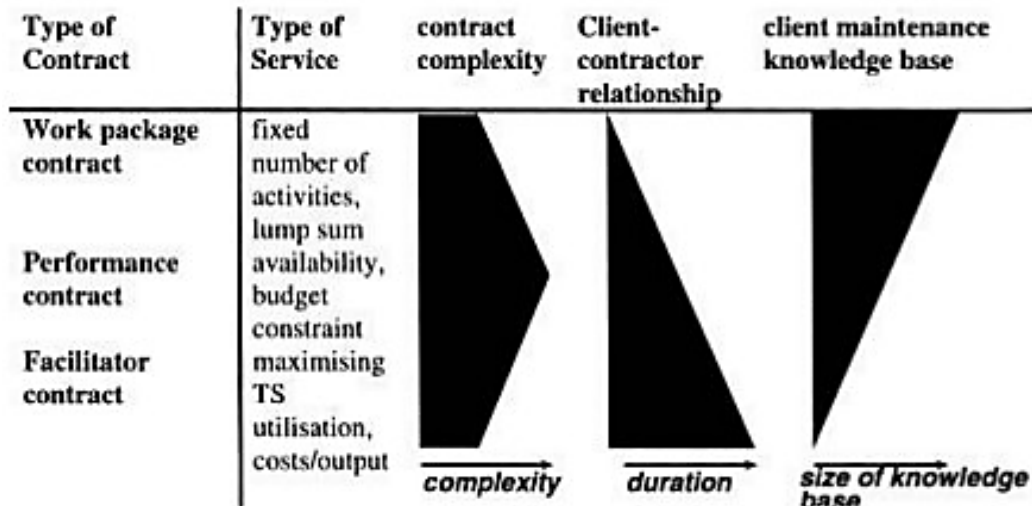


Figure 2.1: Types of maintenance contracts

Source: Martin (1997)

Work Package Contract. A maintenance contract whereby the client performs all the planning and control logic in-house and only calls the contractor when there are maintenance activities to be performed. This is a fairly simple contract which requires maintenance activities to be well defined by the client.

Performance Contract. A maintenance contract whereby the contractor guarantees a certain availability of technical systems (TSs) owned by the client. This contract is complex as it requires “responsibilities of all aspects concerning the modes of operation of the TSs by the client and the maintenance carried out by the contractor to be explicitly separated between both parties” (Martin, 1997, p. 85)

Facilitator Contract. A maintenance contract whereby the contractor is the owner and maintainer of the TSs and the client only pays for the right of use. The complexity of this contract in lieu of a performance contract is reduced because most of the management logic is the responsibility of the contractor. Martin (1997) explains that the Facilitator Contract requires trust and openness between the owner and the contractor in terms of information sharing and, where possible requires the parties to make strategic business decisions jointly, so that maintenance management goals align with the company’s strategic management goals.

The use of outsourcing can be risky and must be utilised with caution. Tsang (2002) cautioned that outsourcing can expose the owner to various risks including (1) loss of critical skills, (2)

loss of cross-functional communication, (3) loss of control over supplier, (4) shifts in the balance of power during the contract period, (5) lack of employee morale, (6) hidden costs, and limited access to external talent. Murthy, Atrens and Eccleston (2002) distinguish between maintenance management and maintenance implementation and cautioned that the former should not be outsourced because (1) maintenance and production are closely linked and this link can be weakened by outsourcing, (2) actions of the service agent are not optimal in the long-term due to misalignment of goals with the owner, and (3) the risk exposure of relying on a single service provider are large. Murthy et al. (2002) use agency theory and also advise that the owner needs to be aware of adverse selection whereby the principal cannot assess the competencies of all service providers and moral hazard whereby the agent tends not to carry out all maintenance tasks properly resulting in adverse long-term implications for the overall business performance.

2.9 Strategic Maintenance Management

The proper upkeep or maintenance of equipment is key for any business. This is because a company's equipment is critical for business success and therefore businesses that do not have their equipment in fully operational mode are susceptible to incur heavy losses (Murthy, Atrens & Eccleston, 2002). According to Murthy et al. (2002), there are two key elements to the strategic maintenance management (SMM) approach. The first is that maintenance management needs to be viewed as a vital core business activity, and the second is that effective maintenance "needs to be based on quantitative business models that integrate maintenance with other decisions such as production, etc." (Murthy et al., 2002, p. 290). The authors add that the SMM approach considers maintenance to be a multi-disciplinary activity whereby maintenance is viewed strategically from an overall business perspective. The literature says that maintenance is a core business activity and therefore needs to be managed strategically, and also states that effective maintenance needs to be based on quantitative business models that integrate maintenance with other decisions such as production (Murthy et al., 2002). Murthy et al. (2002) did research based on interactions with businesses in Australia, and recommended changes to maintenance management at a business level in the form of:

- 1) Maintenance management being a core element of business whereby top management understand the risk implications associated with unreliable equipment;
- 2) Creation of a culture that emphasises the importance of maintenance across all business units;

- 3) Setting up systems of continuous improvement at all levels of management;
- 4) Providing middle and junior managers with the right skills;
- 5) Proper data collection; and
- 6) Proper data analysis.

The continuous improvement paradigm involves three main steps of (1) understanding the equipment being maintained, (2) planning optimal maintenance steps (i.e. collecting relevant data, analysing the data to determine equipment state, building models to predict the consequences of different maintenance actions and operating loads, and deciding on optimal maintenance actions), (3) implementing the optimal maintenance actions (Murthy, Atrons & Eccleston, 2002).

2.10 Dimensions of Maintenance

Tsang (2002) makes reference to Visser's (1998) 'input-output model' which views maintenance as a transformation process with four strategic dimensions of maintenance which relate to:

“ ...

- 1) Service-delivery options: the choice between in-house capability and outsourced service.
- 2) Organisation of the maintenance function and the way maintenance tasks are structured.
- 3) Maintenance methodology: the selection of maintenance policies.
- 4) Design of the infrastructure that supports maintenance.” (p. 10)

These dimensions as described by Tsang (2002) are expanded on below:

Service Delivery Options – Service delivery options entail the choice between using in-house capability and outsourcing a service. The concept of service delivery options stems from the notion that organisations need to focus their skills and resources on their core competencies. In the context of maintenance, it is recommended that a company outsource activities that do not fulfil a strategic purpose or form part of the organisation's special capability (Tsang, 2002).

Organisation and Work Structuring - The organisation and work structuring decisions involve organisational design and structuring of maintenance work and are based on the consideration

of factors such as workload characteristics, plant location, cost of unavailability, skills and knowledge required, production policy and human resource policy (Tsang, 2002).

Maintenance Methodology - The maintenance methodology adopted in an organisation is determined by the decisions relating to which maintenance approach or policies an organisation or entity will choose. These maintenance approaches span a wide spectrum and include run-to-failure (RTF), preventative maintenance (PM), condition-based maintenance (CBM), design improvement (DI), reliability centred maintenance (RCM), total productive maintenance (TPM), and total quality management (TQM) (Tsang, 2002).

Design of Infrastructure that Supports Maintenance - Tsang (2002) explains that the strategic maintenance dimensions described above often fail due to their misalignment with company values, management behaviours and support systems. The support systems include information sharing, training, performance management, reward systems, and effective deployment of information technology that supports maintenance activities. In summary, the overarching strand that cuts across these dimensions are the human factors and information flows (Tsang, 2002).

2.11 Maintenance of Infrastructure

In their research, Zhang and Gao (2011) explain that the deterioration of any infrastructure asset over a period of time is inevitable, and this results in an increase in the failure rate of assets over time. From their observations and the literature reviewed so far, we can conclude that it is crucial to put proper maintenance mechanisms in place to prolong the life-span of infrastructure assets; especially given their contribution towards economic growth and the wellbeing of society in both developed and developing nations. It is evident, therefore that periodic implementation of maintenance can be used to preserve the condition of an infrastructure system and mitigate its premature deterioration over time (Zhang & Gao, 2011).

To further illustrate the points made above, a report commissioned by the World Bank, *Africa's Infrastructure: A Time for Transformation*, highlighted the impact of a lack of maintenance of infrastructure assets on African countries (Foster & Briceno-Garmendia, 2010). Firstly, the report stated that addressing Africa's current infrastructure needs would cost an estimated \$93 billion a year, a third of which would need to be allocated to operation and maintenance requirements. Secondly, it was estimated that, on average, about 30 percent of infrastructure assets of a typical African country need rehabilitation, a situation which could have otherwise been avoided, given that rehabilitation of infrastructure costs a lot higher than sound

preventative maintenance. The report therefore strongly recommends that these countries should make provision in their capital budgets for maintenance expenditure to avoid the need for costly rehabilitation efforts in the long run. This will clearly require raising awareness to bring a mind-set shift amongst stakeholders to help them to view maintenance as an investment in asset preservation as opposed to viewing it as an unnecessary expense (Foster & Briceno-Garmendia, 2010, p. 16)

The argument of viewing maintenance as an investment can be best illustrated by various examples where a lack of maintenance has resulted in premature deterioration of infrastructure assets, leading to unnecessary expenses. In a report commissioned by the Federation of Zambian Road Hauliers is a good example that shows that a lack of maintenance of infrastructure assets, not only imposes exorbitant future costs on an economy, but also imposes “additional, immediate, costs to users” (Rioja, 2003) of those assets. In this example the Zambian Federation often incurs unnecessary additional operating costs where vehicular components frequently break down or get prematurely damaged (e.g. damaged clutches, springs, brakes, shocks etc.) because the fleet is not periodically well maintained. In another example, (Mohamed & Zayed, 2013) discovered that a lack of maintenance and deterioration of water distribution systems leads to various adverse results, which include impaired water quality, reduced hydraulic capacity, high leakage rate, and frequent break-downs.

It is evident from the above background that even though developing countries have made progress in providing new public infrastructure stock, these governments incur huge rehabilitation and replacement costs due to not providing budgets for periodic maintenance. Rioja (2003a) reports that, in addition to incurring high costs to rehabilitate deteriorated infrastructure assets; developing countries also lose out on potential income as a result of a loss of potential production output from their assets, because these become inefficient and ineffective prematurely.

2.12 Infrastructure Asset Management

The literature reviewed so far has focused on maintenance management. It is however important to understand that in more advanced organisations; maintenance management forms part of a more holistic approach to the overall maintenance of all capital assets within an organisation, referred to as asset management. Cagle (2003) defines asset management as a set of processes or activities that are conducted to address the proactive management of capital assets. Proactive management on the other hand entails the intervention at strategic

points during the normal life-cycle of an asset, or system of assets to extend the expected service life, (Cagle, 2003). Cagle (2003) describes 'intervention' as the process concerned with repairs, preventative and/or predictive maintenance, and/or rehabilitation of assets. The result of the cycle of repair/maintenance and rehabilitation is that the overall condition of an asset is constantly evaluated to extend its overall life-cycle (Cagle, 2003). The other benefit of regularly evaluating the state of assets throughout their life-cycle is that over-time the costs of maintenance can be weighed against the costs of replacing them as they age; because historical information of costs will be on record. This leads to the need to establish performance measures or tools to help managers in their decision making process as described below.

Cahyo et al. (2015) explain that the "maintenance of resource provision is one of the asset management system activities" (p. 124). According to Cahyo et al. (2015), maintenance resource management "comprises the management of all resources required to perform all maintenance tasks" (p. 123). The authors explain that implications of wrong decision making can lead to insufficient resources allocated to perform maintenance tasks resulting in an ineffective maintenance process (Cahyo et al., 2015, p. 123). Conversely, too many resources allocated to certain maintenance tasks can lead to wasteful expenditure. Asset management therefore requires the optimal allocation of resources for maintenance of individual assets. Fwa and Farhan (2012) provided an explanation of conventional five approaches for fund appropriation among competing highway asset components and categorised them as shown below (pp. 1179-1180):

- 1) Appropriation on the basis of historical allocation proportions
- 2) Formula-based appropriation
- 3) Asset value-based appropriation
- 4) Maintenance needs-based appropriation
- 5) Performance based appropriation

These funding appropriations can be generalised to other asset classes. The use of these traditional budget appropriation models have been cautioned due to their limitations. Other researchers have proposed various permutations to these models.

2.13 Performance Measurement of Infrastructure Maintenance

Performance measurement is a concept that helps asset managers makes decisions about where improvements to the maintenance process are pertinent at any given point.

It is critical for both asset managers and owners of assets to understand the “relationship between the output of maintenance processes in terms of their total contribution to business goals and their inputs to the different sub processes” (Parida & Chattopadhyay, 2007, pp 241-242). In their research to investigate the multi-criteria hierarchical framework of maintenance performance measurement (MPM), Parida and Chattopadhyay (2007) argue that the effectiveness of maintenance and its quality need to be measured in order to justify whether continued investment is still valid or not. The authors add that this emphasises the need to develop and implement an appropriate performance measurement system that ensures that maintenance actions are aligned with the strategies and objectives of the business. This ensures that maintenance costs of assets do not undermine company goals and objectives. Maintenance costs are evaluated using maintenance performance indicators as discussed below.

Maintenance performance indicators are defined as a set of measures used for tracking the impact of maintenance processes on the overall performance of infrastructure assets (Parida & Chattopadhyay, 2007). Maintenance performance indicators are beneficial in gauging the wellbeing of an asset and act as an early warning system before catastrophic failures can occur. Leading indicators can be defined as those that act as key early warning system, that helps to ascertain an assets’ present status in reference to normal operational standards (e.g. abnormal noise, vibration, thermograph and unusual particles in oil can all be leading indicators at a maintenance level that something is wrong). Lagging indicators on the other hand, “act as outcome measures that provide the basis for studying deviations after the completion of maintenance activities (e.g. cost of maintenance, return on investment or time between breakdowns” (Parida & Chattopadhyay, 2007, p. 244). These leading and lagging indicators help in the monitoring, controlling and measuring of the performance and effectiveness of maintenance processes within an organisation.

The selection of appropriate maintenance performance indicators (MPIs), is informed by the vision, objectives and strategy of an organisation and are further dependent on both internal and external requirements. MPI’s are linked to the multi-hierarchical levels (Parida & Chattopadhyay, 2007) of the organisation which include strategic, tactical, managerial, functional and operational levels. Parida & Chattopadhyay (2007) list seven categories of MPIs as follows (pp. 250-253):

- a) Equipment-related indicators (e.g. availability, performance rate, downtime and quality)
- b) Maintenance task related indicators (change over time, unplanned maintenance tasks, and response time for maintenance)

- c) Cost-related indicators (e.g. maintenance cost/unit, production cost/unit, return on maintenance investment (ROMI))
- d) Impact on customer satisfaction (e.g. number of quality complaints, low quality returns, customer satisfaction, customer retention, and number of new customers added)
- e) Learning and growth (e.g. number of new ideas generated, skills and competency development/training)
- f) Health, safety, security and environment (HSSE) (e.g. number of accidents/incidents, number of legal cases, number of HSSE complaints)
- g) Employee satisfaction (e.g. employee absentees, employee complaints, and employee turn-over rate)

The linkage between the overall vision, objectives and strategy of an organisation and its measures of maintenance performance is done through maintenance performance measurement (MPM) frameworks. There are a host of MPM frameworks that have emerged in the literature reviewed. Sharp et al. (1997) incorporated the Total Quality Management (TQM) philosophy to the maintenance department to improve maintenance processes. The authors argued that adapting the TQM philosophy to the maintenance department to improve maintenance processes in a manufacturing setting; results in operational efficiencies and improved output; with benefits which contribute to cost savings leading to higher profits. Kutucuoglu et al. (2001) on the other hand, developed a performance maintenance system (PMS) based on a quality function deployment (QFD) which consists of three main stages being, (1) identification and alignment of key performance indicators, (2) selecting measurement unit specific measures, and (3) measurement and evaluation (p. 184).

2.14 Funding Infrastructure Maintenance

Ensuring that there are sustainable mechanisms in place for sufficient funding of infrastructure maintenance is critical for the upkeep of infrastructure assets. The long-term consequences of a lack of maintenance outweigh the provision of funds committed to sustainable maintenance in the short-term. There are various ways that have been adopted to finance infrastructure.

The economic concept of correct pricing of private and public goods to achieve considerable gains in economic efficiency is well established (Rogers, de Silva & Bhatia, 2002, p.2). In the case of infrastructure delivery, correct pricing to achieve economic efficiency means that the pricing must reflect the costs of producing and delivering a service (Molinos-Senante & Hernandez-Sancho, 2013, 1998). Alternatively, the dire consequences of an economically

inefficient system is one that is “operated, where user fees do not reflect the full cost of providing services” (Rehan, Knight, Unger & Haas, 2014, p. 117).

Funding for maintenance is normally financed via user charges and tariffs, or co-financing by central or local governments or donors (Fonseca, Smits, Nyarko, Naafs & Franceys, 2013). Fonseca et al. (2013) explain that a system of a ‘sustainable cost recovery’ whereby the user pay tariffs cover all costs including the cost of capital maintenance of infrastructure assets is normally enshrined in a lot of state policy guidelines and regulations. This practice is more than often not implemented in reality as will be discussed further in this research paper.

2.14.1 Mechanisms of Financing Infrastructure per Sector

Due to the inefficiencies mentioned the preceding example, alternative mechanisms of financing of infrastructure maintenance may vary per sector. These are discussed in some detail below:

Road Maintenance

Fuel levies are a form of road user charge that governments use to supplement road maintenance funding (Africa Development Bank, 2011, p. 301). In sub-Saharan Africa, the funding of road maintenance through road funds has grown in prominence. In fact shortfalls in road maintenance are more severe in countries without road funds (World Bank, 2009, p. 36). In sub-Saharan Africa, 80% or more of the user charge revenue is from fuel levies (Benmaamar, 2006). In these countries, most governments combine these road funds with transfers to local governments for road maintenance purposes (World Bank, 2009, p. 36).

In most countries these conventional road funds systems fail, and this has led to the creation of second generation road funds that have “a specific legal and institutional framework which would assure proper management of the funds and accountability to users and government” (Benmaamar, 2006, p. 3). These second generation funds ensure that funding is collected and apportioned to the mandated road agencies in a transparent manner. Benmaamar (2006, p. 6) explains that second generation road funds are characterised by (1) a sound legal basis, (2) they are allocated to an agency which is a purchaser not a provider of road maintenance services, (3) have strong oversight, (4) have revenues that increase with the government’s budget (5) have sound financial management systems, and (6) have in-built regular technical and financial audits.

Water Sector Maintenance

The maintenance of water infrastructure is usually done through tariffs charged by local governments or authorised service providers within a specific country. The optimal way of pricing these tariffs for water is by using a “cost recovery model whereby service providers turn a profit through selling their services, and re-invest revenues in long-term system maintenance and rehabilitation” (Rodriguez, van den Berg & McMahon, 2012, p18). Rodriguez, et al (2012) explain that the purpose of applying tariffs for cost recovery purposes is two-fold: firstly it allows for the recovery of direct costs (i.e. basic operation and maintenance, renewal of existing infrastructure, and the possible capital expansion of water services) of the service to guarantee sustainable services, and secondly to provide an incentive for consumers to use water more efficiently.

The reality is that most developing countries do not adopt sustainable cost recovery models; as reflected in their under-pricing of tariffs costs to consumers. One of the reasons that water tariffs are often under-priced, is because this issue is often politicised where local authorities are forced to strike a balance between providing a commodity that doubles up as an input or factor of production with high economic value and; providing a commodity that is a basic human need that has to be provided to members of the public at affordable prices (Rodriguez, van den Berg&McMahon, 2012). The inadequate cost recovery not only stems from low tariffs, but is also attributable to other operational inefficiencies that lead to low collection rates, water that is unaccounted for, and high revenue losses; all of which lead to the poor quality of public services (Rodriguez, van den Berg&McMahon, 2012).

2.15 Delivering Infrastructure Maintenance via Integrated Contracts

To avoid inefficiencies discussed above, developed countries have historically used integrated contracts that are now becoming a popular means of delivering maintenance of infrastructure assets in developing countries. The rationale for redirecting tasks that were previously performed by the public sector to the private sector is because “it is expected that private contractors are able to identify and develop innovative facilities, deliver more quickly and at a lower cost, and provide private funding and operate facilities more efficiently” (Lenferink, Tillema and Arts, 2013, p. 617). Public organisations in developing countries now have the option of choosing integrated contracts to fit their maintenance requirements as means of

improving their efficiency. Below is a brief description of some of the contracts available to the public sector.

2.15.1 Design Build Finance Maintain Contracts (DBFM)

A Design-Build-Finance-Maintain (DBFM) contract “diverts the responsibilities of design, construction and maintenance from the public sector to the contracted private contractor” (Lenferink, Tillema and Arts, 2013, p. 617). The DBFM contract cannot be considered as pure privatisation as it excludes the operation of the infrastructure asset. The contract can, where necessary be amended to include operations of the infrastructure asset through a Design-Build-Finance-Maintain-Operate (DBFMO) which usually operates through an agreed concession.

2.15.2 Performance Based Maintenance Contracts (PBMC)

Another form of delivering maintenance of infrastructure is through performance based maintenance by contracting. This form of contracting entails the appointment of an outsourced contractor “to plan, design, and implement maintenance activities in order to achieve short-term and long-term infrastructure conditions for a fixed price subject to specified risk allocation” (Sultana, Rahman & Chowdhury, 2013, p. 277). Sultana et al. (2013) explain that the contractor is reimbursed on confirmation that performance standards as defined in the contract are met. In their research, the authors, make specific reference to road infrastructure maintenance, highlighting that the PBMCs have the advantage over traditional methods of contracting, namely:

- 1) long-term benefits in the form of lower maintenance costs, higher levels of service and lower levels of risk to the owner;
- 2) introduction of innovation, allowing the contractor to control materials and methods used for maintenance
- 3) reduction of unnecessary construction delays and impact to public (i.e. noise and other environmental impacts)
- 4) reduction of supervision/administrative costs and increase in efficiency
- 5) increase in user satisfaction
- 6) better risk sharing between the owner and the contractor
- 7) better quality assurance

- 8) sustainable road management system and assurance of long-term funding
- 9) increase in flexibility for the service provider
- 10) increase in transparency and reduction in chances of corruption

(Sultana, Rahman & Chowdhury, 2013)

PBMCs are not without their own challenges. Sultana, Rahman & Chowdhury (2013, p. 288) note that these challenges are more exacerbated in developing countries, and range from: (1) lack of support from government, (2) are dependent on external funding, (3) are prone to political influence and corruption, (4) lack of experience and knowledge of PBMCs, (5) lack of experience in proper planning, (6) government personnel have a fear that introduction of contractors will lead to job losses (7) challenges in estimating the cost of PBMCs, (8) bad performance and attitude of contractors where there is lack of competition.

It is important to caution however, that applying a broad brush on developing countries can be misleading, and that each country has its own unique challenges and strengths.

2.16 Infrastructure Maintenance Challenges

2.16.1 Challenges of Decision Making in Asset Management for Public Agencies

As the main custodian of infrastructure assets, public agencies face a myriad of challenges in their quest to deliver effective assets for public benefit. These challenges are complex and vary in severity based on the country under scrutiny. Schraven, Hartmann, & Dewulf (2011) summarise the general areas of decision making in asset management for public agencies as follows:

- 1) Decisions with regard to the infrastructure objectives of the public agencies
- 2) Decisions with regard to the performance-related situation of the agencies' infrastructure assets, and;
- 3) Decisions with regard to the interventions applied by the agency to the infrastructure assets

In their case study of a provincial public agency in the Netherlands, the authors identified three major challenges that affect the effectiveness of asset management in public agencies with

regards to maintenance, renovation and reconstruction (MR&R) (Schraven, Hartmann, & Dewulf 2011).

Firstly, the authors found that there was a misalignment of decisions concerning infrastructure maintenance objectives, situation and intervention. It became apparent that the misalignment was caused by the fact that objectives governing the management of infrastructure assets were unclear and insufficiently formulated and this made it difficult to assess the condition and performance of the agency's infrastructure assets in the long-run. In reality, a lack of clear objectives means that employees have to depend on their own knowledge and experience to determine whether maintenance was overdue and to what extent.

Secondly, it was found that another challenge for public agencies was in the "definition of infrastructure objectives, which provide the rationale for the evaluation of infrastructure condition and performance, and prioritisation of MR&R activities (Schraven, Hartmann, & Dewulf, 2011, p. 71). A consequence of not having defined infrastructure objectives that align with the agency's strategic goals means the contributions of these assets are difficult to translate into thresholds and indicators of an asset's functional and technical performance.

Thirdly, it became clear that there was a challenge in formulating infrastructure objectives that meet all the expectations of multiple stakeholders (e.g. user groups, political bodies, private sector organisations). The authors note that "effective governance from an asset management perspective, becomes to some extent, the effective management of stakeholder relationships and interests, and argue that the asset management process in terms of definition of infrastructure objectives should start with a clear identification of stakeholder interests" (Schraven, Hartmann, & Dewulf, 2011, p. 71).

2.16.2 Developing Maintenance Management Capability

Infrastructure owners or agencies need to constantly enhance their maintenance management processes in order to ensure that their infrastructure assets are delivering the envisaged output requirements, which includes delivering the desired level of service and performance to support business operations (Too, 2012). Proper maintenance management processes add value to an organisation because delivering the required quality of maintenance can play a significant role in cutting operational costs and increasing overall organisational returns. On the other hand, maintenance that is ad hoc and underperforming can cause assets to fail, thus adversely affecting business operations and increasing underlying operational costs (Too, 2012).

The main challenge for most infrastructure agencies given the above background therefore, continues to be how to effectively enhance the management processes of their maintenance departments. Too (2012) utilised a strategic management lens to address this challenge, coming from a premise that achieving a sustainable competitive advantage is necessary to sustain superior performance. The author used this theory to argue that to achieve a sustainable competitive advantage in this modern era, organisations need to invest in new stock to replace ailing assets, constantly develop and train their human resources to acquire new capabilities in order to effectively deliver high quality infrastructure services.

2.16.3 Challenges of Implementing an Effective Maintenance Management Process

The study utilised a multiple case study method to “identify the capability/ies needed in the maintenance management process of infrastructure to enhance their competitive position and thus sustain their performance” (Too, 2012, p.137). The study revealed that infrastructure organisations are moving away from the traditional time-based-maintenance approach to a more proactive condition-based-maintenance approach, with in-built risk detection mechanisms in their maintenance plans to ensure that they are better prepared for infrastructure asset failure, and therefore minimise the impact. Notwithstanding the benefits of condition-based maintenance, this maintenance methodology also has its own challenges.

The findings of a study by Too (2002), describes the main challenges of conducting an effective condition-based-maintenance management process as described below.

2.16.3.1 Lack of Skilled and Experienced Personnel to Conduct Condition-Based-Maintenance Management

The shortage of skilled and experienced personnel to develop effective maintenance management processes has been cited as one of the key challenges facing infrastructure agencies in many developing countries (Too, 2012). These functions require judgement and experience of skilled asset managers to prepare effective maintenance plans, which outline asset performance requirements, provide guidelines for the collection and interpretation of condition data and lastly analyse the risks involved.

2.16.3.2 Reduced Inspections and Maintenance Window

The window of time needed to carry out inspections and to conduct maintenance has been reduced by the increased demand on infrastructure networks. This restraint inhibits access to infrastructure assets in order to ensure that all critical maintenance works are consistently identified (Too, 2002). This challenge also leads to higher incidents of infrastructure failures.

2.16.4 The Use of Technologies to Overcome Challenges

The advent of technology to supplement human personnel has fared well in helping overcome some of the maintenance challenges mentioned above and therefore assisting in the delivery of infrastructure maintenance in a more effective manner. Too (2012) has proposed the incorporation of technology into the maintenance management process as a tool to overcome the above mentioned challenges. The author argues that more organisations are utilising technology for condition monitoring as a replacement for manual human inspection and notes that this growing trend is due to, (1) increasing costs of skilled maintenance personnel, (2) coverage of infrastructure with a wide reach, (3) reduction in inconsistencies and subjectivity offered by technology over humans, (4) increased quality of data, and (5) the ability of using technology effectively without affecting business operations. Technology should however not be seen as a means of replacing skilled maintenance personnel, but rather as a supplementary resource to fill the voids where there are shortfalls.

Computerised maintenance management systems (CMMS) have also been introduced to assist with maintenance. CMMS have improved the way maintenance staff and managers operate. These systems assist maintenance teams by providing “capabilities to store, retrieve and analyse information” (Swanson, 1997). Swanson (1997) explains that CMMS is a powerful tool for managing the vast amount of data collected by maintenance staff and coming to optimal decisions that are associated with managing the maintenance function. Swanson (1997) further explains that CMMS facilitate communication and coordination of maintenance related activities. All these capabilities offer maintenance teams the ability to respond to the ever increasing demanding production environment (Swanson, 1997).

2.17 The Infrastructure Maintenance Challenges in Developing Countries

The issue of lack of infrastructure in Africa is exacerbated by the inefficient mechanisms that are put in place to finance the maintenance of infrastructure assets during their life-cycle. Deferred maintenance and rehabilitation due to insufficient funding can lead to premature deterioration of infrastructure in the long run. Bridging Africa's infrastructure gap is therefore not only about increasing investment in new infrastructure, but about also ensuring adequate financing is available for maintenance over the life-span of the asset. This is because maintenance offers one of the highest returns to infrastructure spending by ensuring the upkeep and preservation of infrastructure assets, and should therefore be a prerequisite in the funding of all major capital programs (Foster & Brinceno-Garmendia, 2010).

There is currently a large funding gap between the investment in maintenance of infrastructure in low income and middle income countries. It is estimated that sector spending in low-income countries is divided almost equally between new investment (expansion) and maintenance and rehabilitation, in contrast to middle income countries that focus half of their spending on maintenance, with rehabilitation and infrastructure expansion being less of a priority (Banerjee & Morella, 2011). As a result of this practise, it is estimated that one-third of Africa's infrastructure assets need rehabilitation due to a lack of maintenance (Foster & Brinceno-Garmendia, 2010).

2.18 The Reasons for a Lack of Maintenance of Infrastructure in Developing Countries

Alm (2013) explains that the 'user pay system' is widely used in developing countries to generate revenues to fund infrastructure operations and maintenance expenses. The author explains that the actual cost recovery in most developing countries, as explained earlier in this study, is problematic due to inadequate billing and collection procedures, insufficient attention to operations and maintenance, political constraints and low purchase power by users.

One of the key factors for success of implementation of a maintenance strategy is to ensure that the right personnel are in place to execute the maintenance activities that are required. As explained in previous paragraphs, Too (2013) argues that a lack of experienced personnel to implement and manage an adequate maintenance plan can also compound the problem of incompetent maintenance of assets.

2.19 The Reasons for a lack of Maintenance of Infrastructure in South Africa

South Africa shares experiences similar to the rest of other African countries with respect to a lack of maintenance of infrastructure. The Infrastructure Report Card (IRC) for South Africa prepared in 2011 stated that, as with many African countries, one of the key challenges is the lack of funding for infrastructure maintenance for both existing and new infrastructure assets (South African Institution of Civil Engineering, 2011). The report also attributes the lack of infrastructure maintenance to lack of reliable data on existing infrastructure stock, funding constraints for maintenance, uncoordinated efforts by maintenance departments in government agencies, and the lack of life-cycle costing at procurement stage (South African Institution of Civil Engineering, 2011).

2.20 Developing a Culture of Maintenance

The role that human mind sets, attitudes and culture play in the state of maintenance of infrastructure assets or lack thereof within infrastructure agencies, is often overlooked. This oversight by researchers and practitioners is costly because the people within these organisations are involved in collective decision making concerning the type and quality of infrastructure assets that are put in place and whether infrastructure maintenance is catered for. This makes developing a culture of constructive human interactions within organisations a fundamental element of ensuring the provision of appropriate infrastructure assets and the maintenance thereof (Omoregie & Ehiorobo, 2011). Gummings & Worley (2015) further assert that there is a general consensus amongst researchers that organisational culture can make the difference between the success and dismal failure of an organisation

In order to determine how a culture of maintenance can be introduced in a public administration setting, it is important to analyse the concept of organisational culture. Organisational culture is defined as a system of shared assumptions, values and beliefs which governs how people behave in an organisation, (John McLaughlin, www.study.com). Robbins & Judge (2013) define it as the overall subjective perception of the organisation by employees regarding the degree of risk tolerance, team emphasis, and support of people which inevitably becomes the organisation's culture or personality.

Organisational culture can manifest itself into sub-cultures, and thus influence how these sub-cultures operate. Various researchers also show that the values, attitudes and beliefs that are engrained in an organisation's culture play a major role in the operations of different

organisational departments. For example, Glendon and Stanton (2000) explain how contrasting “perspectives of organisational culture can be used as a framework for how values, attitudes and beliefs about safety are expressed and how they might influence directions that organisations take in respect of safety culture” (p. 201). In another research paper, Wakjira and Singh (2012) show that one of the stages for total productive maintenance (TPM) implementation involves the institutionalisation of TPM into organisational culture.

It is important to note however that changing an organisation’s culture can be a difficult exercise, especially in large organisations and Government institutions. The strongest negative factors that affect successful organisational change have been reported as breakdowns in leadership, communication with employees about the change, project management failures, and the strength of the existing culture (Smith, 2003).

It is therefore prudent to approach the introduction of any culture change within an organisation carefully and to do the necessary background work to avoid employee resistance. A study conducted by Hofstede, Neuijen, Ohayv & Sanders. (1990) established a six dimensional model of organisational culture which quantifies cultural differences within organisations. The authors cited the usefulness of the model in assessing cultural constraints, establishing whether an organisation is made of a single or multitude of subcultures and measuring cultural change over time (Hofstedes et al., 1990). Once there is a deeper understanding of organisational culture, and where problems or bottlenecks arise, then it’s easier to formulate change strategies to tackle the underlying problems.

An example by Brunetto et al. (2014) shows that organisational culture in asset management firms and infrastructure Government agencies is more of a reactive nature and needs to be strengthened to be more proactive, risk taking and customer centred; in order to optimise long-term asset performance, save money for customers and minimise asset down-times. The authors in their study cited weak organisational culture and poor employee engagement as a major hindrances to the successful implementation of maintenance strategies in many organisations causing them fail to achieve their pivotal goals.

Smith (2003) also found that one of the key factors to successful organisational change is to recognise the crucial role that middle management can play as agents of change. They can achieve this by supporting change initiatives using quantitative performance measures and rewarding employees for positively adapting to change initiatives. Other factors leading to successful change management are identified as; guidance provided for managers to manage change, development of plans to manage change, identification of an agent to champion the change process, ensuring that the cultural change is embedded in the business strategy, garnering executive and departmental support for the change, and lastly ensuring that the

change effected is manageable (Smith, 2003). The success of this process can greatly change the culture of viewing infrastructure maintenance as an unnecessary expense to one that understands it to be an investment that will prolong the life-span of infrastructure assets, thus contributing to savings in rehabilitation costs, improving efficiencies of productive infrastructure assets, increasing outputs and therefore ensuring high returns. This will turn contribute to economic growth downstream in developing countries.

2.21 Implementation of Adequate Maintenance of Infrastructure Assets

The organisational culture that developing countries needs to introduce, is one that teaches personnel in infrastructure organisations that it is imperative that financial provision for infrastructure maintenance is made during the planning stage of any project. In a World Bank report by Foster & Brinceno-Garmendia (2010), recommendations are made for a three-pronged approach to the funding of major capital programs, entailing a combination of funding mechanisms, institutional capacity building and contractual incentives. He gives an example of the road sector to demonstrate the successful implementation of this framework as follows: (1) Funding mechanisms for operations and maintenance are primarily funded through the 'user pay system' already mentioned in this study, (2) the introduction of road funds in a majority of African countries is a prime example of improving institutional capacity to handle these funds, and (3) the use of multi-layered performance-based road construction contracts has contributed to the efficacy and efficiency of road maintenance.

2.22 Conclusion

The literature emphasises the importance of infrastructure in the context of maintaining economic growth on the African continent. The literature also emphasises how much maintenance of this infrastructure has been neglected on the continent. Some of the challenges posed for the lack of infrastructure maintenance are a lack of funding, lack of skilled personnel in maintenance teams, insufficient attention to operations and maintenance, and a general lack of political will from politicians. The literature encourages the use of technologies to overcome some of these maintenance challenges. The research questions to be posed in the next chapter stem from the literature review conducted.

3 RESEARCH QUESTIONS

The development of the research questions is an important part of the research study because it influences other components, more specifically the research design. According to Maxwell (2013, p. 75), the research questions serve three crucial functions. The first function is to explain what the study is intended to assist both the author and reader to learn or understand. The second and the third function relate to the research design, in that the research questions help the author to focus the study by relating the research questions to the goals and conceptual framework being investigated. The research questions also provide guidance on how to conduct the research design by relating the research questions to the methods and validity. Does this make sense? Ur sentence seemed incomplete.

The researcher is cognisant that questions need to possess qualities of both ‘reliability and validity’ and this was taken into careful consideration. Questions are said to be reliable if they “evoke consistent responses (that is, if a person would answer the question the same way in subsequent interviews” (H. F Weisberg and B. D Brown, 1977, p. 43). A question is valid if it fully measures the concept of interest or adequately addresses the objectives of the study (H. F Weisberg and B. D Brown, 1977). Threats to reliability and validity will be discussed later on this research and how the author will tackle them.

The aim of this research is to develop a viable mechanism to deliver effective maintenance of infrastructure assets in emerging markets. The overarching theme that emerged from the literature review is that there is generally a lack of maintenance of infrastructure in emerging markets. The research questions will investigate the factors that lead to a lack of maintenance of infrastructure assets in emerging markets, and determine viable mechanisms of mitigating the effects of these factors in order to improve quality of maintenance of infrastructure assets.

The main research questions to be addressed by the research study are as follows:

3.1 Research Question 1

What are the factors that lead to a lack of maintenance of infrastructure assets in emerging markets?

3.2 Research Question 2

What are the viable mechanisms to finance and deliver effective maintenance of infrastructure assets in emerging markets?

3.3 Research Question 3

What is a viable way to ensure a linkage between financing models, maintenance structure and life cycle costing of infrastructure assets in emerging markets?

4 RESEARCH METHODOLOGY

4.1 Introduction

The aim of the research design is to outline a clear and concise plan of how the author plans to address the research questions that emerged from the literature reviewed in the study regarding maintenance of infrastructure in South Africa. The planned data collection methodology, and the justification thereof, will be discussed in detail. The chapter will further provide a justification of the method of data analysis chosen by the researcher. The chapter will close with an explanation of how the author plans to address the reliability, validity, and ethical considerations of the research and data collected.

4.2 Description of the Research Questions

It is important to establish the nature of the research questions in order to inform the research strategy to be adopted. Research approaches can either be descriptive, exploratory or explanatory in nature. In summary, descriptive studies are used to identify characteristics of a research phenomenon or determine possible correlations between two or more phenomena under study (Saunders, Lewis & Thornhill, 2012). Exploratory studies are done with the aim of gaining deep insights into a research phenomenon, while explanatory studies help the researcher to establish and explain the causal relationships between variables Saunders et al. (2012). The authors further explain that exploratory studies rely heavily on qualitative research techniques. Below is a description of the nature of the research questions used in this particular research study.

Research Question 1 - What are the factors that lead to the lack of maintenance of infrastructure assets in emerging markets?

This research question is exploratory in nature as it aims to interrogate factors that lead to a lack of maintenance of infrastructure assets in emerging markets. An inductive approach is appropriate to address this research question as it aims to contextualise how certain events have taken place.

Research Question 2 - What are the viable mechanisms to finance and deliver effective maintenance of infrastructure assets in emerging markets?

Similarly to the first research question, this question is exploratory in nature as it aims to investigate viable mechanisms that can be used to finance and deliver effective maintenance of infrastructure.

Research Question 3 - What is a viable way to ensure a linkage between financing models, maintenance structure and life-cycle of infrastructure assets in emerging markets?

Similarly to the first and second research question, this question is exploratory in nature as it aims to investigate viable mechanisms that can be used to finance and deliver effective maintenance of infrastructure.

4.3 Research Design

4.3.1 Nature of Research Design

An appropriate research design was determined by conducting a concise review of how well the research questions addressed the research objectives posed by the study. The research study seeks to determine the dynamics that lead to a lack of maintenance of infrastructure in emerging countries, and to further determine viable means of delivering effective infrastructure maintenance in these economies. The research study is theory orientated as it aims to contribute to the development of new theory in the field of infrastructure maintenance. Dul and Hak (2008) explain that any theory orientated research needs to start with an exploration of existing theory and practice in order to find propositions on the research topic (p. 39). This exploration was conducted through the literature reviewed and was then translated into the research questions that have been asked.

A review of the research questions establishes that these are exploratory in nature as they can be categorised into the “what” and “why” type of questions. The exploratory nature of the research questions makes them well suited to an exploratory research design, as they can assist the researcher to develop theoretical concepts of the phenomena being studied more clearly (Cooper & Schindler, 1998). Moreover, exploratory studies are advantageous because they provide “valuable means to ask open questions to discover what is happening and to gain insights about a topic of particular interest” (Saunders, Lewis, and Thornhill, 2012, p. 171).

Lastly, a qualitative research approach was selected due to its suitability for exploratory research studies, because it allows the researcher to develop richer theoretical perspectives than those that already exist in literature that is reviewed, with the end goal of drawing inferences and new insights from the data collected (Saunders, Lewis, and Thornhill, 2012).

4.3.2 Selection of an Appropriate Research Methodology

There are various factors to consider in determining the appropriate research methodology or strategy to be adopted as part of the research design. Yin (2003) proposed that three conditions need to be considered when choosing an appropriate research methodology being “(a) the type of research questions posed, (b) the extent of control an investigator has over actual behavioural events, and c) the degree of focus on contemporary as opposed to historical events”. Saunders et al. (2012, p. 173) emphasise the importance of considering pragmatic factors that may influence the choice of research strategy, such as the depth of existing research, the amount of time and resources available to the researcher, and access to participants and pertinent data required for the research.

The criteria mentioned above were considered in selecting an appropriate research methodology/strategy for the study. The criteria used to choose the research methodology was the need for the author to ‘probe deeply’ to get an in-depth understanding of the phenomenon being studied, as well as the exploratory nature of the research questions. Access to information and the author’s time constraints to conduct the research were also an important consideration from a practical point of view.

4.3.2.1 Assessment of Potential Research Methods

Saunders et al. (2012) conducted a comprehensive description of research strategies and considerations that need to be taken in their selection. These considerations were used as a basis for selecting an appropriate research methodology for the study. A review of the various research strategies helped the author to immediately eliminate both experimental research descriptive surveys as they are only suitable for quantitative research. Below is an assessment of the potential research strategies based on the selection criteria mentioned above.

4.3.2.1.1 Archival Research

This research strategy utilises administrative records and documents as the primary source of data. This is classified as secondary data. The disadvantage of this research method is that it is constrained by the nature and availability of the administrative records and documents available to the researcher (Saunders et al., 2012, p. 179). Getting access to administrative records on infrastructure maintenance would be challenging due to the fact that most organisations may treat this information as confidential as it forms up part of their intellectual property. There other challenge may also be the shortage of records related to the delivery of infrastructure maintenance in South Africa, because of a lack expertise in this field as compared to developed economies. Lastly, archival research strategy may not be suitable to address the exploratory nature of the research questions in this study, since they require a methodology that will allow the researcher to probe deeply and to interrogate the issues under review. Given the issues that have been highlighted, the archival research method was therefore not adopted for this particular research study.

4.3.2.1.2 Ethnography

Ethnography is a research method that is concerned with the study of cultural groups, (Saunders et al., 2012; Patton, 2002). Patton (2002, p. 81) explains that this research strategy involves intensive fieldwork in which the researcher needs to get immersed in the culture of the group being studied. Although organisational culture plays an important role in the delivery of infrastructure maintenance, it does not form the cornerstone of the research study as there a number of other factors that need to be investigated. The requirement for the researcher to immerse him or herself in the culture of the group being studied is a time consuming process and would therefore not be practical for this research study given the time constraints of the researcher. For these reasons, the ethnography research method was also not adopted for this research study.

4.3.2.1.3 Action Research

McNiff and Whitehead (2009) offer a comprehensive description of how action research distinguishes itself from other forms of research. The first distinction is that the aim of action

research is to improve a personal or social situation. This is done by the researcher offering descriptions, explanations and analysis for action.

4.3.2.1.4 Grounded Theory

Grounded theory entails a systematic process of obtaining and analysing data in a social setting with the aim of discovering new theory from the data (Glasser & Strauss, 2008). According to Glasser and Strauss (2008), grounded theory in the sociology context is aimed at (1) enabling prediction and explanation of existing behaviour, (2) being useful in advancing theoretical sociology, (3) being useful in practical applications, (4) providing a perspective on behaviour, and (5) guiding and providing a style for research on particular areas of behaviour (p. 3). The research process involves the simultaneous collection and analysis of data, developing analytical codes as these emerge from the data, in order to reorganise into different categories (Saunders et al., 2012, p. 185). The method underpinning the coding is a process of constant comparison which enables each item of data collected to compare with others and against these codes that are used to categorise the data. The different classes of data are then constantly compared against and against the codes that are used to categorise the data (Saunders et al., 2012, p. 186). Saunders et al. (2012) note that the main implications of conducting grounded theory is that it is “time-consuming, intensive and reflective” (p. 186) and explain that the main factors that need consideration are, the time available to the researcher, the level of competence required, access to data, and the logistical implications of immersing one’s self in such an intensive approach to research. Similarly to considerations for ethnography and action research, time was a critical constraint for the author. Access to data and willingness of participants in different organisations was also viewed as a inhibiting factor in adopting action research. For these reasons, action research was not conducted by the researcher.

4.3.2.1.5 Narrative Inquiry

Narrative inquiry is a discovery-orientated approach that attempts to minimise the researcher’s manipulation of the study setting and places no constraints on the outcomes of the research (Patton, 2002, p.39). This research method distinguishes itself from “controlled experimental evaluation designs” (Patton, 2002, p.42), because it embraces real world conditions, which are subject to change and redirection. According to Saunders et al. (2012) narrative inquiry is

suitable for qualitative research that seeks to analyse linkages, relationships and socially constructed explanations (p. 190). It does however lack the structural and coherent form of analysis such as those used for grounded theory. Saunders et al. (2012) caution that this method is very intensive and time-consuming as it generates large volumes of data in the form of interview transcripts and observational notes (p. 189). Time, or lack thereof, was considered a main constraint of not adopting this research approach.

4.3.2.1.6 Case Studies

Various authors have offered useful definitions of a case study. Gerring (2007) describes a case study as an intense study of a single case where the purpose of that study is to shed light on a larger class of cases. Stake (1995) explains that case study research attempts to study the particularity and complexity of a single case, and understanding its contribution within important circumstances of interest by the researcher. Interest in studying a particular case, is therefore sparked by its uniqueness and commonality with other similar cases (Stake, 1995). Rule & John (2011) explain further that a unique feature of the case study method is that, “it is a specific example of something or an instance that belongs to a larger category of instances”, (p.4). This makes an individual case a feature of a larger category of occurrences. Yin (2003) explains that the use of the case study research strategy arises out of the desire to understand complex social phenomena. Lastly, Gerring (2007, p. 38) mentions that case studies are more useful for generating new hypothesis, with all other things being equal.

There are compelling advantages and reasons why a researcher may opt to utilise the case study route as a research strategy. Firstly, case study research is advantageous if the researcher wants to gain a richer understanding of the context of the research and the process being investigated (Saunders et al., 2012, p. 179). This is because case study research has the ability to address both exploratory and explanatory research questions (i.e. “why”, “what” and “how” type of questions). Secondly, Gerring (2007, p. 33) explains that case studies are versatile in that they offer a researcher the ability to employ both quantitative and qualitative techniques for collecting and analysing data; which gives them flexibility; giving the researcher the choice to either use a single case study or multiple case study research strategy (Rule & John, 2011, p. 7). Another factor that makes case study research attractive is that it is more manageable than its counterparts, especially when dealing with a large scale survey, as well as in situations where time and resources are constraints (Rule & John, 2011, p. 8).

4.3.3 Justification for the use of a Case Study Method

The case study research methodology was selected as the most appropriate to address the objectives of this specific study. The various criteria discussed by Yin (2003) were used to assess its suitability. The case study method was then chosen because it fulfils the following conditions as described by Yin (2003).

- (1) It has the ability to address the qualitative and exploratory type of research questions posed in this research study and therefore offers the researcher the ability to gain a rich understanding of the context of the phenomena being investigated,
- (2) It assists in generating answers to the “why” and “what” research questions designed by the researcher
- (3) It will allow the researcher to have relatively good control over actual behavioural events, which is advantageous because the study is dealing with a contemporary issue in an environment that cannot be manipulated.
- (4) It allows for the researcher to work within limited time and resource constraints that he faced.

4.3.4 Single or Multiple Case Study?

4.3.4.1 Single Case Studies

It determined that the case study method would be utilised for the research study. The next step was to determine whether to adopt a single or multiple case study method. According to Rule and John (2011), the single case study research method is selected when the researcher has intimate insider knowledge (p. 21). In addition, Rule and John (2011) explain that the single case study method is suitable in the instance where the case under consideration is relatively unique in its category, can be studied in great depth and detail, and provides for ease of reference by the researcher (p. 21). The single case study method is however limited because findings cannot be generalised or applied to other cases, and the inherent potential for bias may adversely influence findings of the research (Rule & John, 2011, p. 21).

4.3.4.2 Multiple Case Studies

Rule and John (2011, p. 21) explain that the motivation for adopting a multiple case study methodology resides is that it allows the researcher to generalise by selecting cases that represent the class of classes better. It also “allows for comparison across cases, it has breadth and width of focus; it offers methodological replication between and across cases, and has ability to study cases within a common theoretical framework” (Rule & John, 2011, p. 21). One of the criticisms of multiple case studies however, is the limited ability to explain causal pathways at work in a causal relationship (Gerring, 2007, p. 44).

4.3.4.3 Single Case Study vs Multiple Case Study

There are various considerations that the researcher needs to consider when making a decision on whether to adopt a single or multiple case study method. Gerring (2007) argues that unlike the multiple case study methodology, the single case study methodology is more useful when the researcher is attempting to investigate a subject he is encountering for the first time or considering it in a fundamentally new way (p. 40). Gerring (2007) further argues that the subjectivity that is characteristic of the single case study methodology is what allows the researcher to generate a large number of hypothesis, in lieu of the multiple case study methodology whereby the researcher works with a “thinner set of empirical data across a large number of cases and with a more determinate (fixed) definition of cases, variables, and outcomes” (p. 41). The more systematic approach related to the multiple case study methodology does however make it more reliable in comparison to the single case study method, because it limits “authorial intervention” as evidence can be analysed in a limited number of ways (Gerring, 2007, p. 41).

When faced with the option, Yin (2003) recommends that the researcher should opt for a multiple case study design, with a minimum of two cases. Yin (2003) explains that the analytical “conclusions independently coming from two cases, as with two experiments, will be more powerful than those coming from a single case (or single experiment)” (p. 53). Yin (2003) further argues that the benefit of having two or more cases to form part of the research will have “expanded the generalisability of your findings, again compared to those from a single case alone” (p. 53).

Gerring (2007) argues that the two methodologies, whether of a single or multiple case study design, need not be working in opposition to each other, but rather need to be seen as

complementary (p. 12). The argument is based on the notion that the researcher needs to have a good idea of both the broader population, and the intricacies associated with the individual cases. According to Gerring (2007) the “exploratory case study method should culminate in a cross-case confirmatory analysis” (p. 85) because without this “cross-case generalization” the case study faces a threat that it may not reflect the reality of the larger group of similar cases. In this instance, the case study would not reflect reality and therefore lose relevance.

It was for the above mentioned compelling reasons that the author opted to adopt a multiple case or cross-case study methodology for the research design.

4.3.5 Sampling Population

The target population for the case studies is infrastructure projects and their related assets in South Africa. The assumption is that all infrastructure assets require maintenance, the extent of which is dependent on their continued level of use. The population will be narrowed down to infrastructure projects implemented and maintained by the public sector as these are deemed to be more prone to neglect of maintenance. This general assumption regarding a lack of maintenance of infrastructure in the public sector is inferred from the literature reviewed thus far.

4.3.6 Unit of Analysis

The unit of analysis will be narrowed down to the operation and maintenance stage of the life-cycle of infrastructure projects selected for the case studies.

4.3.7 Sampling Method and Size

A non-probability, purposive sampling approach was used to select the case studies. The non-probability sampling technique is dependent on the expertise and judgement of the researcher (Robbins, 2009). The section below details the selection criteria that was used by the author to identify the cases for the research study.

4.3.7.1 Selection of Case Studies

Identification of the cases for the case study research method is a crucial part of the research design. Rule and John (2011) note that the first step of this exercise requires the researcher to identify the population within which the case falls, and thereafter find individual cases that make up part of this population (p. 13). The researcher has to develop a clear selection criteria and screening process that will help him or her choose from the range of potential cases (Rule & John, 2011, p. 13). According to Yin (2003). The goal of the screening procedure is to ensure that the researcher identifies cases properly prior to the formal data collection process in order to avoid abortive time spent on data collection and analysis (p. 78). The selection criteria recommended by John and Rule (2011) was adopted in the selection of potential cases for the research study taking into consideration the following:

- 1) purpose of the study;
- 2) the class of cases to which the case belongs;
- 3) the desired relationship between the case and the class of cases;
- 4) the number of cases to be studied; and
- 5) practical considerations such as accessibility and the availability of data.

A criteria will be developed to select appropriate case studies for the research. The criteria will include the following salient points.

- 1) The size of the investment of the infrastructure;
- 2) The impact that the infrastructure asset has on the socio-economic performance of the country;
- 3) The importance given to the project in terms of government's strategic plans; and
- 4) The ease of access to information related to the project.

The criteria will be refined further based on the emerging themes from the literature review.

A maximum of four case studies was used for the research study. The limitation of the number of cases was due to the time and resource constraints under which the researcher had to complete the research study.

4.4 Research Instrument and Data Collection

Consideration of data collection methods to be adopted is a critical part of research design. Maxwell (2013) cautions the general perception that data collection methods follow a logical deduction from the research questions, and argues that the two are distinct and separate parts of the research design, i.e. there is no way of mechanically converting research questions into research methodology. Instead, Maxwell (2013) argues that the research methodology is a means to answering the selected research questions, and not a logical transformation of same. The author therefore argues that the selection of the research methodology not only depends on the research questions, but is also contextual in that the research methodology needs to be practical in the applicable situation. Below is an assessment of each research question and the justification of the proposed data collection methodology to be adopted.

4.4.1 Part 1: Collection of data to determine factors that lead to the lack of maintenance of infrastructure assets in emerging markets.

As previously mentioned, the research question is exploratory in nature. The interview research methodology will be adopted due to its advantage of having the ability to extract in-depth and detailed information from respondents (Copper & Schindler, 1998). The interview methodology is also justifiable because it allows the interviewer to ask probing and complex questions face-to-face, which cannot necessarily be asked in telephone or mail surveys Zikmund (2003). It was determined that interviews would therefore allow the author to collect data that provides for a much deeper and contextual understanding of the factors at play that lead to the lack of maintenance of infrastructure assets in emerging markets.

Semi-structured interviews (in lieu of structured and unstructured interviews) will be adopted by the researcher. The semi-structured interviews strike a balance between structured and unstructured interviews because of the ability to combine key themes and key questions, while allowing the interviewer the flexibility to adapt the line of questioning as and when required (Saunders et al., 2012).

4.4.2 Part 2: Collection of data to determine viable mechanisms to finance and deliver effective maintenance of infrastructure assets in emerging markets

Similarly to the data collection methodology used to address the first research question, the interview methodology in the form of semi-structured interviews will be used as a data collection instrument to determine viable mechanisms to finance and deliver effective infrastructure maintenance in emerging markets.

4.4.3 Part 3: Collection of data to determine a viable way to ensure a linkage between financing models, maintenance structure and durability or life cycle of infrastructure assets in emerging markets

Similarly to the data collection methodology used to address the first and second research questions, the interview methodology in the form of semi-structured interviews will be used as a data collection instrument to determine the linkage between financing models, maintenance structure and durability or life cycle costing of infrastructure assets in emerging markets.

4.4.4 Justification of using Semi-Structured Interview

Semi-structured interviews have been selected to address two out of four of the research questions (i.e. questions 1 and 2). As stated previously, these questions are exploratory in nature. This makes them well suited for semi-structured interviews as a data collection method. Semi-structured interviews utilise open-ended questions. Closed interview questions have the disadvantage that they force the interviewee to fit their knowledge, experiences, and feeling towards a particular subject into the researcher's categories (Patton, 2002, p. 348). Patton (2002) explains that qualitative interviews which utilise open-ended questions, on the contrary, are beneficial because they have the ability to capture the participants' view of the world, they enable the researcher to have insights into their frame of reference, terminology, reasoning and judgements, and to capture the complexities of their individual personal perceptions and experiences. The use of semi-structured questions allows the interviewer to better understand the reason for the participants' decisions, their attitudes and opinions. These qualitative interviews provide important context and contextual material for the research study (Saunders et al., 2012).

4.4.5 Semi-structured Interview: Planning and Implementation

4.4.5.1 Semi-structured Interview Questionnaire Development

As previously stated, a semi-structured approach for the interviewing process will be utilised by the author. This approach has an important influence on the type of interview questions that were adopted. Maxwell (2013) states that there is a linkage between research questions and interview questions, and explains that research questions formulate what the researcher(s) wants to understand, whilst interview questions relate to what the researcher or interviewer asks the participant in order to gain that understanding. With this consideration in mind, it is important that the development of interview questions is done with creativity and insight in mind, as opposed to a mechanical conversion of research questions replicated on an interview schedule (Maxwell, 2013).

The first step towards preparing the interview questions will be to develop interview themes. The interview themes will be derived from the literature review, common sense and general knowledge of the researcher. Preparation of the main questions follows a combination of three basic processes as described by Rubin and Rubin (2012). The first approach entails the determination of the main questions based on what the researcher already knew about infrastructure maintenance and its associated challenges. The second approach entails the review of the literature to inform the main questions. The third approach entails the use of preliminary research in order to discover and formulate main questions. The author conducted a majority of the preliminary research through the research supervisor who was personally involved in infrastructure maintenance advisory on a professional level.

The nature of semi-structured interviews favours less structured approaches to interview questions in the form of open-ended questions. Open-ended questions were therefore utilised by the researcher for the interview questionnaire. Open-ended questions allow the researcher to respond more freely to questions, elaborate on answers, disagree with particular questions, and to raise new issues (Rubin and Rubin, 2012, p. 29).

4.4.6 Sampling Method for Semi-Structured Interviews

The respondents for the interviews will comprise of practitioners from both the public and private sector who are responsible for the financing and implementation of maintenance

operations of infrastructure assets. These practitioners will include financiers, Treasury finance officials, and infrastructure asset managers.

The initial participants will be identified from the researcher's own personal contacts. The potential participants will be made aware of the aim of the research and associated confidentiality provisions through the informed consent letter. A draft of the informed consent letter will need to go through a formal process of approval by the research institution, before it can be circulated to any potential participants. Once approved, the informed consent letter will be forwarded to the participant in electronic format by email. Interviews will only be conducted upon formal approval and consent by the potential participant. A combination of judgement and snowball non-probability sampling will thereafter be used as a sampling technique to identify additional respondents for the semi-structured interviews. A similar method of getting the participant's approval for an interview through an informed consent letter will be utilised. This sampling approach was deemed to be suitable due to the specialist nature of the infrastructure asset management fields.

4.4.7 Data Gathering Process

A Dictaphone will be used to record the interview proceedings between the interviewer and the various interviewees. The interviewer will utilise the questionnaire prepared for the semi-structured interviews to conduct the interviews. Once recorded, the interviews will be transcribed by the interviewer.

4.5 Data Analysis

Similarly to data collection, the process of analysing data is an important part of research design. A lot of research textbooks emphasise the complexity and difficulty of analysing qualitative data and how this section tends to be the weakest from a methodical perspective for most scholars (Gill & Johnson, 2010, p. 172; Maxwell, 2013, p. 104). Gill and Johnson (2010) argue that there is a need for qualitative researchers to present their method of data analysis in a manner that enables for the justification of their findings. Gill and Johnson (2010) further argue that a well thought out and executed analysis is essential for the evaluation of those findings.

4.5.1 Data Analysis Approach for Case Studies

A key consideration in deciding on the approach to adopt for the analysis of qualitative data is whether the research was done inductively or deductively (Saunders et al., 2012). A deductive approach entails the use of theoretical propositions to create a framework to assist in organising and directing the data analysis; whilst an inductive approach begins with collecting data and thereafter exploring same to determine which themes or issues emerge (Saunders et al., 2012). The result of an inductive approach is new theory which emerges from the data collection and analysis process. The choice of the procedure for data analysis is determined by the choice of research philosophy, research strategy, and nature of data collection method adopted (Saunders et al., 2012).

Stake (1995) makes a distinction between *intrinsic* and *instrumental* case studies. The basis of intrinsic case studies is to learn about a particular case, and we do not necessarily learn about other cases or general problem or phenomenon (p. 3). Instrumental case studies, on the other hand, are utilised to get a general understanding of the research question, general problem or phenomenon being tackled by the researcher, or relationships within the case. As Stake (1995) simply puts it, the use of instrumental case studies is “to understand something else” (p. 3).

The nature of the case study, whether it is an intrinsic or instrumental case study, will affect the method of data analysis adopted. The purpose of intrinsic case studies is to understand a particular case and therefore most of the researcher’s time is spent on the direct interpretation of the case (Stake, 1995, p. 3). In contrast, instrumental case studies are concerned with understanding a phenomena or relationships within them, which decreases the need for more direct interpretation and increases the need for categorical aggregation. Categorical aggregation involves seeking an aggregation of different instances in a case until something can be said about those instances as a class (Stake, 1995, p. 74). This particular research is instrumental in its nature and is more suitable for adopting categorical aggregation as a data analysis strategy. Categorical aggregation involves coding of data, aggregating frequencies, and thereafter determining patterns that may arise (Stake, 1995, p. 78). This method of data analysis is explained in the sections below.

4.5.2 The Analysis of Semi-Structured Interview Data

4.5.2.1 Preparing the Data for Analysis

The first step in the analysis is to transcribe the interview data, i.e. to turn the oral data to a word-processed form (Saunders et al., 2012, p. 550). First prize for transcription is for an interviewer to transcribe his or her own interviews. In this way the interviewer not only picks up on exactly what was said, but can also get an indication of the tone in which it was said. The researcher will also be able to interpret the interviewee's non-verbal communication (Saunders et al., 2013, p. 550). The author opted to outsource the function of transcribing the audio-recorded interviews to a professional touch-typist, due to its time consuming nature and his given time constraints.

It is important to note that the transcribed data will still need to be edited to check for errors and omissions. The purpose of the editor at this point is to ensure that data is "(1) accurate, (2) consistent with other information, (3) uniformly entered, (4) complete, and (5) arranged to simplify coding and tabulation" (Cooper & Schindler, 1998, p. 411).

4.5.2.2 Coding of Transcribed Interview Data – Qualitative Content Analysis

The analysis of qualitative data forms an important aspect of research design. Once transcribed, the data had to be transformed into a format that was more useful to the researcher. Qualitative Content Analysis (QCA) was used to analyse the transcriptions developed from the semi-structured interviews. This type of analysis measures the semantic content or the 'what' aspect of the message (Cooper & Schindler, 1998). Patton (2002) describes content analysis as a "qualitative data reduction and sense making effort that takes the volume of qualitative material and attempts to identify core consistencies and meanings" (p. 453). These core meanings are referred to as patterns or themes, which are then grouped into manageable and meaningful classifications through the process of coding.

From a practical sense, the process of coding entails the assignment of codes to the newly created constructs and concepts, and then reporting the frequency of occurrence at which they occur in the interview transcription (Remenyi, 2012). The information from the coding frames was then used to make comparisons between the various case studies with the aim of drawing conclusions to the research questions posed. Recommendations will then be drawn from this process.

As described above, coding of data entails the assignment of numbers or symbols to responses into limited number of classes or categories (Cooper & Schindler, 1998, p. 413). By rearranging data into categories, comparisons between things in the same category can be made, and theoretical concepts can be developed (Maxwell, 2013, p. 107). The identification of categories is driven by the purpose of the research as expressed in the research questions and objectives (Saunders et al., 2012, p. 557). Maxwell (2013) explains that categorisation involves the identification of units or segments that seem important or meaningful. This can be done by utilising prior knowledge of what is important, or adopting an inductive approach which attempts to capture new insights.

4.5.2.3 Development of the Coding Frame

The coding categories were developed from the themes that emerged from the literature review process and the research questions to be addressed. The four rules to guide the establishment of category sets as described by Cooper and Schindler (1998, p. 413) were adopted. These rules ensure that the categories are (1) appropriate to the research problem and purpose, (2) exhaustive, (3) mutually exclusive, and (4) derived from one classification. A theoretic criterion as described by Shreier (2012) was used to ascertain where one unit of coding ends and where another begins. Shreier (2012) explains that the thematic criterion is more suited for interview data which lacks an inherent structure.

The themes that emerged from the literature review were as follows:

- 1) Maintenance as a core business activity
- 2) Maintenance techniques
- 3) Outsourcing of maintenance activities
- 4) Maintenance performance indicators (MPI's)
- 5) Linkage of MPI's with organisation vision, objectives and strategy
- 6) Funding of maintenance
- 7) Use of technologies to supplement human personnel
- 8) Skills and capacity
- 9) Turnover of staff
- 10) Culture of maintenance
- 11) Linkage between financing models, maintenance structures and life cycle costing

The coding frame is shown in Appendix 2 of this report.

4.5.3 Multiple Case Study Analysis

An analysis method that is in line with a multiple case study approach was adopted for the research. The implication of a multiple case study approach means that the cases themselves are layered. The layering approach recognises that the researcher can always build larger cases out of smaller ones by combining studies of individual cases into a more holistic cross analysis of the cases (Patton, 2002, p. 447). Patton (2002) emphasises the importance of ensuring that the researcher collects data on the lowest level unit of analysis and aggregates from this point to build towards the analysis of the chosen population of cases.

In terms of methodology, a two-staged approach as described by Merriam (1998), namely a within-case and cross-case analysis, was used for the analysis of the case studies. The first step method that was utilised was the within-case method, which entails the analysis of a single case or stand-alone unit. The second step was the cross-case analysis, which entails the assessment of similarities and differences across cases. According to Merriam, the cross-case analysis will allow the researcher to build general explanations to fit each of the individual cases.

4.6 Addressing Threats to Reliability and Validity of Research

Reliability and validity were briefly touched on in chapter three, and in this chapter the author expands on them in more detail. Research is prone to the risk of losing credibility if the threats to reliability and validity are not identified and addressed by the researcher. These two aspects of research are imperative to ensure that a high quality standard research is achieved. It was thus important to ensure that this aspect of the research was addressed in the study. This chapter outlines the various factors that were identified as possible threats to reliability and validity of the interview and case study research, and how these were addressed by the researcher.

4.6.1 Threats to Reliability of Research

In the context of academic research, the construct of *reliability* refers to the consistency and trustworthiness of research findings, and verifies whether the findings of a particular research study are reproducible by other researchers at different or other times (Kvale, 2007, p. 123).

The consistency and trustworthiness of research findings lies in whether the selected data collection techniques and analytical procedures utilised by the researcher can be replicated or reproduced at different occasions or by a different researcher (Saunders et al., 2012, p. 192). Saunders et al. (2012) mentions that a number of threats to the reliability of research may occur in the form of (1) participant error, (2) participant bias, (3) researcher error, and (4) researcher bias. These are explained further below by the authors:

- 1) *Participant error* refers to any factor which may adversely alter the way a participant partakes in the research.
- 2) Participant bias refers to any factor which induces a false response from a participant.
- 3) Researcher error refers to any factor which alters the researchers interpretation of data collected.
- 4) Researcher bias refers to any factor which induces bias in the researcher's recording of responses.

The threats to reliability may lead the researcher to come to dubious findings and conclusions which may be affect the credibility of the research report. It was therefore imperative for the researcher to assess possible sources or threats to reliability and ensure that these are rigorously addressed.

4.6.2 Addressing threats to Reliability of the Interview data

In the context of interviews, Kvale (2007) explains that reliability refers to whether different transcribers and analysers will produce the same transcriptions and analyses. . Given the fact that the interviews were transcribed, the researcher endeavoured to listen to the interviews again to pick up on any discrepancies between the recordings and the transcriptions, and to also pick up on an emotional aspects of the interview, that affect the analysis of data, as recommended by Kvale (2007). Another area of caution regarding qualitative interviewing, is that the findings derived from this type of data collection method are not necessarily intended to be repeatable since they reflect a reality at a specific point in time, and that reality may be subject to change (Saunders et al., 2012, p. 382). This does not however, necessarily render qualitative interviewing weak; because it captures richer data about a phenomenon, but this notion needs to be highlighted nonetheless.

It is recommended that notes from the interviews captured by the interviewee, be retained, should they be required for use in future by others who wish to replicate the research.

Saunders et al. (2012) suggest preparing notes relating to the research design, justification of the choice of research strategy and methods, and data obtained and keeping them for future reference. The authors explain that this will allow other researchers to understand the processes that were utilised as a means to re-analyse the data collected and to expand on it to create new theory.

4.6.3 Threats to Validity of Research

Validity attempts to assess or verify whether a research method in fact investigates what it purports to investigate (Kvale, 2007). Kvale (2007) argues that validity is not confined to a specific section of the research, but rather permeates throughout the entire research process through the skilful craftsmanship of the researcher to continually check, question and theoretically interpret the research findings. This ensures that that high quality standards are maintained from a process and findings perspective.

It is important to note however that, the concept of validity for quantitative research may be different to that applied in qualitative research. Maxwell (2013) explains that there has been ongoing debate amongst researchers because some argue that, unlike validity in quantitative research which refers to validity as a “real world” construct, validity in qualitative research can be outside the constructs of different individuals and societies. Researchers in support of this approach have recommended the concepts of trustworthiness, authenticity, and quality to be accepted as standard constructs for qualitative research. Maxwell (2013) argues that is better to give careful consideration to the concept of threats to validity, which highlights that a researcher might be wrong in their interpretation of data collected. This view therefore looks at alternative explanations and interpretations (i.e. other possible ways of understanding the data collected) called “rival hypothesis” Maxwell (2013). The author concludes that validity in the research design should identify the threats foreseen, and outline the strategies that will be utilised to determine whether these threats are plausible, and how to deal with them should plausibility be verified.

Maxwell (2013) describes two forms of threats to validity, being researcher bias and reactivity. Researcher bias may result from the researcher’s own theories, beliefs, and perceptions, which are impossible to eliminate. Maxwell (2013) recommends that the researcher should be aware of these possible biases, honestly explain them and show how he or she plans to address them in the research. The second threat to validity is referred to as reactivity, and relates to the effect the researcher has on the individuals being interviewed. Maxwell (2003, p.) explains that this influence is impossible to eliminate, and that the aim is to rather

understand it and use it productively. Other forms of validity as mentioned by Saunders et al. (2012) are highlighted below:

- 1) Construct validity-refers to the extent to which the research actually measures what the researcher intended.
- 2) Internal validity- is determined when the research demonstrates a causal relationship between two variables.
- 3) External validity-is concerned with whether the research findings of a study can be generalised to other relevant settings or groups.

4.6.4 Addressing threats to Validity of Interview Data

Validity in qualitative interviewing relates primarily to addressing the threats of interview bias which can take various forms. Kvale (2007) explains how validity in qualitative interviewing speaks to how our social construction of social reality through the discourse of the community, in lieu of the research method adopted, becomes the focal point. The author mentions two types of validation in qualitative interviewing, which are communicative and pragmatic forms of validation (Kvale, 2007). Communicative validation is further broken down into three forms, the first being self-understanding, and this relates to the interviewer's interpretation of the interviewee's own understanding of their statement. The second form of communicative validation is critical common sense understanding; which relates to researcher's interpretation going beyond the participant's own understanding, which may go into that of the general public. Lastly, the third form of communicative validation is theoretical understanding, which goes beyond the participant and public interpretation into that of scholar's familiarity with the interview themes. It is important to note that none of these perspectives is better than the other, but rather that these perspectives depend on the appropriateness of the research questions posed (Kvale, 2007).

4.7 Ethics in Research

There is a relationship between ethics and quality that needs to be addressed. Flick (2007) explains that this relationship can be described from three angles. The first angle defines quality as a precondition for an ethically sound research study and, recognising that it is unethical to make people participate in research that is not of a high quality. The second aspect is that ethical issues such as data protection, avoidance or mitigation of harm to interview

participants, respect of peoples' perspectives and their privacy is deemed to be another pre-requisite feature of a quality research study. The third aspect is for the researcher to be cognisant of the conflicts that may sometimes arise whilst trying to strike a balance between achieving high quality standards for the research and dealing with ethical concerns that may be cause harm on the participants.

4.7.1 Ethical Considerations for Research Interviews

Research interviews are particularly challenging from an ethical perspective. Patton (2002, p. 405) explains that the purpose of a research interview is purely to gather data, and cautions the researcher to avoid the temptation of being compelled to try to be a change-agent in the lives of the interview participants. The researcher is required to be as neutral as possible in his or her conduct during an interview, because interviews have the power both to open old wounds, or alternatively to heal them (Patton, 2002, p. 406). Patton (2002) further explains that interviews can also have an effect on the interviewers' observations and feelings which can directly impact on the quality of the data gathered. Interviewees can also reveal sensitive information that they never intended the interviewer to be privy to, and this may expose the interviewer to other risks, which in some instances may have legal ramifications. As a result, the researcher needs to tread very carefully around these and other ethical issues that may arise during the interview process.

Patton (2002) recommended the adoption of an ethical framework to help the researcher deal with the issues highlighted above. A checklist prepared by Patton (2002) was adopted by the author to address ethical issues in the design, data collection and analysis stages of the research study, and these include:

- 1) Explanation of the purpose of the research to the participant,
- 2) Promises and reciprocity by the participant,
- 3) Risk assessment of the impact of the interview on participant,
- 4) Promise that confidentiality will be fully honoured,
- 5) Informed consent through an approval process by the institutional review board (IRB),
- 6) Data access and ownership
- 7) Assessment of interviewer's mental health
- 8) Advice for researcher from suitable confidant
- 9) Data collection boundaries set by the researcher; and

10) Ethical versus legal considerations informed by the researcher's ethical framework.

An informed consent letter was prepared by the author and forwarded to the institutional research board for approval before it was issued to potential interviewees. The informed consent letter stipulated the purpose of the interview, the parties administering the interviews and institution that will act as custodian of information gathered and analysed; the type of questions that will be asked during the interview, confidentiality provisions in terms of the handling of responses, and the risks and/or benefits associated with the research. Only interviewees that provided formal written consent were consulted for an interview.

5 RESULTS

5.1 Company 1

5.1.1 Company Description

Company 1 is a chemicals and energy company. The company originated in South Africa and has grown its footprint to several strategic countries around the world. The company's product range includes liquid fuels, chemicals and low-carbon electricity. Company 1 is renowned for its state-of-the-art production facilities and technologies.

5.1.2 Semi-Structured Interviews to determine viable mechanisms for delivering effective maintenance of infrastructure assets in emerging markets

This section of the research discusses the results of the interviews that were conducted with two personnel that were part of management in the maintenance department at Company 1. The interview with Respondent 1 was held on the 29th September 2016 and lasted a duration of approximately one hour and six minutes. The interview with Respondent 2 was held on the 6th October 2016 and lasted a duration of approximately 52 minutes.

5.1.2.1 Profile of Respondents

Respondent 1

Respondent 1 holds the role of a Section Leader. As a Section Leader, Respondent 1 heads a technical support team which consists of a group of technicians who support the maintenance team. Part of the support function involves the execution of small projects that form part of the maintenance strategy.

Respondent 2

Respondent 2 holds the position of an Electrical Maintenance Manager. Respondent 2 is responsible for ensuring the maintenance of all electrical components for one of the facilities that form part of the chemical processing operations.

5.1.2.2 Maintenance as a Core Business Activity

Company 1 is an asset intensive organisation with a host of different assets under management utilised for operations. Respondent 2 mentioned some of the assets owned by the organisation, “we have got assets which is the plant equipment but it includes also the buildings, the workshops and we also have rail loading, we have the plant which is the chemical plant, the rail loading where we have the trains that are loading the products and taking them to the harbour” (personal communication, October 6, 2016). Maintenance is thus a critical business activity as it ensures the upkeep of the large asset stock. The assets also need to be in an acceptable state for operations to ensure that the organisation produces the required product for sale to its customers thus bringing in revenue. Respondent 2 explained the importance of maintenance for operations, “Yes it is a core business activity. If the equipment stops working you cannot produce” (personal communication, October 6, 2016). The organisation is continuously working 24 hours a day, “as I have mentioned, the operations, they are 24/7...I mean *Company 1* being a petro chemical, some of the equipment that are used they are being operated in a hazardous location. So it is key that maintenance is done accordingly” (Respondent 1, personal communication, September 29, 2016).

Maintenance also gets prioritised from a management structure perspective. Respondent 2 explained how maintenance managers at the various plants report directly to the vice president, “under the senior vice president there is the vice president that is looking after different production plants and there is other senior vice presidents that are in the other operations reporting to the same person; and then under that vice president there will be production managers and also maintenance managers like chemical and electrical instruments maintenance managers:” (personal communication, October 6, 2016). This statement also shows how the maintenance management structure has also been well resourced as there is provision made for maintenance managers who handle different asset classes. There are also support structures put in place by the organisation to support the maintenance department, “Ok, for one, in the department that I am in it is a technical support group whereby we have a team of technicians and engineers that provide high level support to maintenance” (Respondent 1, personal communication, September 29, 2016).

5.1.2.3 Maintenance Techniques

Both Respondent 1 and Respondent 2 made reference to the SAMI STAR system (also referred to as the T minus 7 system) that is used by Company 1. Respondent 1 explained that

the system is based on a maintenance routine that is planned at 7-weekly cycle intervals, “Basically how maintenance is being done, they plan it over a 7 week period and then basically over the 7 weeks we list all the activities that we intend doing over the 7 week period and then as we count down we ensure that when the time comes to do maintenance on the particular equipment, it is available to do maintenance, the spares are available and also the resources. I mean personnel and also tools and equipment that are necessary to do that” (personal communication, September 29, 2016). Respondent 2 also reiterated the same explanation regarding the T minus 7 system, “So the jobs are planned 7 weeks ahead and then every week we check because we check that it is okay. This week we can log down the plan, everything all the resources are in, the parts and all those things. Then we log the plan for next week and we keep counting. So it’s a T minus 7 planning system” (personal communication, October 6, 2016). Company 1 goes as far as planning each artisan’s hours in a single day to ensure that resources are fully utilised, “So within that we plan our artisans for 6 hours in a day. So, all planned jobs are 6 hours. And then on top of that because they are working about 9 hours a day, then the other one is just to cater for, like breakdowns and all those things” (Respondent 2, personal communication, October 6, 2016).

Maintenance at Company 1 is classified into three tiers, being capital projects, renewals and normal maintenance. There are different strategies that are utilised under normal maintenance, namely preventative maintenance, condition based maintenance and run-to-failure maintenance. Respondent 1 explained that a suitable strategy is determined for each type of equipment owned by the organisation, “As I have mentioned, each piece of equipment it has maintenance strategy and then basically from that strategy, I will try and get a copy of that document, so that you can also review” (personal communication, September 29, 2016). Respondent 2 elaborated on the process undertaken for condition based maintenance, saying, “We do have the condition based where we check, we do inspections or monthly, weekly or six monthly or yearly inspections. Then from those inspections then we generate job cards. When we find there is a fault then we repair the equipment” (personal communication, October 6, 2016). The respondent continued to explain that preventative maintenance is implemented on certain equipment depending on its categorisation, “Then we have got also scheduled maintenance where we know that every three months we have to grease the motor we have to do something I think like that” (Respondent 2, personal communication, October 6, 2016). Run-to-failure strategies are implemented on items of low monetary and operational impact value, “But you also have like run to failure strategy. For smaller equipment like smaller motors where it is not very cost effective. Also things like lights. Lights, you don’t need to do any condition monitoring on the lights. It runs until it fails when

that has failed then we just change it” (Respondent 2, personal communication, October 6, 2016).

Respondent 1 explained that the job cards that are generated from the condition based inspections ensure that the maintenance department keeps track of the condition of its equipment implement any remedial action that is required. Each job card has a set of questionnaires that the site personnel doing the inspection has to fill in, “So it is done in a manner that each job card that is produced, it has got questionnaires and then they basically tick through the check boxes to check that whatever they see, whatever they test for they are able to record and then feedback the results” (Respondent 1, personal communication, September 29, 2016). The respondent highlighted that a notification is generated and fed to a central system if a defect is recorded from the inspection, and the loop will only be closed once the defect has been rectified, “If there was none then there was none, but if there was something then from an inspection, if there is a defect noted, then it triggers the next notification to say ok, maybe in a week or so shutdown that particular equipment” (Respondent 1, personal communication, September 29, 2016).

Respondent 1 mentioned that one of the best practices adopted at Company 1 is keeping a history of the state of all its equipment over time, “I think this is the one thing that is being done correct at *Company 1* because for every piece of equipment as I have mentioned, over time, history has been developed to determine that” (personal communication, September 29, 2016). From historic readings of each piece of equipment, the maintenance department can start picking up trends and anomalies that raise ‘red flags’, “Such readings, they are recorded just basically to make sure that the trend is sort of even, it is not picking up. So over time, you would notice if maybe there is something wrong, typically if there is excessive vibrations then we would pick it up and say ok, something is going to go wrong here. Shut down, move over to stand by and maintain this particular” (Respondent 1, personal communication, September 29, 2016). The maintenance personnel at Company 1 understand that being aware of early warning signs means that they can be proactive and address potential issues early, rather than be reactive and address issues when a piece of equipment is faulty.

5.1.2.4 Outsourcing of Maintenance Activities

The two interviewees noted that the outsourcing of maintenance at Company 1 is limited to specialist equipment. Respondent 2 explained the outsourcing philosophy as follows, “We don’t outsource that much, but there are some mechanical you find that most of the time they will have a service provider that is like, doing the pumps for them. There are some few things

but not that much. We do have things like air-conditioning where people come and check them, like service providers come and check the two refill chemicals and checking the conditions. We do have but it is limited.” (personal communication, October 6, 2016). Respondent 1 also reaffirmed this outsourcing philosophy, “On large equipment, like typically your motors, your transformers, pumps and so forth” (personal communication, September 29, 2016). The majority of maintenance is done in-house and provision has been made to ensure that the maintenance department is well-resourced to execute the maintenance activities required, “So in my structure I have got 3 electrical foremen with 5 artisans each, and then they have got 2 maintenance operators each as well...I have got technicians as well. Each foreman has got his own workshop and they have like small stalls where they keep their spares for breakdowns and when they got call outs so they keep those minimum emergency spares as well” (Respondent 2, personal communication, October 6, 2016). One of the reasons for doing a majority of maintenance in-house is for cost saving purposes, “We were outsourcing things likes lights before but you know looking at what we have to pay for overheads even that one we have brought it back to us” (Respondent 2, personal communication, October 6, 2016).

Respondent 1 explained that the outsourced contractors go through a short listing process in order to become approved vendors, “So basically they have a pool of their approved service providers who does maintenance and they have done it in such a way that whoever they approved, you know, there is equal share for everyone whenever there is a need to do maintenance” (personal communication, September 29, 2016). Once appointed, the outsourced contractors are appointed on the basis of a performance contract, “Yes, yes, there are performance contracts. For example the lifts, we have got lifts in the plant that are used for the production areas so you will have companies like Otis maintaining them” (Respondent 2, personal communication, October 6, 2016).

5.1.2.5 Maintenance Performance Indicators (MPI's)

At Company 1, the maintenance department had adopted various maintenance performance indicators (MPI's) to assist in the execution of maintenance. According to both respondents, one of the key MPI's was availability (of equipment). Respondent 1 explained how availability of equipment as an MPI's is utilised, “So basically they measure the availability of equipment. What they would do in a way to ensure that each piece of equipment gets a fair share of operation and that it is always available when needed, they will alternate like typically once a week they would run motor A and then the next week they would run motor B and so forth and

switch over to make sure that you don't run just one motor for years and then it fails..." (personal communication, September 29, 2016). Respondent 2 mentioned how the availability MPI measure has been one of the most successful maintenance interventions implemented by the maintenance department, "Okay, the successful measures are the availability of the plant that you measure. If you measure that if you have to meet a 95% plant availability target you have to make sure that you maintain your things early enough or if you've got targets like that it works better because you have to make sure that your equipment is available all the time and then your product is producing all the time" (personal communication, October 6, 2016). Availability is measured using the mean time before failure (MTBF) MPI, "We also do things like MTBF on the pumps and motors. We do that to check the availability. So that is mean time before failure on the motors" (Respondent 2, personal communication, October 6, 2016). Respondent 2 further added how the availability measures forces the maintenance team to be more proactive in addressing maintenance, rather than being reactive, "So it pushes you to be upfront with everything. To be proactive and ensure that things are okay before something shows signs that it is going to give you problems you maintain it right there and then" (personal communication, October 6, 2016). The maintenance department also monitors other MPI's which include man power utilisation, "And we also look at the utilisation of our artisans" (Respondent 2, personal communication, October 6, 2016). The percentage number of breakdowns is measured as part of the preventative maintenance strategy, "And then at the end of the week we look at how many breakdowns did we have for monitoring and the percentage of breakdowns. We want that percentage to be less than 10% because you want to make sure that our preventative maintenance system is working well so that we don't have more breakdowns" (Respondent 2, personal communication, October 6, 2016). Another MPI that Respondent 2 mentioned was the monitoring of maintenance costs and how the maintenance department aims to reduce these costs year on year, "that is why it drives us to make sure that with the cost plans that we have, we are supposed to also reduce our maintenance cost by about 10% year on year. So that is what we do to make sure that whatever we have done last year, we are saving money" (personal communication, October 6, 2016).

5.1.2.6 Linkage of MPI's to Organisation Vision, Objectives and Strategy

Respondent 1 strongly felt that Company 1's maintenance is linked to the organisation's visions, objectives, and strategy, "*Company 1's* one value is excellence in all we do. Ok there is 6 of them. I just chose excellence in all we do for this particular point in time. I think you

know, there is a saying that you know, and they say the machine runs like a well-oiled machine. Meaning that it is running smooth, no hiccups and so forth. So *Company 1* does take pride in ensuring that the personnel that does the maintenance as well as the personnel that operate that particular equipment, they are trained, they are of the required standard required to either maintain or operate that particular piece of equipment” (personal communication, September 29, 2016). Judging from the responses in the interviews, it is correct to state the maintenance department did strive for excellence in the execution of maintenance.

5.1.2.7 Funding of Maintenance

Funding for maintenance at *Company 1* is classified into three categories being capital, renewal and normal maintenance, “Okay, so I mentioned that we have got capital budget, we have also got renewal budget, and the normal maintenance budget” (Respondent 2, personal communication, October 6, 2016). Respondent 2 explained how the different types of maintenance are distinguished, “So if we just want to change some equipment, we use capital. And when we are changing from different technology to a new technology, so then we have got renewals, so renewals is like for like. So we have that budget as well to budget for renewals.” (personal communication, October 6, 2016). The funding for maintenance is budgeted annually. Respondent 2 explained how the annual budget for maintenance is determined, “When we start in the beginning of the year we allocate funds for normal maintenance and renewal and then for the capital budget we just indicate what we need to do, what projects you need to do, small or big projects, and then that one a budget pool is created to cover those projects and then you apply within that year.” (personal communication, October 6, 2016). All budgets need to be motivated through the business units that evaluate the budget allocations, “For one, within *Company 1* there is a business unit, I think they call themselves, the name just runs off my mind but basically there is a business unit that employs business analysts, employed by *Company 1* and then basically they support the operations department whereby, when there is a need to develop a business case or a justification they would check that whatever you are applying for, if it is economically justifiable, if there is a need to do it” (Respondent 1, personal communication, September 29, 2016). Maintenance that requires larger amounts of capital need to be evaluated and approved by the executive committee, “Then basically once it passes that gate from the team of analysts the business case would then, depending on the monetary value, it escalated to the Exco for approval but it is based on the monetary value” (Respondent 1, personal communication, September 29, 2016).

5.1.2.8 Use of Technologies to Supplement Human Personnel

Company 1 has taken advantage of various technologies to supplement human personnel. A combination of SAP, Meridium, and Inspection One software solutions are utilised by the maintenance department. The three software systems are interlinked. Meridium is an asset performance management (APM) software solution that drives work prioritisation on critical equipment and systems (Meridium, 2016). Inspection One is a “paperless solution for planning, executing and managing inspections and critical-task observations” (Inspection One, 2016). Respondent 2 explained how the Meridium and SAP software systems help the maintenance department to plan maintenance activities, “SAP systems which is also linked to a Meridium systems...and then on that Meridium it kicks out the job cards automatically every 6 months to say now you are supposed to do this type of work on this piece of equipment. Then it helps us on the planning side”, (personal communication, October 6, 2016). The jobs cards generated by Meridium are forwarded directly to SAP which is the department’s central system.

By linking the software system, Company 1 has created an innovative system to ensure that maintenance activities and status of equipment are captured onto a central system. Respondent 2 explained how the system works during inspections by the artisans, “But then on SAP and the Meridium it is interlinked between them to create a job card on the scanner which has got a list of equipment that has to be inspected and then the artisan just take the scanner, go to the plant and those equipment will have a tag or barcode which scans the piece of equipment on the barcode and then start inspecting” (personal communication, October 6, 2016). The scanning equipment prompts the artisan to answer a set of questions during the inspection, “But there is a questionnaire on the barcode as well saying that okay is this fine yes or no this fine yes or no. So the artisan will keep ticking yes if everything is fine. If there is a fault then he says no. The moment he says no, the system will automatically generate a job card for him to come and repair afterwards. So it is an automated system and then it generates a job card like that” (Respondent 2, personal communication, October 6, 2016). By answering a set of questions, the maintenance department can be assured that the artisan in doing the inspections in the right manner by feeding the system the right information.

The maintenance department has installed various monitoring equipment on critical machines to monitor the performance of this equipment. Respondent 2 explained how some of the monitoring equipment works, which includes auto-lubers, run-hour meters and vibration meters, “Yes, we do also install monitor equipment to monitor. We install also automatic like auto-lubers. Automatic greasing equipment, where every let’s say 30 seconds it just releases

a small amount of grease into the bearing of a motor or pump...then also install like a run hour meters to check how many hours a specific equipment has be running. Also we installed some like, your vibration meters to monitor vibration in some of the equipment and that” (personal communication, October 6, 2016). This monitoring equipment assists the personnel to detect maintenance issues on equipment early before they become detrimental to operations.

5.1.2.9 Skills and Capacity

Both interviews felt that Company 1 had enough skills and capacity to execute the maintenance function. They both attributed the wealth of good skills in the maintenance department to the extensive training that Company 1 provides for its staff. Respondent 2 spoke about the training facility that the organisation has set up to train its artisans and technicians, “We train mainly our own artisans and technicians. So we have got a training centre where people with matric maths and science or even the qualifications they come and they start getting trained to become artisans and they know the plants and they know how we do the maintenance so it makes the transfer of skills easier as well” (personal communication, October 6, 2016). Respondent 1 also confirmed that there was a training facility set up by the company, “There is an academy. There are training practitioners. They are certified by Department of Labour. It is an in-house thing” (personal communication, September 29, 2016). Respondent 1 explained how training is treated as a continuous process by the organisation, “For one Sasol they invest in ensuring that people are trained, they are competent and then it doesn’t just end whereby you send a person for training once-off. From time to time there is re-evaluation and then how that is being done in most institutions...” (personal communication, September 29, 2016). Respondent 1 spoke to how the company sometimes outsources training to outside service providers because it strives to keep their maintenance staff abreast of new maintenance methods and technological advances, “Some of the training is done in-house but typically for the technical training because every day there is innovative ideas or technologies, and Sasol they are what, they are very big on implementing cutting edge or new technology. So in such aspects because they don’t have the trainers in-house it would be outsourced and basically there would be a specialist training for that matter” (personal communication, September 29, 2016). Respondent 1 noted that the maintenance department also appoints staff who have not been trained or groomed through the training academy when required, “But we still do also appointments from outside now and then depending on the availability of those people that are being trained and the skills that

they have because if we don't have enough fully trained to qualify as an artisan then we appoint from our side as well" (personal communication, September 29, 2016).

5.1.2.10 Turnover of Staff

There were contradictory comments regarding turnover of staff by the two interviewees. Respondent 1 believed that there was relatively high turnover with the younger staff members, "I would say it is a bit of both. More in the new generation of people that are sort of coming in, there is some turnover" (personal communication, September 29, 2016). Respondent 2 felt that the turnover of staff was low and made reference to the low turnover in his own team, "It is less than 7%. Inside in this position, I have only lost 3 people who like resigned and then I have got only one who took retirement...Yes it's a big group I have got 26 people" (personal communication, October 6, 2016).

5.1.2.11 Culture of Maintenance

The responses from both respondents regarding the culture of maintenance in the organisation were insufficient. Given the responses regarding the maintenance interventions that have been implemented, it can be determined that the culture of maintenance in the organisation is well ingrained.

5.1.2.12 Linkage between Financing Models, Maintenance Structures and Life Cycle Costing

The two interviewees both felt that there is a link in the organisation between financing models, maintenance structures and life cycle costing. Respondent 1 attributed the linkage to the strategic sourcing (procurement) department which evaluates and approves all items to be procured by the maintenance department (personal communication, September 29, 2016). Respondent 2 attributed the linkage to the asset management strategy meetings that are held between the different refinery plants to ensure standardisation in processes, sharing views on best practices and planning for future maintenance, "we have got asset strategy meetings that we attend together with like Sasol and other areas like Germiston, Sasol gas so that we align our maintenance strategies so that we don't do different things. We adopt the best strategy in all different areas and then so we do that we also have like asset strategies where we look at

equipment and how we are going to maintain it until let's say 2050" (personal communication, October 6, 2016).

Respondent 2 also spoke about the engagements between the maintenance department and the asset management department, "Okay, that asset management department is mainly, we call it a Reliability department where they look at the resources, what we are doing, if it is effective enough. And then for our maintenance purposes we have to work together all the time so we have interactive meetings where we sit together and look at the maintenance and how things are going. So we sit together and discuss and also, we also work on the strategies together because at the end of the day everything has to talk one language so we have to look at that. Making sure that everything is synchronised" (personal communication, October 6, 2016).

5.2 COMPANY 2

5.2.1 Company Description

Company 2 is a government department that builds, manages and maintains infrastructure on behalf of the education and health provincial departments. The maintenance department employs over 2 7000 employees and manages the maintenance of over 40 provincial hospitals.

5.2.2 Semi-Structured Interviews to determine viable mechanisms for delivering effective maintenance of infrastructure assets in emerging markets

This section of the research discusses the results of the interviews that were conducted with two personnel that formed part of the management of the infrastructure maintenance department at Company 2. The interview with Respondent 3 was held on the 14th September 2016 and lasted a duration of approximately 49 minutes. The interview with Respondent 4 was held on the 26th September 2016 and lasted a duration of approximately 43 minutes.

5.2.3 Profile of Respondents

Respondent 3

Respondent 3 is the head of the engineering department at the provincial government infrastructure department. This department offers technical support to both the Capex and maintenance departments. The technical support functions involve amongst other things, the review of project designs and the implementation of both electrical and mechanical equipment projects. At the time of the interview, Respondent 3 also held the position of Acting Deputy Director General for the Capex department. The respondent had held this position for three months at the time of the interview.

Respondent 4

Respondent 4 is the Chief Engineer (Mechanical) for the engineering department. The role entails offering technical support to both the maintenance and Capex divisions. The technical

support offered to the Capex department ensures that all the designs comply with the regulations and standards of the Head Facilities. The technical support offered to the maintenance department ensures that all mechanical equipment is properly maintained and that this equipment complies with the best industry standards to ensure a safe environment for the patients and the medical personnel.

5.2.3.1 Maintenance as a Core Business Activity

Both the respondents advised that maintenance was seen as a core business activity at the provincial department and the way it is structured is testament to that. Respondent 3 explained that the department had seen the need to ring-fence the maintenance function. Firstly, there was a dedicated maintenance department in the provincial department. The sheer size of the maintenance department also shows that the provincial department views maintenance as a core business activity. According to Respondent 3, maintenance department has a staff complement of over 2 700 employees that services approximately 40 hospitals and 400 clinics in the province (personal interview, September 14, 2016).

Respondent 3 noted that the provincial department had also seen the need to restructure the divisions as it had determined that the projects (Capex) and Maintenance departments were dysfunctional. The Engineering department was therefore formed to offer the technical support required for both the Capex and Maintenance departments (personal interview, September 14, 2016).

The positions that have also been allocated in these departments also show that the provincial department treats maintenance as a core business activity. Respondent 4 is a Chief Engineer (Mechanical). This role sits in the Engineering department. As the Chief Engineer (Mechanical), Respondent 4 explained that he is responsible for ensuring that equipment in the health facilities is maintained to best industry practices (personal communication, September 26, 2016).

Both respondents cited political will as one of the challenges that the maintenance department faces with regards to running maintenance effectively. Respondent 4 expressed frustration due the fact that some of the department's proposed interventions are put to a halt by powers at the top (personal communication, September 26, 2016). Respondent 3 also mentioned that one of the programmes they were implementing was put on hold due to a lack of funding from Treasury (personal communication, September 14, 2016). This programme was subsequently revitalised.

Respondent 4 noted that there is generally a lack of accountability instilled by management which leads to a lot of the maintenance being left unattended (personal communication, September 26, 2016). Respondent 4 attributes the lack of accountability to a lack of political will on the part of top government officials running the department (personal communication, September 26, 2016).

5.2.3.2 Maintenance Techniques

According to the discussions with both respondents, a formalised maintenance strategy with associated maintenance techniques was previously not in place at the provincial department. Respondent 3 explained that the new maintenance programme which is now in place is based on the Infrastructure Delivery Management Model (IDMD) which is prescribed by the Construction Industry Development Board (CIDB) (personal communication, September 14, 2016). The IDBM stipulates how government departments have to deal with an asset, “They want government departments to create asset, manage asset and dispose of it in a standardised way so they have described asset creation processes, they have prescribed project management processes, they have prescribed operation and maintenance processes” (Respondent 3, personal communication, September 14, 2016).

The previous maintenance approach adopted by the department was reactive, “Currently since I have tried to enforce moving away from a reactive maintenance approach because there has been that way of doing things to wait until they fail” (Respondent 4, personal communication, September 26, 2016). Respondent 4 explained that “the previous reactive approach to maintenance had dire implications as a lot of the equipment at the hospitals was not compliant with statutory regulations” (personal communication, September 26, 2016).

Both respondents noted that a clear maintenance strategy needed to be put in place in line with the introduction of the new Engineering department. Respondent 3 explained that the maintenance practices were changed from a reactive to a more proactive Reliability Centred Maintenance (RCM) approach to focus efforts on those parts where reliability is critical (personal communication, September 14, 2016). The RCM approach is made up of a combination of preventative, condition based and reactive maintenance techniques. This was reaffirmed during the interviews, “So because of this restructuring, we are adopting the conventional maintenance practices of, like mentioned, reliability centred maintenance strategies which incorporates preventative maintenance, planned maintenance, condition base as well as elements of reactive maintenance” (Respondent 3, personal communication, September 14, 2016). Both respondents explained that the first part of the maintenance

strategy was to classify the equipment into different categories based on its value and importance, from a regulatory and statutory perspective. Preventative maintenance is conducted on equipment with a high classification. Preventative maintenance would therefore be conducted on equipment such as the boilers, “preventative maintenance which currently are only focussed on those that are legislated are statutory equipment like your boilers that you need to ensure that every 6 months that the boiler is overhauled and tested to comply” (Respondent 4, personal communication, September 26, 2016). Respondent 4 also noted that one of the main challenges hindering the effective implementation of maintenance approaches was the lack of historic record keeping of the state of equipment and maintenance conducted on equipment to date (personal communication, September 26, 2016).

5.2.3.3 Outsourcing of Maintenance Activities

Respondent 3 explained that the out-sourcing of maintenance is primarily done on specialised equipment (personal communication, September 14, 2016). This comprises of equipment such as boilers, laundry equipment, and generators. The reason outlined for this type of out-sourcing is the lack of capacity from within the department to execute this specialised type of maintenance, “Boilers are specialised type of equipment and the reason why we had some of this is the capacity was totally lacking before” (Respondent 3, personal communication, September 14, 2016). Respondent 4 noted that another reason for the out-sourcing is for the government department to create opportunities for up and coming entrepreneurs (personal communication, September 26, 2016).

On the positive side, Respondent 3 advised that the department is in the process of training its artisans to conduct maintenance on some of the specialised equipment, including generators and boilers (personal communication, September 14, 2016). The training of internal staff was necessitated by the unsatisfactory performance of out-sourced contractors, “At the moment we have to rely appoint a contractor who will go and outsource and come back with the wrong parts, wrong material, can’t do the work, job that in Sasol would have been sorted out in three days by our guys in the plant here can take four five months” (Respondent 3, personal communication, September 14, 2016). The challenge of conducting maintenance in-house is caused by the fact that workshops have been abolished by the department, meaning that maintenance cannot be conducted effectively and timeously. Respondent 3 noted that there has been no buy-in from the provincial heads to resuscitate workshops in the department (personal communication, September 14, 2016).

There were contradictory responses from the interviewees in terms of the type of contract(s) utilised by the department for outsourcing purposes. Respondent 3 was unsure and stated that the assumption was that the department utilised performance contracts (personal communication, September 14, 2016), while Respondent 4 mentioned that work package contracts were utilised (personal communication, September 26, 2016).

5.2.3.4 Maintenance Performance Indicators (MPI's)

The respondents advised that maintenance performance indicators (MPI's) utilised by the maintenance department to monitor the performance of its maintenance activities. Respondent 3 expanded on the MPI's utilised by the department, "We are going to check that mean time to repair, the reliability, availability and we will look at system effectiveness which combines quality, reliability and availability" (personal communication, September 14, 2016). The importance of the 'mean time to repair' indicator was emphasised by Respondent 4 who said that the maintenance department also monitors the number of defects logged against the number of defects fixed over a specific period (personal communication, September 26, 2016). The MPI's are reported to the higher structures of the department, "So those one are part of the organisations objectives and they get measured on a quarterly basis and get reported to the MEC and to the legislature. So they are part of the overall organisation performance objective" (Respondent 4, September 26, 2016). Respondent 3 noted that the capturing and monitoring of the 'reliability of equipment' indicator is still lagging behind (personal communication, September 14, 2016).

Respondent 4 explained that there have been material improvement on overall efficiency of the delivery of maintenance by the department due to the implementation of the MPI's, "But in terms of performance efficiency overview we talking about the time to repair there has been an improvement in terms of how long we take to repair or bring back the equipment to operations" (personal communication, September 26, 2016). Both respondents reported that the department has not been able to determine the exact impact of the implementation of the MPI's in terms of cost savings of maintenance spend by the department. Respondent 3 attributed this to the fact that costs of maintenance are not scrutinised as much as those in the private sector, "That I have not realised yet. I have note realised the impact especially government people are not into it. It is not like a private company they just spend, maybe hopefully we will see that in the future" (personal communication, September 14, 2016).

5.2.3.5 Linkage of MPI's with the Organisation Vision, Objectives and Strategy

Respondent 1 advised that there was a link between the MPI's and the department's vision, objectives and strategy. Respondent 3 noted that the MPI's and the department's visions, objectives and strategy are all aligned in accordance to the IDMS (personal communication, September 14, 2016). This forms part of the department's new strategy of the formalised and structured approach to maintenance.

5.2.3.6 Funding of Maintenance

The interviewees noted that the funding for maintenance activities comes from the Treasury. Treasury allocates an amount of funding to the department on an annual basis, "Here it is basically comes from government the funding for all the maintenance so it comes from the client whom we are providing service, for whom in our place, which is the department of health so every year they allocate a specific amount budget for" (Respondent 4, September 26, 2016). The respondents reported that all other maintenance activities that fall out of the budget, specified as "emergency maintenance" need to be motivated. Respondent 3 (2016) explained how the process works, "That fund, we have to apply and then the senior management will have to approach Treasury for the funds" (September 14, 2016). Respondent 4 explained that the variation in terms of the money that can be allocated from the motivation is capped at 20% of the contract amount (personal communication, September 26, 2016).

5.2.3.7 Use of Technologies to Supplement Human Personnel

The provincial infrastructure department had adopted various technologies to assist with delivering its maintenance activities. One of the technologies adopted was a system called e-maintenance. This was a web-based application that was created internally to cater for the specific needs of the maintenance department (Respondent 4, personal communication, September 26, 2016). The system works via an 'app' that is uploaded onto a cellphone, "It is called e-maintenance. You can log into it from your cell phone and I can log a request on my cell phone. That is developed by our guys" (Respondent 3, personal communication, September 14, 2016). The system allowed the maintenance staff and the public to log in maintenance defects. The system was advantageous as it provided a snapshot of the status of maintenance at any given point in time, "Anyone can go in there, you will see how much

backlog is sitting there, how many defects have been loaded and how many have been fixed...” (Respondent 4, personal communication, September 26, 2016). Respondent 3 explained how e-maintenance has improved the efficiency of the maintenance department in addressing maintenance issues, “So e-maintenance is something that has revolutionised the way maintenance is being done because it has linked all the maintenance teams even to the stocks...So it is just to facilitate the response time” (personal communication, September 14, 2016). The e-maintenance system has also been able to increase the amount of accountability by the maintenance staff, “We are able to account now we are able to call people for a disciplinary hearing” (Respondent 3, personal communication, September 14, 2016).

The e-maintenance system did however have its limitations as it was only able to address reactive maintenance related activities. The provincial department was in the process of implementing a SAP software solution to conduct its planned maintenance activities. “But that one immediately addressed what you call reactive matters to make sure the works, artisans, chief artisans and stuff can do their work. It is not structured to implement planned maintenance so that is why we bring in SAP” (Respondent 3, personal communication, September 14, 2016). Respondent 3 explained that the implementation of the software solution is a work in progress and will take time to implement, “It is a launching, it won’t even be complete when I leave. By the time I leave someone will take over, we are looking at about 5 years to see it fully running” (personal communication, September 14, 2016). Respondent 3 explained that the department has also brought in management consultants such as Accenture and Ernest & Young (EY) to assist with the implementation of their maintenance management software system. Respondent 3 explained that once fully commissioned, SAP will have all the functionalities required to run an efficient and effective maintenance of all its facilities (personal communication, September 14, 2016).

5.2.3.8 Skills and Capacity

Both respondents stated that the skills base in the provincial department was low. Respondent 3 expressed the challenge faced by the department in terms of getting sufficient number of engineers, “I got only two civil engineers but I need 15. I got more electrical engineers and mechanical engineers but they are all not there” (personal communication, September 14, 2016). Respondent noted that the department lacks enough of the necessary skills they need, “No currently we don’t have really. The ones we have is quite a minimal in terms of their skills. In terms of the skills we...okay, let me put it this way - we do have the skills we don’t have enough” (personal communication, September 26, 2016). On the positive, the skills base of

the maintenance department was growing, “The skills base is growing at the moment. Before there was not but because they are transforming. The skill base is growing in the last two years we have more engineers than the organisation has ever had in the last ten years so that is growing under my structure I need sixty people I think I am sitting at 30%” (Respondent 3, personal communication, September 14, 2016). The lack of skills was attributed to the challenge of attracting good skills from the private sector into the public sector space. Respondent 3 noted that the wage gap and lack of job satisfaction were some of the challenges of attracting the right skills to execute maintenance in the department (Respondent 3, personal communication, September 14, 2016).

5.2.3.9 Turnover of Staff

Turnover of staff was not deemed to be a major issue inhibiting the effective delivery of maintenance at the department. Respondent 4 (2016) noted that the attraction of the right skills, rather than turnover of staff, was the main challenge that needed to be addressed (Respondent 4, personal communication, September 26, 2016).

5.2.3.10 Culture of Maintenance

It was not clear from the interviews to determine whether there was a culture of maintenance in the department. Respondent 3 felt that a culture of maintenance in the department was weak but with potential to improve, “I would say this is weak at the moment. On the scale of 1 to 5 we are probably sitting at 2 to 3 but it slowly happening with the new vision it is slowly happening” (personal communication, September 14, 2016). Respondent 4 had initially expressed that there is a high culture of maintenance in the department, “There is a culture of maintenance, people they know cos there is dedicated people that does deal with maintenance, so it is what they do on a daily basis and not an additional thing that they do. So I can say in that perspective yes we do have a culture of maintenance engrained” (personal communication, September 26, 2016). Respondent 4 later retracted this statement and advised that the culture of maintenance was weak and attributed this to historic treatment or view of maintenance by the department, “I think one of the issue is one you call it – it is history. You know people are not use to doing maintenance the modern way” (personal communication, September 26, 2016). One of the reasons for the contradiction could be the respondent’s initial interpretation of the question, which was later corrected. It can therefore

be determined that the culture of maintenance is weak in the department based on responses from both interviewees.

5.2.3.11 Linkage between Financing Models, Maintenance Structures and Life Cycle Costing

There was a consensus between both respondents that the linkage between financing models, maintenance structure and durability/life cycle costing is weak within the department's maintenance division. Respondent 3 felt strongly about the weak linkages and implications thereof, "Maintenance structure, financial models and durability of lifecycle assets. You know this is weak as well. It is also weak, there is no financing model at the moment, we are still in reactive mode and everybody panics when something happens" (personal communication, September 14, 2016). Respondent 4 shared this sentiment and explained how it is impossible to track any maintenance spend on equipment, "Ja, I have been asking the same thing. They can't give me. They make an excuse that our system cannot tell us for example we have this equipment in this hospital can you tell me how much you have spent in that. They can't" (personal communication, September 26, 2016). It was unclear how the respondents felt that this issue could be addressed by the department.

5.3 COMPANY 3

5.3.1 Company Description

Company 3 is a large bulk water utility which supplies water to municipalities, mines and various industries. Company 3 is a public entity. The entity also supplies bulk sanitation services. The organisation has assets that are valued in excess of R90 billion. This includes a water reticulation pipeline system of over 3 000 km.

5.3.2 Semi-Structured Interviews to determine viable mechanisms for delivering effective maintenance of infrastructure assets in emerging markets

This section of the research discusses the results of the interviews that were conducted with two personnel that are part of the maintenance and asset management departments at Company 3. The interview with Respondent 5 was held on the 30th September 2016 and lasted a duration of approximately 59 minutes. The interview with Respondent 6 was held on the 1st October 2016 and lasted a duration of approximately 50 minutes.

5.3.2.1 Profile of Respondents

Respondent 5

Respondent 5 holds the position of a Maintenance Planning Manager at Company 3. This role involves overseeing all of the maintenance strategies of the organisation, and to offer support services to all the various sites that form part of the organisation and house the organisation's vast assets. These assets include water treatment plants and pipe reticulation systems

Respondent 6

Respondent 6 holds the position of Senior Process Engineer in the Assets Department of the bulk water distribution company. The department is responsible for overseeing the asset

management function of all the assets that are owned by the organisation, including process assets, electrical assets, and automation assets.

5.3.2.2 Maintenance as a Core Business Activity

Maintenance is a critical business activity for Company 3. Respondent 5 explains that the reason for the criticality of maintenance is because Company 3 owns a large asset base of high value, “Okay obviously the maintenance is critical for Rand Water. We are a very asset intensive organisation. We have assets that are worth at least R90 billion and there is 1000s of assets in Rand Water and they need to be maintained” (personal communication, September 30, 2016). Respondent 6 also stressed the importance of having a dedicated maintenance department, “Ja, no definitely for our assets if maintenance is not done then we are in trouble. That is why there are specific maintenance department being established in the company otherwise I don’t know what would happen to our assets” (personal communication, October 1, 2016). These assets deliver a key strategic service which also makes maintenance a vital core business activity to ensure continuous water supply to customers. Respondent 5 noted the previous year was the first time supply was interrupted which caused by power failures from the electricity supplier (personal communication, September 30, 2016). Respondent 5 explained that maintenance of the organisation’s assets has become more critical due to increased demand and tighter budgets, “But in recent years obviously the budgets were a bit tight and things like that so managing the assets have become more critical because if you look at in terms of water supply it has increased you know right up to R4900 mega litres per day” (personal communication, September 30, 2016). The ever increasing demand on supply has meant that the organisation has had to sweat its assets, which has also made maintenance very critical for continued operations.

Given the large scale of assets owned by the organisation, a dedicated asset management division has been set up to manage these assets. Respondent 6 explained the rationale for having an asset management department, as follows, “Now the introduction of the asset management department specifically was so that we can plan accordingly, including maintenance, strategic thinking” (personal communication, October 1, 2016). Part of the planning by the asset management department is to ensure availability of equipment at all times during operations, “You don’t want to get to a point where you realise that your asset has reached its end of life and you have not been able to replace it so we plan ahead to make sure that at each point in time you always have production of water meeting the demand at that point in time” (Respondent 6, personal communication, October 6, 2016). There are

various branches within the asset management division that are responsible for different types of assets, “there is the asset department and within the asset department there is different assets that gets looked at. So there will be several assets management, there will be process assets management, there will electrical asset management, automation and all assets that Company 3 actually does have” (Respondent 6, personal communication, October 1, 2016).

5.3.2.3 Maintenance Techniques

The first part of Company 3’s maintenance strategy has been to do a criticality analysis which involves the classification of equipment in terms of their criticality to operations. All critical equipment undergoes preventative maintenance, “So we rate them from A to B, high criticality is A, low criticality is B and then what we said is that we must ensure that critically A assets, all of them have a preventive maintenance programme in place and the B as well” (Respondent 5, personal communication, September 30, 2016). Respondent 5 explained that RCM is utilised on critical equipment and allowing the maintenance team to understand how each piece of equipment operates and determine how to mitigate failure via preventative maintenance measures. The maintenance department runs preventative maintenance, “That is the preventive maintenance optimiser where we run the failure history of the plant and then we mitigate those failures either to root cause analysis, whatever and then at the same time what we have is we have a strategy in place and what we would do is we have an asset care planned strategy” (Respondent 5, personal communication, September 30, 2016). In summary, the department has various maintenance programmes in place, including preventative maintenance, condition based maintenance programme, and RCM. Respondent 5 also explained that the department has also put in place a root cause analysis procedure, which provides guidance in terms of how equipment needs to be handled following a condition assessment, which can vary from a modification, a procedure change, or training of an operator (Respondent 5, personal communication, September 30, 2016).

The department had made provision for an internal auditor to ensure that maintenance was being conducted to the required standards. “We have an SABS approved plus we have an internal auditor. So basically these guys are there to see that to say well you say you do this” (Respondent 5, personal communication, September 30, 2016). The department has also set maintenance standards that need to be adhered to by its personnel, “We saying people must do preventative maintenance but not just finishing maintenance, it must be done on time so we got a standard and if it is a weekly pm we must do it within 2 days. If it is a monthly pm

within 6 days” (Respondent 5, personal communication, September 30, 2016). These interventions ensure that there is proper accountability within the maintenance department.

5.3.2.4 Outsourcing of Maintenance Activities

Based on the responses from the interviews, Company 3 does not outsource a lot of its maintenance activities. Most maintenance activities are done in-house. This maintenance is serviced by the department’s own workshops, “Exactly we have a lot of workshops” (Respondent 5, personal communication, September 30, 2016). The maintenance department has opted to outsource maintenance only for specialised equipment, “We try not to outsource a lot of maintenance work. I think the only type of work that is outsourced are mainly regulatory where you need specialist contracting companies to come and do some regulatory work for instance boiler analysis etc.” (Respondent 5, personal communication, September 30, 2016). Respondent 2 made an example of chlorine tanks in the chlorine plantroom that are owned, filled and serviced by an external contractor. Respondent 5 explained that the commercial department runs the procurement process to appoint contractors to maintain specialised equipment on behalf of the maintenance department (personal communication, September 30, 2016). The scope of work for the tender documentation is however prepared by the maintenance department.

5.3.2.5 Maintenance Performance Indicators (MPI's)

The maintenance department has adopted various maintenance performance indicators (MPI's). Respondent 5 mentioned that the key MPI's adopted by the department are availability and reliability, “So what we do is we say we need to measure availability and reliability as the key indicators for that and then from there we ensure that availability is part of the corporate KPI and so is reliability” (personal communication, September 30, 2016). Respondent 1 expanded further on MPI's utilised by the department, which included meantime to repair, man power utilisation, number of failures per plant, and top five failures. Respondent 6 advised that the asset management department did generate any MPI's themselves, but rather used those supplied by the maintenance department (Respondent 6, personal communication, October 1, 2016).

5.3.2.6 Linkage of MPI's with the Organisation Vision, Objectives and Strategy

None of the respondents mentioned any linkages of MPI's with the organisation's visions, objectives and strategy.

5.3.2.7 Funding of Maintenance

Respondent 5 explained that there are two types of budgets from which maintenance is funded, being the operational budget and the periodic maintenance budget (personal communication, September 30, 2016). The budgets serve two types of maintenance regimes, "So the day to day maintenance expenses come out of the operational budget and then the periodic maintenance is basically a yearly planned maintenance that could be overhauls, regulatory works like crane load tests, transformer, oil etc. pressure vessels all those stuff" (Respondent 5, personal communication, September 30, 2016). Respondent 5 noted that the organisation does ensure that sufficient funds are provided for maintenance given that water is a basic need (personal communication, September 30, 2016). The fact that the company is a non-profit entity is also advantageous for funding of the maintenance department. There is still a need to use the money for maintenance due to growing budget constraints created by growing demand.

5.3.2.8 Use of Technologies to Supplement Human Personnel

The maintenance department has adopted a multitude of technologies in the form of software solutions to assist in delivering maintenance more efficiently. Respondent 5 mentioned a software application for that can be downloaded onto mobile devices (e.g. cellphones) had been created in-house (personal communication, September 30, 2016). The main function of the app is for the field maintenance personnel to capture maintenance faults and direct them onto a central system, "At the moment we got this app is you can down load it on any android phone. From there what happens, it sends a message to our main maintenance system which opens the service requested. What we do is, we said for quality purposes we would like our planning office to check this before" (Respondent 5, personal communication, September 30, 2016). Other software solutions that had been adopted are GIS, a software map that can be incorporated into analysis, reports and dashboards information (Tableau, 2016, p.), and Maximo, an asset management software tool that allows an organisation to manage its

physical assets on a common platform (IBM, 2016). The field data captured by the maintenance personal can be captured in the GIS system and uploaded onto Maximo. The combination of the phone app, GIS and Maximo has proven beneficial for trouble shooting leaks on pipelines, “When there is a leak they will take a picture of it and it will give you the GPS co-ordinates and we take that detail and plot it onto our GIS. That will give you all the leaks on the pipeline and then you can see you know where your problem areas are” (Respondent 5, personal communication, September 30, 2016). Respondent 5 explained that the maintenance department can now hone in and address a specific problem area on a pipeline rather than have to repair the full line, “and you see soil condition changes because in some places there will be wetland and some places there is a road, some places there is perfect conditions so the deterioration of the pipe is not the same so by plotting the leaks now we can see where the problem areas is” (personal communication, September 30, 2016). This means that limited resources in terms of budget and manpower can be used more effectively, “Before they will fix a leak but no one took the co-ordinates. When you cover it what happens, we were fixing and spending a fortune. Now we can reduce that capital expenditure” (Respondent 5, personal communication, September 30, 2016).

Respondent 5 explained that the software has assisted the maintenance department to have historic and current data of the status of their assets at any given point in time (personal communication, September 30, 2016). Respondent 5 noted that capturing the maintenance information of all assets onto a central system means that the maintenance department can better plan for the maintenance of their asset moving forward, “so long so we can actually plan now to replace that section so we can come up with better methodologies and let’s say to increase the life span of the rest of the pipe” (personal communication, September 30, 2016).

The maintenance department has realised that no amount of systems will be useful if the right data is not being captured by the maintenance staff, “Then one of the biggest problems we found and I found that with my research is that you can have all the systems, the best systems in the world but if you don’t know what data to collect you will not know what to do with it” (Respondent 5, personal communication, September 30, 2016). For this reason, management at the maintenance department created schedules which outline the type of data that the maintenance personal need to capture on their site visits, “So you as management need to determine what data they collect down on the field because those guys on the field don’t know.” (Respondent 5, personal communication, September 30, 2016).

The next step for the maintenance department is to integrate their phone app, Maximo, GIS and SAP onto a central system called Enterprise Asset Management System (EAMS). Respondent 5 explained the rationale for the integration of systems, “What we are doing is we

are doing an integration between these systems so that information flows freely” (personal communication, September 30, 2016). According to Respondent 5, this project is still in progress and is scheduled to be completed by the end of 2017, “We already started with that project at the moment so we will be finished by latest 2017 December” (personal communication, September 30, 2016).

5.3.2.9 Skills and Capacity

Respondent 5 explained that the main challenge from a skills and capacity perspective is that the old experienced artisans are retiring and the younger incoming staff do not want to be artisans because they do not consider this trade to be a good career move, “The other challenge in terms of personnel resources that is getting a bit difficult because you are getting young people they don’t want to become artisans you know. They don’t want to work in the machines and stuff like that so that becomes a little bit of a challenge” (personal communication, September 30, 2016). Respondent 5 advised that a viable solution to this issue is to make being an artisan more attractive by paying artisans better salaries, “So at some stage we have to continue you know promoting that artisans and tradesman actually should be better paid for the future” (personal communication, September 30, 2016). Respondent 5 noted that the organisation has created its own Academy whereby it trains not only its own staff, but also staff from other municipalities (personal communication, September 30, 2016).

5.3.2.10 Turnover of Staff

Respondent 5 noted that they do not have high staff turnover in the maintenance department, “so on there is not a very high turnover. I mean I am here 20 years I have got people working here there are 4 ladies here, Victoria is 12 years, Hardin is about 18 years I have got” (personal communication, September 30, 2016). Respondent 5 attributed the high retention to the high level of job satisfaction in the maintenance department, “There is a job satisfaction. The people that I am quite lucky because the people that I have got here they all love their job and they love working for this organisation” (personal communication, September 30, 2016). Respondent 6 commended the maintenance department for its high levels of skills set, but cautioned that this may be short-lived if the current staff were to leave the organisation, “But I think if we lose people like Farouk then we will have a problem. If Farouk decides he is done

his time here then we will start having a problem” (personal communication, October 1, 2016). Based on the responses from the interviews, it was clear that even though the organisation has a good retention of maintenance staff, there is no clear strategy to ensure the attraction, development and retention of superior skills for the future, more especially artisans who are the back bone of the execution of the maintenance function.

5.3.2.11 Culture of Maintenance

Respondent 5 was cautious to say that a culture of maintenance was engrained in the organisation, but instead opted to describe the culture of maintenance as a process that has to be continuously improved upon, “There is always improvements. Maintenance evolves continuously. You can have a discussion with me today come back next year things will change totally” (personal communication, September 30, 2016). Respondent 6 noted that in terms of head office which has a lot of other departments outside of maintenance, the culture of maintenance is not engrained, “So we don’t have a culture in head office. At site I think it is a totally different story because they have to continue and make sure that that stuff is working” (personal communication, October 1, 2016). Respondent 6 attributed this to the fact that maintenance may not be held in high regard by other staff at head office, “People look down on asset management because they think it is maintenance, because they look down on maintenance. They just think that it is something that you do and you just fix this and you fix that. That it does not require brains, they don’t know that there is planning involved” (personal communication, October 1, 2016). Given the maintenance department’s impressive track record, head office’s impression on the department is not deemed to be detrimental to its performance moving forward.

5.3.2.12 Linkage between Financing Models, Maintenance Structures and Life Cycle *Costing*

The creation of the asset management department has been beneficial in that it has improved the linkage between the organisation’s financing models, maintenance structures and life cycle costing. Before the introduction of the asset management department, the maintenance department was working in isolation from other departments, “In the past the engineering division was separate so they divorced themselves from maintenance. They never bothered about maintenance. They will design something give it to operations walk away from there and then they never came to us and said well listen give us the maintenance history from this plant

we want to put in a new filter house there” (Respondent 5, personal communication, September 30, 2016). The asset management division has helped integrate these previously isolated departments, “You got an asset management division now. So the implementation of this is very successful because now there is no silos so you got asset managers, we have monthly meetings basically where the asset managers are involved, operations are involved and project guys are involved” (Respondent 5, personal communication, September 30, 2016). Respondent 5 explained how the integration of asset management has been a paradigm shift in terms of better management of the company’s assets, “So remember we have an asset management team who is now embarking on a life cycle management on the assets so basically we are looking at an entire life now of the asset for the next 20 years for each asset” (personal communication, September 30, 2016). The asset management department has forced the organisation to put in place long-term planning for its assets and to budget accordingly, “Then we are going to come up with this long term plans and then try to say well we are going to plan a capital replacement and then we are going to look at a plan and then we are going to look at our actual and try and get that to meet.” (Respondent 5, personal communication, September 30, 2016). Respondent 1 mentioned that part of the improvements imposed by asset management onto the maintenance department is an asset improvement programme on existing assets. The maintenance department has utilised a criticality analysis as a tool to assist in the implementation of the asset improvement programme, “We have done a criticality analysis. We have reviewed it as well. Every two years we review this because the criticality changes as time goes and now the guys are saying well your critical assets should be the focus for your asset improvement plan” (Respondent 5, personal communication, September 30, 2016).

Respondent 6 explained how the asset management division’s main foundation is based on life-cycle costing, “We use that a lot. It is basically the foundation of what we do” (personal communication, October 1, 2016). The asset management division utilises outputs from the maintenance department for planning purposes, “like I was saying that we use certain outputs from maintenance to plan accordingly and one of those things is planned versus unplanned maintenance” (Respondent 6, personal communication, October 1, 2016). According to Respondent 6, the asset management department utilises expenditure as a factor to analyse planned and unplanned maintenance, saying, “Unplanned maintenance versus planned maintenance and we only look at expenditure” (personal communication, October 1, 2016). Respondent 6 further noted that by evaluating the expenditure of planned and unplanned maintenance, the asset managers can determine which assets are being neglected and prone to failure, “But if you are having a lot more unplanned maintenance expenditure it means that you are reducing the life cycle of this asset and therefore you are not taking care of the asset

in the way that it needs to be taken care of” (personal communication, October 1, 2016). The evaluation of expenditure has therefore become a critical input for the assessment and planning done by the asset managers, “Ja, exactly like I said looking at their maintenance expenditure it informs a lot of our plans and we could curb things sooner rather than later and we can see just looking at the expenditure we don’t even need to know if you maintained this pump or maintained that pump. Just expenditure” (Respondent 6, personal communication, October 1, 2016). The asset managers, maintenance managers and engineers now sit in on monthly meetings. This has proven beneficial for all parties as explained by Respondent 6, “It is always very interesting to sit in those meetings because even though you think on strategic level, the operators are very important in the sense that when you design a plant for example there are certain things that you truly have not thought about and they work with these things every single day” (Respondent 6, personal communication, October 1, 2016).

5.4 COMPANY 4

5.4.1 Company Description

Company 4 is a mining company which focuses its efforts primarily on the mining of coal. Most of the company's coal is supplied to the national power utility, Eskom. The company also mines ferrous metals. Some of the company's expansion programmes for ferrous metal mines have been put on hold due to low iron prices and high project development costs. The mining house has a dedicated maintenance department which takes care of the maintenance needs of all of its assets. The maintenance department is split into departments that take care of civils, electrical and mechanical infrastructure.

5.4.2 Semi-Structured Interviews to determine viable mechanisms for delivering effective maintenance of infrastructure assets in emerging markets

This section of the research discusses the results of the interview which was conducted with personnel who formed part of the maintenance department at Company 4. The interview with Respondent 7 was held on the 26th September 2016 and lasted a duration of approximately one hour and four minutes.

5.4.2.1 Profile of Respondents

Respondent 7

Respondent 7 holds the position of Senior Civil Engineer within Company 4's engineering department. The engineering department is responsible for overseeing maintenance of the mine's assets, and Respondent 7 is responsible for ensuring the structural integrity of these mine's assets.

5.4.2.2 Maintenance as a Core Business Activity

Respondent 7 felt strongly that maintenance was a core business activity for the mining company. The interviewee was clear that as a mining house that produces product for sale, the mine's assets need to be maintained to ensure sustainability of the business, "The relevance

is well we do maintenance for the purpose of ensuring that we stay in business, we are able to continue mining. That is the only reason I can say. Just so that we can continue mining. Not to have breakdowns. The whole idea is to prevent breakdowns due to structural failure.” (personal communication, September 26, 2016). In the competitive mining industry, failure to produce relating to breakdowns caused by a lack of maintenance can lead to loss of revenue. Respondent 7 explained reaffirmed that mitigating the production losses is the main goal, “Exactly. So it is basically trying to mitigate a risk of structural failure. In summary that is what it is. It prevents production losses” (personal communication, September 26, 2016).

5.4.2.3 Maintenance Techniques

Respondent 7 mentioned that the maintenance department is in the process of running a Structural Integrity Management System (SIMS) (personal communication, September 26, 2016). The aim of the programme is to eliminate or minimise risks related to structural failures. Respondent 7 explained that the programme is broken into two parts, with the first part being done on the basis of condition monitoring, “So what we do is, it is like it is in 2 parts, it is a condition monitoring programme which is the first programme” (personal communication, September 26, 2016). Respondent 7 explained the rationale behind the condition based maintenance phase as follows, “Condition monitoring, the idea is to identify the onset of deterioration so then we are able to address it before it continues to deteriorate further. So that is the whole idea of condition based maintenance” (personal communication, September 26, 2016). The previous way of doing maintenance before SIMS was not effective, “But what we found was because we never really had a structured programme most of the issues that were identified were never really addressed” (Respondent 7, personal communication, September 26, 2016). The condition monitoring programme is broken down into 3 sort of phases, if I can call it.” (Respondent 7, personal communication, September 26, 2016). Respondent 7 elaborated on the 3 phases that fall under the condition based monitoring programme, “The first phase we do, you can call it local inspections which is done by the foreman on the mines on a quarterly basis and then annually we do what we call our engineering inspections which are done by myself which is an internal engineer from head office. And then on a 3 yearly basis we do an external structural inspection which is done by an external consultant...” (Respondent 7, personal communication, September 26, 2016). The maintenance team thereafter does a risk management exercise whereby risk items are classified into different categories based on severity, “Now what we do there is we take a risk management approach to our asset management where, what we do is we run our condition

monitoring programme. The idea is to, we classify and we prioritise our defence based on whatever risks that we categorise them under” (Respondent 7, personal communication, September 26, 2016). The categories are divided into “high priority repairs” which refers to maintenance items that require immediate repair, “total structural repairs” which relates to items “typical rehabilitation projects”, and lastly the “long-term system” which relates to “continuous condition monitoring and maintenance” (Respondent 7, personal communication, September 26, 2016).

The findings of the inspections form the basis of the second phase of the programme which is the implementation phase, “...and based on our findings from all those 3 inspections, what we do is we then have another phase now which is what we call our implementation which is second to our condition monitoring programme”. (Respondent 7, personal communication, September 26, 2016). The implementation phase involves the remedial work required to address the issues raised from the inspections, “So within our implementation phase what we are doing there is basically the implementation of the remedial works that are recommended from these three inspections that we do. That is a construction project that just runs for however long it takes to do the repairs” (Respondent 7, personal communication, September 26, 2016). Respondent 7 mentioned that the SIMS programme was at the time of interview the most successful maintenance intervention because it started measuring business units (BU’s) in terms of their maintenance performance (in addition to measuring production) (personal communication, September 26, 2016). Respondent 7 further mentioned that there has been a noticeable improvement in standing time since the SIMS programme, “But what we are seeing with this SIMS philosophy is that we are already seeking a reduction in standing time due to structural failures” (personal communication, September 26, 2016).

5.4.2.4 Outsourcing of Maintenance Activities

Respondent 7 noted that maintenance the roll-out of maintenance from a procurement perspective is managed in-house (personal communication, September 26, 2016). The respondent noted that the design (where required) and execution of maintenance work for the civils and structural components is outsourced, “. So we will appoint someone to come and do a design for us and we would appoint a contractor to come in and fix a specific defect for us” (Respondent 7, personal communication, September 26, 2016). Unlike electrical or mechanical maintenance, civils and structural related maintenance is outsourced due to the infrequency of the work, “Civil works, typically you are looking at 8 years, every 8 years you

would have to come in and do some work. So it doesn't justify having a civils team in-house" (Respondent 7, personal communication, September 26, 2016).

5.4.2.5 Maintenance Performance Indicators

Respondent 7 reported that MPI's have not yet been adopted by the civil and structural maintenance team (personal communication, September 26, 2016). Respondent 7 attributed the lack of MPI adoption to the fact that the SIMS programme is still at the early stages, "As part of an asset management strategy? Look, I don't think we are quite there yet in the sense that we have only started formalising our SIMS programme I think like 3 years ago" (personal communication, September 26, 2016). The interviewee noted that the SIMS programme is still in the second phase of the condition based maintenance, i.e. total structural repairs or rehabilitation. Respondent 7 advised that the MPI's will be adopted in the "long term system" phase of the SIMS programme, "Now this long term phase, this is where now we have started to look at what strategies can we put in place now to monitor the work that we are doing, to monitor almost like deterioration rates and start to pick up those sort of things, performance indicators and so forth and so forth. We haven't moved as well as we could have" (personal communication, September 26, 2016). Respondent 7 relayed the frustration of the civils maintenance team which is running with SIMS as it had been difficult to show the impact of the programme on the bottom line of the business, "Look, the SIMS performance measurement has actually been quite difficult to measure in a sense that the one thing that we keep trying to quantify is in fact, what is the value of the maintenance work that we are doing on the bottom line to the business" (personal communication, September 26, 2016). The team had still not determined suitable monitoring MPI's for the civils infrastructure at the time of the interview, "We were trying to motivate that where we were saying at the end of the day how do we quantify this work that we are doing. At this stage we don't have an answer for that because there is a lot of inputs that need to come in for a ... to do that" (personal communication, September 26, 2016). Respondent 7 added to this sentiment as follows, "We know that we are reducing our risk on safety but how do we put a financial figure to it." (personal communication, September 26, 2016). The figures showing the impact or benefits of the SIMS programme would be required to garner support from the top management structures, which would assist in the ease of implementation on the ground.

5.4.2.6 Linkage of Maintenance to Organisation Vision, Objectives and Strategies

Respondent 7 believed that not much had been done to link the maintenance to the company's vision, objectives and strategies (personal communication, September 26, 2016). Respondent 7 responded as follows to the question on the linkage, "We have had a couple of structural failures in the couple of years but internally we haven't really made much of an effort to almost capture the information and do proper studies and link those studies to impacts on production or impact on say safety. I don't think we have done it as well as we should have. The focus is always, we have had a failure, ok let's fix it" (personal communication, September 26, 2016).

5.4.2.7 Funding of Maintenance

Respondent 7 advised that the normal maintenance work is funded from the 'Opex' budget (personal communication, September 26, 2016). The maintenance budget is determined annually in consult with the business units, "Opex is basically our operational costs which is what we budget for on an annual basis that goes directly towards maintenance. So what we do on Opex, on budget, is that we annually, our maintenance team on the business units, which is on the mines, they would budget for certain work to be done which is the work say that we would have identified through our inspections" (personal communication, September 26, 2016). The annual budget receives final approval from the executive team, "So annually we budget for whatever maintenance work we think we will do and then we take it, you know every section needs to put in a budget and it goes all the way up to Exco and then they approve it" (Respondent 7, personal communication, September 26, 2016). Respondent 7 mentioned that the annual budget for maintenance can have a long forecast, "Yes we budget for it annually. We have to put in our forecast annually and in certain cases you put forecast even on a 5 year sort of projection" (personal communication, September 26, 2016). There is also a 'Capex' budget that caters for rehabilitation works, "Now once you have exceeded that 20 to 30 years you need to go in and you have rehabilitate that specific structure for the purpose of increasing its life or ensuring that you are able to sustain whatever life that you require for the life of the mine. So that typically we put on capex. It is seen as rehabilitation. It is not day to day maintenance" (personal communication, September 26, 2016). Respondent 7 explained that Opex maintenance budget is funded by the business units while the maintenance from Capex is funded from head office via the projects department, "So Opex is typically run by the business units which is the mines. Capex typically that would come to head office and depending on the scale of the project, we have a projects department at head

office and typically we would run that from our departments here” (personal communication, September 26, 2016).

5.4.2.8 Use of Technologies to Supplement Human Personnel

Respondent 7 noted that the mining house has implemented SAP software solution to manage its maintenance activities. The SAP platform helps with planning and monitoring maintenance activities, “One of the things that we have done on this long term system now, we have implemented a programme that we call, we actually call it SIMS and SAP and if you understand that on a mine our maintenance function we are running it off SAP” (personal communication, September 26, 2016). The SAP system ensures that site foremen get receipt of any work orders relating to maintenance that needs to be executed, “All our scheduled inspections they are scheduled on SAP. If there is a work order that needs to go out, it goes through SAP directly to the, call it the foreman” (Respondent 7, personal communication, September 26, 2016).

Respondent 7 advised that the maintenance department has developed an in-house phone app to assist site personnel with inspections (personal communication, September 26, 2016). The ‘app’ allows the site inspector to capture information from the inspection onto the phone app which then sends the information to a central system (i.e. SAP), “Instead of going in with a camera and having to write that thing out and then coming in and typing it on a computer. So what that does is from an inspection it sends information right through into SAP. It generates the reports for you. You are able to plan the maintenance work on that) device” (Respondent 7, personal communication, September 26, 2016). The phone app assists with planning of maintenance activities. The phone app also allows the engineer overseeing the work to review feedback from the site inspector, which is sent via the phone to the SAP system, and provide comments and recommendations, “You are able to, once your foreman is done his inspection, that report will go to an engineer who also on the same system is able to do his whole recommendations, technical recommendations. So we sort of try to automate the whole thing just to avoid this whole paper exercise, avoid this whole human, this tedious process that you have to go through” (Respondent 7, personal communication, September 26, 2016).

Respondent 7 explained how the implementation of the abovementioned technologies has assisted the maintenance to work more efficiently and to track maintenance work, “So technology is helping in that regard in a sense that it speeds up the inspections. It allows us also to track all of these things now that you are doing because on the same system you can

see all the various defects quite easily unlike the thing sitting on a reporting document” (personal communication, September 26, 2016). Respondent 7 explained that there is still a transition underway from the manual processes to the more technologically savvy processes (personal communication, September 26, 2016). The respondent also explained how one of the biggest challenges of adopting the technologies is the resistance to using the new technologies from some of the maintenance staff, “And the reason for that is because it just takes time to convert from a manual process to an automatic process so in rolling out this new programme, this new system, obviously you are dealing with people who have been operating in a certain manner for a couple of years and guys don’t necessarily want to switch like that. So it hasn’t been easy to convert the guys” (personal communication, September 26, 2016). Respondent 7 attributed this resistance to a “mental block” on the part of the maintenance staff, “...because the biggest challenge is, I don’t know, I feel like there is a mental block, guys just don’t want to do things for the sake of “I don’t want to change”” (personal communication, September 26, 2016). The respondent also mentioned underutilisation by those who are using the technology, “Those guys that are sort of embracing it, they are also not fully utilising it. So we are not seeing the full value because we are not using it as efficiently and as effectively as we should” (Respondent 7, personal communication, September 26, 2016). As a result, the technologies are not being fully utilised by the maintenance division. This is the biggest challenge thus far in the implementation of the technologies.

5.4.2.9 Skills and Capacity

Respondent 7 felt strongly that the maintenance department has the requisite skills to execute maintenance (personal communication, September 26, 2016). The respondent noted the following with regards to skills in the maintenance department, “the maintenance, these are guys that are trained, they are skilled. I mean it is foremen, guys that are professional boilermakers. So the guys definitely from a qualifications and a training point of view, they have it” (Respondent 7, personal communication, September 26, 2016). The respondent did however express that the civil engineering skills in the department can be improved, “So in the past couple of years they have actually appointed a couple of civil engineers on the mines who are now starting to build this additional capacity now. So they had to look after civil maintenance but it is recent. Some of the mines we have only had a civil engineer now for 6 months” (Respondent 7, personal communication, September 26, 2016). The interviewee however mentioned that the inefficiencies in the department do inhibit the delivery of

maintenance, “I definitely believe we do. I think the biggest issue there is not necessarily the skills, it is more inefficiencies” (Respondent 7, personal communication, September 26, 2016).

5.4.2.10 Turnover of Staff

Respondent 7 did not believe that there was a high turnover of staff in the maintenance department. The respondent did however believe that there is a movement of staff internally, “I wouldn’t say guys are leaving. There is a high turnover internally. So people move from one section to the next which is also adding to our difficulties with running the programme” (personal communication, September 26, 2016). Respondent 7 noted that the movement of staff internally creates problems because intellectual property is lost one a key maintenance staff member is rotated, “So it is almost like we lose that knowledge, the historical information, where the guys knows that, listen in 2010 it was in this area, this was the problem that we had with the structure, the next guy that comes in is almost oblivious to these issues so that creates all of those problems but typically the guys would move within the mine but they generally don’t leave I find” (personal communication, September 26, 2016).

5.4.2.11 Culture of Maintenance

Respondent 7 was adamant that there was no culture of maintenance in the organisation (personal communication, September 26, 2016). According to the Respondent 7, the lack of culture of maintenance is due to the mining culture of running assets to failure, “No, I don’t think so. I honestly don’t think so. I think the issue is the whole, it goes back down to the issue of the mining culture that I mentioned earlier. I think we have always had this culture of you run your structure to failure, you run your assets to failure. We don’t have this preventative maintenance culture” (personal communication, September 26, 2016). Respondent 7 noted that this is not just an issue for maintenance of civils assets, but a wider issue in the maintenance department, “it is not unique to civils. I think it is the same as everything else, mechanicals and electrical equipment. They just run the thing until they can’t run it anymore and then they replace it” (personal communication, September 26, 2016). Respondent 7 mentioned that the mind-set is starting to change, “We only starting now to sort of try and drive it but it is not the mining culture thing. I think it’s just the way things were done in the past. It’s just a feeling I get” (personal communication, September 26, 2016).

5.4.2.12 Linkage between Financing Models, Maintenance Structure, and Life Cycle Costing

Respondent 7 reported that there was no evident linkage between financing models, maintenance structure and life cycle costing, “I don’t see it within our organisation. I honestly don’t see it” (personal communication, September 26, 2016). Respondent 7 noted that this issue has been brought forward for discussion, “In fact that is the one thing that we keep debating. The maintenance work that we are doing, how does it affect the overall risk on the business, how does it affect the bottom line, how does it affect the way we plan our budgets going forward in the next say 5 years or whatever the case may be. I can honestly say that I don’t think we understand how all these things come together” (personal communication, September 26, 2016). Based on the responses from the respondent, it did not seem as though management was prioritising this matter to reach a solution in the short-term.

5.5 COMPANY 5

5.5.1 Company Description

Company 5 is the one of the largest producers and suppliers of cast high chrome grinding media in the southern hemisphere. The company is also one of the leading producers and suppliers of high chrome and forged grinding balls to most of the African platinum, copper and gold mining companies. The case is based on the operations of their high chrome grinding media.

5.5.2 Semi-Structured Interviews to determine viable mechanisms for delivering effective maintenance of infrastructure assets in emerging markets

This section of the research discusses the results of the interview that was conducted one of the business unit managers who was responsible for overseeing one of the production facilities at Company 5. The interview with Respondent 8 was held on the 6th September 2016 and lasted a duration of approximately one hour.

5.5.2.1 Profile of Respondents

Respondent 8

Respondent 8 holds the position of General Manager of the Grinding Media operation at Company 5. This is a position Respondent 8 has held for the past three years. Respondent 8's primary role is to ensure that the production facilities are producing the grinding media product in a satisfactory manner in order to meet market demand. This entails ensuring that there ensuring that there are sufficient inputs for production, and ensuring that the facilities are well maintained to produce efficiently and to minimise breakdowns.

5.5.2.2 Maintenance as a Core Business Activity

Respondent 8 explained that maintenance is a core business activity by virtue of the fact that it is required to help the production plant run efficiently in order to produce and meet its clients'

demand, “We need to make sure that the plant is in a healthy state where it can produce consistently and that has an impact on just the ability to meet market demand but also the cost side of it in terms of making sure we can do it cost effectively” (personal communication, September 6, 2016). Any maintenance related breakdowns due to lack of maintenance will adversely affect the revenue streams of the company. Respondent 8 also referred to the management structure and explained of how the maintenance department has been well-resourced to meet maintenance demands at the production plant and the company as a whole, “I have got an in-house maintenance manager who reports directly to me and then I have a plan manager who would basically look into the production aspect and the production management reporting to the plan management. We also have, at group level across the whole book, we also have an executive responsible for technical services” (personal communication, September 6, 2016).

5.5.2.3 Maintenance Techniques

Respondent 8 advised that the maintenance done at the production plant is a combination of preventative and condition based maintenance, “A lot of it will be a combination of preventative and condition based” (personal communication, September 6, 2016). Based on the responses, it seemed that the bulk of the maintenance done by the division is condition based maintenance, “So if for example the plant is in a good condition and you can then maybe you can skip a week and then do it on the other week. You will never go for more than 2 weeks without”. (Respondent 8, personal communication, September 6, 2016). Further along in the interview, the interviewee noted that a reactive maintenance approach which stems from a historic way of doing things is still prevalent at the production plant, “...because of where we come from we have always focussed more on fixing. Like something is broken, fix it in the quickest space of time so that it gets going and I minimise my downtime” (Respondent 8, personal communication, September 6, 2016). The respondent noted that the management’s intention is to adopt a more strategic approach to maintenance which eliminates the inefficiencies created by reactive maintenance, “But what we are saying is that we want to probably think more along the lines of saying, what maintenance would I do, like plan a lot more in advance in terms of what maintenance I need to do more to make sure that the plant stays healthy as opposed to say being a lot more reactive” (Respondent 8, personal communication, September 6, 2016).

At the time of recording, management was looking into formalising a planned (preventative) maintenance programme, “I think we need to obviously move into more of a, we have got a

programme in place where we are looking at formalising planned maintenance where basically you are running it as project in terms of saving” (Respondent 8, personal communication, September 6, 2016). Respondent 8 noted that this programme is being spearheaded by another division in the company, “this is not my division but the company want to say we want to basically change the way we do planned maintenance” (personal communication, September 6, 2016). The respondent did not advise of any timelines regarding the implementation of this programme.

5.5.2.4 Outsourcing of Maintenance Activities

Respondent 8 noted that the majority of maintenance is done in-house by the maintenance team, “No we don’t outsource it. The majority of our maintenance is in-house” (communication, September 6, 2016). The respondent advised that the maintenance that is outsourced is only done on specialist equipment, “We will only do it on special cases where for example there is a fabrication, let’s say there is a heat exchanger that needs to be maintained, we will send it to someone who we know can...Ja, who can specialise in that for us and then same thing with conveyer belts for example” (Respondent 8, personal communication, September 6, 2016). It was unclear whether there are contracts in place with the outsourced service providers. Based on the feedback from Respondent 8, the arrangement with the external contractors is however similar to a work package contract, “If a conveyer belt snaps we would get somebody external to come and even if it is 10 in the evening we have guys who if the need arises we will call them out and they will come and do it but we don’t see the need to have that full complement in our structure” (personal communication, September 6, 2016). Respondent 8 also mentioned that the outsourced contractors simply quote on a job-by-job basis, “They will quote us on a job by job. Most of them will do it on a job by job basis and the way to protect ourselves is every now and then we would go for additional quotes to make sure that” (personal communication, September 6, 2016). There was also maintenance work that the interviewee did not deem to be specialist, but was still outsourced due to the component being critical to operations, “So you would have that part of it and you will also have other jobs where it is not necessarily specialist but there is still fabrication where from experience you know this guy does it well so you will almost always go to him because you don’t want to take a chance because this piece of equipment might cost you R10,000 but if something goes wrong you know you would lose a lot” (Respondent 8, personal communication, September 6, 2016). In summary, the outsourcing seems to be conducted on a needs basis and not necessarily structured.

5.5.2.5 Maintenance Performance Indicators (MPI's)

Based on the interview, the maintenance department at Company 5 had limited MPI's that they utilised to monitor and track maintenance. More specifically, Respondent 8 only mentioned one MPI that was utilised during the interview, "There isn't really a system that we use but we do is, on a daily basis, we would look at downtime, engineering related downtime" (personal communication, September 6, 2016). The downtime MPI is measured against a benchmark that has been set by the department, "So maintenance related downtime and we would have set targets that says any delay we will question it in terms of why and obviously understand how we can manage it going forward" (Respondent 8, personal communication, September 6, 2016). The maintenance team keeps track of the downtime over time and to see if there are any anomalies that warrant remedial work on the equipment, "even though we don't have sort of a system that we track it based on the downtime that we monitor we will say this downtime is now increasing over time and as a result how do we bring it back to. It is very basic but it works" (Respondent 8, personal communication, September 6, 2016). Based on the last statement, it is evident that this has been a maintenance approach that has been extensively in the past. The maintenance department could see better results by adopting other MPI's to their maintenance regime.

5.5.2.6 Linkage of Maintenance to Organisation Vision, Objectives and Strategy

Respondent 8 felt that there was a linkage between maintenance and the organisation's vision, objectives and strategy. Respondent 8 attributed this linkage to the fact that the managers are measured on not only costs, but process efficiencies as well, "I mean sitting on my score card would be a profit measure and then there will be something explicit around costs, around what we need to do on costs and then there would also be a parameter that relates to other process efficiencies" (personal communication, September 6, 2016). It is importance to note that this is insufficient to fully determine whether there is a linkage of maintenance to organisation's vision's, objectives and goals.

5.5.2.7 Funding of Maintenance

The funding for maintenance is funded from the operations. Respondent 8 explained that the funding for maintenance works on a system whereby release of funds depends on the

benchmarks set by the company (personal communication, September 6, 2016). This means that only certain individuals would be able to approve funding for maintenance activities depending on the monetary amount required, “we spend maintenance money in three ways. So you would have first stuff, I think normally if stuff is less than R10 000 for example, you would let the guys, the guys would place an order and get that stuff done and then if for example he gets up to R50000 I would then be able to approve it on a daily or weekly basis to get those expenses out. But then in certain instances you have got let’s say, probably expenses above R500 000, where then you might have to start putting a capital vote to get” (Respondent 8, personal communication, September 6, 2016). The system is simple and easy to follow. Respondent 8 advised that there is also an annual budget that the business unit will prepare, at times even 14 months in advance, “So we will have an SIB (stay in business) budget. So stuff that you want to do and stuff that you know that pays off equipment is critical and this is what I need to do and then you might have the new things that come up that you, at the time of drawing your budget, when you draw up your budgets say 14 months in advance” (personal communication, September 6, 2016).

5.5.2.8 Use of Technologies to Supplement Human Personnel

Based on the feedback from the interview, the use of technology by the maintenance department was limited. Respondent 8 explained that technology is only used for monitoring critical equipment, “So we use technology for maybe only critical items. So we use it mostly on critical items but it is not as widespread as you would find it in other industries that are more advanced, like in your automotives” (personal communication, September 6, 2016). The use of technology on the critical items was also very basic, “I mean we would be measuring temperatures for example. If temperature goes above a certain rate then you would look at pressure for example, if it’s a hydraulic piece of equipment that operates under pressure, then you would look at responses in pressure over a 24 period to pick up an deviations” (Respondent 8, personal communication, September 6, 2016). Respondent 8 explained that most of the maintenance is done by human personnel, “I think we still rely a lot more on the guys. Not to say we don’t use technology. So I would say if best practice is 100% where you have got everything condition monitored we would probably be sitting here around 20 to 30. So we are not yet” (personal communication, September 6, 2016). Respondent 8 acknowledged that the lack of use of technology and relying heavily on human personnel for maintenance translates into inefficiencies which are costing the company in terms on money “But at the same time if you fall too far behind from a technology point of view it actually even

starts becoming more expensive than if you just had a software. It does actually get expensive to be printing yet we are generating that amount of paperwork whereas if you were able to pull it onto a system, when we go into production meetings we looking at pieces of paper” (personal communication, September 6, 2016).

Respondent 8 mentioned that the company is looking to develop its own maintenance software in-house, “We are developing it in-house. We have got partners around the world. One of the companies that we work with has manufacturing facilities in Brazil, in the USA and I think in Thailand. They have got systems that based on what they have and what we could be doing in other divisions, we are coming up with our own plan” (personal communication, September 6, 2016). Respondent 8 noted that the challenge the company would need to resolve with technology is to get real-time information on the status of equipment and to facilitate planned maintenance, “We basically want people to make more of, basically use technology to get a lot more real time information and then the second part is a really around some of the planning system where we basically want to schedule, or do a lot more preventative, plan a lot more around preventative maintenance” (personal communication, September 6, 2016).

5.5.2.9 Skills and Capacity

Respondent 8 felt that there was enough experience in the maintenance department to execute maintenance. Respondent 8 mentioned how some of the maintenance staff have been in the department for a long time and therefore gathered a lot of experience, “I have got my engineering guy who has been here for 25 years. So a lot of guys have been here for a very long time. So they are experienced” (personal communication, September 6, 2016). The respondent also mentioned that there is a succession programme in place to groom talent in the company, “...actually our systems force us to make sure for every position we have got a succession plan. If that person falls off tomorrow I need to be able to know that if this person gets hit by a car tomorrow I will keep it going. I had my plant engineer, he had a heart attack. He was out of work for 4 months” (Respondent 8, personal communication, September 6, 2016).

5.5.2.10 Turnover of Staff

There seemed to not be an issue of turnover of staff. As stated in the section above, there are maintenance staff members that have been working in the department for approximately 25

years. The company prefers grooming people from within the company, “Because the team has been here for a long time, it is a lot more difficult for an outsider to get recognition and be fully functional. So we find it easier to get people from within the system” (Respondent 8, personal communication, September 6, 2016).

5.5.2.11 Culture of Maintenance

The respondent did not believe that there was a culture of maintenance engrained in the organisation. In fact, Respondent 8 mentioned, and correctly so, that the management of downtime cannot be construed as maintenance culture, “I guess on our side it is not maintenance culture per say. It is probably more, our culture is centred more around managing downtime. I don’t think it is centred around maintenance per say. It is probably centred more around downtime management” (personal communication, September 6, 2016).

5.5.2.12 Linkage between Financing Models, Maintenance Structures and Life Cycle Costing

There did not seem to be any linkage between financing models, maintenance structures and life cycle costing. This was evident in the interviewee’s response, “So I think insofar as, I mean it is not really financing models, I guess where that relates to it probably just comes back to the levels of approvals that are required from a finance point of view because if you needed to make a big step change in your maintenance” (Respondent 8, personal communication, September 6, 2016). There was no evident linkage based on the response.

6 DISCUSSION OF RESULTS

6.1 Introduction

This chapter is a cross-case analysis of the case studies and a discussion of the results. In the previous chapter, five cases in total were selected and individually analysed as stand-alone units. As discussed in Chapter 4 of this research, the cross-case analysis is intended to assess the similarities and differences across the five cases. The cross case analysis was also intended to link the theory in the literature review to the cases. The researcher also highlighted instances where the real life assessment of the cases did not fit into the logic of the literature. In these instances the researcher tried to provide explanations for the discrepancies between reality and theory. The analysis allowed the researcher to build general explanations to fit each of the individual cases.

6.2 Discussion of the Cross-Case Analysis

6.2.1 Maintenance as a Core Business Activity

The respondents provided various feedback when advising whether maintenance was a core business activity. Respondents for companies 2 and 3 advised that maintenance was a core business activity and attributed this to the sheer extent of their organisations' large asset base that had to be preserved. Respondent 3 explained how the provincial department was responsible for the maintenance of 40 hospitals with a staff complement of 40 000 maintenance staff (personal communication, September 14, 2016). Respondent 5 explained how Company 3 which is a bulk water supplier to municipalities has assets to the value of over R90 billion (personal communication, September 30, 2016). The sheer extent of the size of assets meant that they needed dedicated maintenance teams to ensure their upkeep. Companies 2 and 3 were public entities that had strategic assets which provided public services. Company 2 was a provincial department in charge of maintaining health facilities, while company 3 was supplying water to municipalities. Respondent 5 reported on the increased demand for water in the province that the Company 3, "...so managing the assets have become more critical because if you look at in terms of water supply it has increased you know right up to R4900 mega litres per day" (personal communication, September 30, 2016). The respondents reported that maintenance became a core business activity just by the nature

of the service their organisations were providing. The literature that was reviewed does not mention that the size of the maintenance assets are a basis for maintenance in an organisation to become a core business activity. Based on the responses, it can however be argued that by design, having a large asset base compels an organisation to make maintenance a core business activity.

The private companies involved in production activities such as Company 1, Company 4 and Company 5 felt that maintenance was a core business activity because it minimised the probability of loss of production due to breakdown of equipment. Respondent 2 explained that a loss of production due to maintenance can lead to a loss of revenue, “Yes it is a core business activity. If the equipment stops working you cannot produce. So that is why it falls under the make part” (personal communication, October 6, 2016). Respondent 7 mentioned that maintenance of equipment was crucial in ensuring that the main stays in business, “The relevance is well we do maintenance for the purpose of ensuring that we stay in business, we are able to continue mining. That is the only reason I can say” (personal communication, September 26, 2016). Respondent 8 shared a similar sentiment regarding the importance of maintenance at Company 5, “We need to make sure that the plant is in a healthy state where it can produce consistently and that has an impact on just the ability to meet market demand” (personal communication, September 06, 2016). The results of the cross-case study analysis ties in with the literature by Murthy, Atrons and Eccleston (2002) because it shows that maintenance of equipment is critical for business success by making sure that equipment is available in its fully operational mode to avoid production losses.

The organisations that had maintenance as core business activity had engineering departments which were put in place to support their maintenance departments. Respondent 1 was part of a technical support division at company which consisted engineers and technicians that offered high level support to the maintenance department. Respondent 3 explained how the engineering department was recently introduced at the provincial department to support the maintenance and the Capex projects department (personal communication, September 14, 2016). Respondent 7 was and civil engineer in the engineering department which offered technical support to the maintenance department. The only organisation did not have a technical engineering support department was Company 5. An explanation for this could be that Company 5 was not as advanced as the other companies in terms of maintenance.

Apart from the technical support team, some of the companies that showed good maintenance practice had an asset management division that worked closely with the maintenance department. The companies with an asset management division was Company 1 and 3.

Respondent 6 explained how Company 3, which was a bulk water supplier, had introduced an asset management department called the Process Assets Department that had various divisions entrusted with the oversight of different types of assets involved in production, including process, electrical and automation assets (personal communication, October 1, 2016).

The companies whereby respondents stated that maintenance was a core business activity shared a commonality in that the maintenance divisions reported directly to top management and were therefore not merely an oversight from a hierarchical perspective. Respondent 2 explained how the production managers who oversaw maintenance reported directly to the vice president, “under the senior vice president there is the vice president that is looking after different production plants and there is other senior vice presidents that are in the other operations reporting to the same person and then under that vice president there will be production managers and also maintenance manager like chemical and electrical instruments maintenance managers” (personal communication, October 6, 2016). For Company 2, both Respondent 3 and Respondent 4 stated how their technical support and maintenance departments reported directly to the Chief Director of the Provincial Department. Respondent 4 also mentioned how maintenance initiatives such as e-maintenance were fully supported by top level management, including the Deputy Director General (DDG). Top management at these companies understood the risk implications associated with unreliable equipment.

For public institutions, political will may hinder the effective delivery of maintenance. Both respondents mentioned how red tape in terms of lack of political will got in the way of the effective delivery of maintenance. Respondent 3 made an example of how lack of political will led to the closing of maintenance workshops, “Some politician made the decision that close all the maintenance workshops in the facilities and privatise and let people form companies and come back. I proposed a revival of that but I don’t see that changing anytime soon” (personal communication, September 14, 2016). A lack of political will to deliver on maintenance was not mentioned in the other public entity, Company 3. It is therefore not feasible to determine that a lack of political will to deliver on maintenance as prevalent based on the two cases. The literature does mention that a lack of political will does hinder the delivery of effective maintenance.

Given the above, the author strongly believes that strong political plays a major factor in the delivery of effective maintenance.

6.2.2 Maintenance Techniques

The majority of the companies had maintenance techniques or systems in place to assist with the planning, execution and monitoring of their maintenance processes. The company that stood out in terms of a lack of maintenance techniques or systems was Company 5. The other companies fared well, and varied in terms of sophistication of systems. This section assesses the similarities and differences in terms of systems employed by the various entities.

Based on feedback from the interviews, three out of five of the maintenance departments had adopted formal maintenance guidelines to assist in the strategic management of their assets. The maintenance department at Company 1 had adopted the SAMI STAR maintenance guidelines, “It is a SAMI STAR process. I think it is used worldwide and Sasol is implementing it” (Respondent 1, personal communication, September 26, 2016). Company 2 was utilising the Infrastructure Delivery Management Model, “Infrastructure delivery management model. They call its system but actually it is a model proposed by CIDB construction industry development board” (Respondent 3, personal communication, September 14, 2016). And lastly, Company 4 was using SIMS, “Successful maintenances measures, I think the one thing that I can say was successful was this whole SIMS philosophy. Just to structure the whole SIMS maintenance, just not leaving it to the guys on the BU's because they operate under a different mandate” Respondent 7, personal communication, September 26, 2016). These systems were used as a guideline for maintenance and asset management processes. It was unclear which strategic maintenance management guidelines were in place at Company 4. There were no formalised or structured strategic maintenance management systems in place at Company 5.

The literature prescribes numerous maintenance techniques that can be used for the management of the maintenance process. These include preventative maintenance, condition based maintenance and reliability centred maintenance (RCM). Four out of five of the companies utilised a combination of preventative and condition based maintenance. The type of maintenance technique employed was dependent on the category that the equipment was allocated and a criticality analysis. Respondent 2 explained Company 1's maintenance approach, “Then preventative, we do like scheduled maintenance and conditional maintenance and all those strategies we use them” (personal communication, October 6, 2016). Respondent 3 also explained the maintenance techniques adopted at Company 2 as follows, “Reliability centred maintenance. Which is planned maintenance for very expensive electrical equipment and apply some conditional monitoring as well so you can assess condition of equipment and that is huge equipment like boilers” (personal communication,

September 14, 2016). Similarly, Company 3 also adopted a combination of maintenance approaches, “So, when it comes to planned we have a preventive maintenance programme, a condition based and then we do condition assessments done by our asset management team...” (Respondent 5, personal communication, September 30, 2016). Through the SIMS programme, Company 4 utilised a combination of reactive, condition based and preventative maintenance (Respondent 7, personal communication, September 26, 2016). Respondent 8 mentioned that a combination of preventative and condition based maintenance was utilised by the maintenance department at Company 5. This was however not evident based on the balance of responses from the interviewee. In fact, the respondent mentioned that the company is in the process of formalising a preventative maintenance programme, “we have got a programme in place where we are looking at formalising planned maintenance” (Respondent 8, personal communication, September 6, 2016).

6.2.3 Outsourcing of Maintenance Activities

Four out of five of the companies had limited their use of outsourcing of maintenance and conducted most of their maintenance in-house. These companies used outsourcing primarily for the maintenance of specialist equipment. Respondent 2 explained that outsourcing of maintenance at Company 1 was kept to a minimum, “We don’t outsource that much,” (personal communication, October 6, 2016). Respondent 1 gave an example of some of the specialist equipment for which maintenance was outsourced at Company 1, “On large equipment, like typically your motors, your transformers, pumps and so forth” (personal communication, September 26, 2016). There was a similar approach to outsourcing of maintenance at Company 3, “We try not to outsource a lot of maintenance work. I think the only type of work that is outsourced are mainly regulatory where you need specialist contracting companies to come and do some regulatory work for instance boiler analysis etc.” (Respondent 5, personal communication, September 30, 2016). Respondent 7 mentioned that the civils maintenance work was done in-house, “No we don’t outsource the civil function...We do it in-house. The repairs are done in-house” (personal communication, September 26, 2016). Respondent 8 explained how the maintenance work was also done in-house and outsourcing limited to certain specialist work, “No we don’t outsource it. The majority of our maintenance is in-house...We will only do it on special cases where for example there is a fabrication, let’s say there is a heat exchanger that needs to be maintained” (personal communication, September 6, 2016).

Respondent 3 mentioned that a majority of Company 2's maintenance was outsourced and explained that this was attributed to skills capacity constraints, "This was put in place because we didn't have capacity to do that. But we are slowly training people..." (personal communication, September 14, 2016). Respondent 4 added that another reason for a lot of outsourcing of maintenance at Company 2 was because of government's attempt to provide opportunities for entrepreneurs, "and also the focus for government is that you know they need to provide opportunities for entrepreneurs so most of the labour intensive work it gets outsourced" (personal communication, September 26, 2016). The adverse implication of outsourcing the majority of maintenance as cited in the literature is the low performance of the maintenance department in executing maintenance. The literature cautioned that critical skills may be lost by the maintenance department due to outsourcing. This was the case at Company 2. The respondents mentioned a lack of skills and capacity that was prevalent in the department since a decision was made to outsource most of the maintenance activities, "the reason why we had some of this is the capacity was totally lacking before. I mean we are running the facility with artisans who can't even some come here and have even used laptops. They can't schedule, they can't use the MS projects some even" (Respondent 3, personal communication, September 14, 2016). The literature also mentions loss of control over supplier. This was also evident at Company 2, "At the moment we have to rely upon a contractor who will go and outsource and come back with the wrong parts, wrong material, can't do the work, job that in Sasol would have been sorted out in three days by our guys in the plant here can take four five months" (Respondent 3, personal communication, September 14, 2016). The outsourcing at Company 3 had led to dire inefficiencies in the delivery of maintenance. At the time of the interview, Company 3 was trying to build up internal capacity but lack of political will was an issue. Respondent 3 noted how a lack of political will was the reason that workshops could not be revived, "I have proposed the revival of the workshops but the reaction I saw from my superiors is not gonna buy. I see that not happening. That was my proposal." (personal communication, September 14, 2016).

Based on the responses, it makes sense to keep the bulk of maintenance work in-house to make the delivery of maintenance more efficient and effective. This requires well maintained workshops, along with adequate skills and capacity employed in the maintenance department. Outsourcing needs to be limited to specialist equipment.

6.2.4 Maintenance Performance Indicators (MPI's)

The extent of use of MPI's varied across the companies. Company 1 utilised the widest variety of MPI's. The MPI's used at Company 1 included equipment availability, maintainability, mean time before failure, percentage (%) breakdowns, monitoring of planned hours, and manpower utilisation. Some leading indicators such as vibration monitoring of equipment were also monitored, "Also we installed some like your vibration meters to monitor vibration in some of the equipment and that" (Respondent 2, personal communication, October 06, 2016). Respondent 2 also mentioned that the maintenance division at Company 1 monitored maintenance costs. Company 2 measured MPI's such as mean time to repair, reliability and availability. Company 3 utilised availability, reliability, and mean time to repair, man power utilisation. Company 4 had not reached the stage with its SIMS programme whereby the civils maintenance department could start monitoring MPI's. This was going to be implemented as part of the long term plan under the SIMS programme, "Now this long term phase, this is where now we have started to look at what strategies can we put in place now to monitor the work that we are doing, to monitor almost like deterioration rates and start to pick up those sort of things, performance indicators and so forth and so forth" (Respondent 7, personal communication, September 26, 2016). It is important to note that the interview was based on maintenance in the civils department, and that the status of the use of MPI's may have been more advanced in the electrical and mechanical maintenance departments. The only MPI that was mentioned during the interview for Company 5 was downtime. This downtime was measured against a set benchmark, "So maintenance related downtime and we would have set targets that says any delay we will question it in terms of why and obviously understand how we can manage it going forward" (Respondent 8, personal communication, September 6, 2016).

Based on the feedback, the four most prevalent MPI's that were used by the maintenance divisions were availability, reliability, mean time to repair, and man power utilisation. These all fall into the category of lagging indicators in the literature. Respondent 2 from Company 1 is the only interviewee that mentioned the use of leading indicators such vibrations monitoring of equipment. Leading indicators are important as they act as early warning systems. The companies that had good performance of maintenance are those that adopted the aforementioned MPI's. The companies whereby the respondents maintained that maintenance was lacking had the least use of MPI's. This ties in with the literature because having the right performance measurement system in place allows the maintenance team to gauge the effectiveness and quality of their investment in maintenance (Parida and Chattopadhyay, 2007).

6.2.5 Linkage of MPI's to Organisation Vision, Objectives and Strategy

There were mixed and inconsistent responses to the question regarding the linkage of the MPI's to the organisations' vision, objectives and strategy. Respondent 1 noted that maintenance is linked to Company 1's value of excellence, "*Company 1's* one value is excellence in all we do. Ok there is 6 of them. I just chose excellence in all we do for this particular point in time...So *Company 1* does take pride in ensuring that the personnel that does the maintenance as well as the personnel that operate that particular equipment, they are trained, they are of the required standard required to either maintain or operate that particular piece of equipment" (personal communication, September 26, 2016). Respondent 3 advised that the MPI's at Company 2 are linked to the provincial department's IDMS programme, "The new DID is alive to the conventional maintenance practices. All the proposals inside the IDMS roll out" (personal communication, September 14, 2016). Respondent 7 did not believe that this linkage existed at Company 4, "We have had a couple of structural failures in the couple of years but internally we haven't really made much of an effort to almost capture the information and do proper studies and link those studies to impacts on production or impact on say safety. I don't think we have done it as well as we should have" (personal communication, September 26, 2016). Respondent 8's response on the linkage at Company 5 demonstrated a lack of understanding about the context of the question, "Ja, they are because I mean the way it would then cascade is, I mean sitting on my score card would be a profit measure and then there will be something explicit around costs, around what we need to do on costs and then there would also be a parameter that relates to other process efficiencies" (personal communication, September 6, 2016). The other respondents did not respond to the question.

According to the literature, the selection of appropriate maintenance performance indicators (MPI's) is dependent on the vision, objectives and strategy of the organisation (Parida & Chattopadhyay, 2007). It was not evident from the responses posed that the respondents were aware of the linkage of MPI's with their organisation's visions, objectives and goals.

6.2.6 Funding of Maintenance

Ensuring adequate finance is in place for funding maintenance is critical for the upkeep of infrastructure assets. The respondents were part of the maintenance management at their organisations. The respondents' involvement in the funding of maintenance was limited to only their preparation of annual maintenance budget applications that were submitted to their

executives for review and approval. Respondent 1 noted that there was an annual budget that the maintenance department applied for at Company 1, “So what the internal team does, in order to get access to funding to basically do those replacements, per year there is a maintenance budget which is allocated for doing the maintenance” (personal communication, September 26, 2016). Similarly, there was a similar maintenance budget application process at Company 2, “Here it is basically comes from government the funding for all the maintenance so it comes from the client whom we are providing service for whom in our place which is the department of health so every year they allocate a specific amount budget for” (Respondent 4, personal communication, September 26, 2016). At Company 3, daily maintenance was allocated to operational costs while the preventative or planned maintenance was allocated to the annual budget, “So the day to day maintenance expenses come out of the operational budget and then the periodic maintenance is basically a yearly planned maintenance that could be overhauls, regulatory works like crane load tests, transformer, oil etc.” (Respondent 5, personal communication, September 30, 2016). Annual maintenance budgets were also prepared at Company 4, “Opex is basically our operational costs which is what we budget for on an annual basis that goes directly towards maintenance” (Respondent 5, personal communication, September 30, 2016). The same process was followed at Company 5, “But in terms of year as well, you will break it down into what we have budgeted for in our SIB budget. So we will have an SIB (stay in business) budget” (Respondent 8, personal communication, September 6, 2016).

It was unclear on which funding mechanisms (e.g. cost recovery models etc.) were used to fund maintenance at the organisations under scrutiny in the research. There did, however, not seem to be any issues around funding maintenance activities in either the public or private entities. Based on the responses from the interviews, there seems to be sustainable mechanisms in place to fund maintenance activities. Funding was therefore not seen to be a challenge to the effective delivery of maintenance.

6.2.7 Use of Technologies to Supplement Human Personnel

There were similarities noted in the technologies adopted by the maintenance departments to assist with their maintenance. The first similarity was the use of a web-based maintenance application that was linked to mobile devices. This ‘app’ was used by the staff at three out of the five maintenance departments that were being studied. The web-based mobile application was mostly used for assisting site staff with inspections. At Company 1, a web-based system acted as an early warning system for potential faults to equipment, “What it does is for one, it

is linked with the mobile devices, and then as well if ever it alarms it is also linked to SAP to track, you know, at that particular day and time, there was an alarm on that particular equipment. So it is also being tracked on SAP as well” (Respondent 1, personal communication, September 26, 2016). A scanning mobile device was also used at Company 1, “the scanner which has got a list of equipment that has to be inspected and then the artisan just take the scanner, go to the plant and those equipment will have a tag or barcode which scans the piece of equipment on the barcode and then start inspecting” (Respondent 2, personal communication, October 6, 2016). Company 2 had their own in-house web-based application for mobile devices, “I mentioned that there is a system called e-maintenance. It was developed internally which assisted to manage maintenance” (Respondent 4, personal communication, September 26, 2016). The software application at Company 3 was also created in-house, “So now what we are saying is that we created an app where that thing almost tells you listen you select here which pipe what are the co-ordinates, what area, etc. etc. Description of the failure and so forth” (Respondent 5, personal communication, September 30, 2016). There was no software solution for mobile devices being used at both Company 4 and Company 5 at the time of the interviews.

Another similarity on the technology side was the use of SAP by four out of the five companies being studied. SAP, an asset operations and management software tool, was used by four out of five of the companies. The SAP platform was generally linked with the mobile devices software applications. At Company 1, SAP was linked to the mobile scanning device, “But then on SAP and the Meridium it is interlinked between them to create a job card on the scanner which has got a list of equipment that has to be inspected” (Respondent 2, personal communication, October 6, 2016). Respondent 3 mentioned how SAP was used to assist with planned or preventative maintenance “It is not structured to implement planned maintenance so that is why we bring in SAP. SAP has got all the functionalities required to run a facility or factory and maintain all the equipment” (personal communication, September 14, 2016). SAP was used for finance and human resource aspects of maintenance at Company 3, “Then you have GIS which is the Geographical Information system and you have SAP which is the financial system and HR” Respondent 5, personal communication, September 30, 2016). SAP was used for scheduling of inspections and maintenance work at Company 4, “All our scheduled inspections they are scheduled on SAP. If there is a work order that needs to go out, it goes through SAP directly to the, call it the foreman” Respondent 7, personal communication, September 26, 2016). There was no use of SAP that was evident at Company 5. SAP falls under CMMS. The literature states that CMMS is advantageous as it help to store and analyse the vast amount of information collected from maintenance activities. This was confirmed in the responses from the interviews.

Company 1 was the most advanced from a technological perspective as compared to the other four companies. A good example was the automation that was used to monitor the performance of equipment. This automation assisted the maintenance team by monitoring variables such as vibrations, running hours etc. There was also automation called “auto-lubers” which was used for the automatic greasing of equipment at specified intervals. The maintenance practices at Company 1 were in line with the literature which recommended the use of automation to do condition based maintenance.

Company 1 was also more advanced in their collection of good quality data of their assets. This is because Company 1 understood that not having good quality data can be a disadvantage to the execution of an effective maintenance programme. This was confirmed by Respondent 5 who mentioned that the collection of good quality data was one of the main challenges at Company 3 (Respondent 5, personal communication, September 30, 2016). Company 1 had overcome this challenge by having systems that probed the inspector to fill in a questionnaire on the mobile app while doing inspections. A job card was immediately created and logged onto the system if there was a fault identified while the artisan was filling in the questionnaire, “But there is a questionnaire on the barcode as well saying that okay is this fine yes or no this fine yes or no. So the artisan will keep ticking yes if everything is fine. If there is a fault then he says no. The moment he says no, the system will automatically generate a job card for him to come and repair afterwards” (Respondent 2, personal communication, October 6, 2016). The loop could only be closed once the defect had been rectified on the system. Company 1 was therefore a good example of best practice in the implementation of maintenance.

6.2.8 Skills and Capacity

Sufficient skills and capacity are required to execute maintenance effectively. Respondents from four out of five of the companies interviewed believed that they had sufficient skills in their maintenance departments. Respondent 1 mentioned how Company 1 invested a lot in training of its maintenance staff, “For one Sasol they invest in ensuring that people are trained, they are competent and then it doesn’t just end whereby you send a person for training once-off” (personal communication, September 26, 2016). Respondent 2 mentioned that a lot of investment goes into training the technical staff such as technicians and artisan at Company 1, “Yes, definitely. We train mainly our own artisans and technicians” (personal communication, October 6, 2016). Respondent 5 felt that there was a lot of experienced staff at Company 3, “But you find we have a lot of very experienced people” (personal

communication, September 30, 2016). Sparking interest in young job entrants to get into more technical and artisan roles was a challenge at Company 3, “The other challenge in terms of personnel human resources that is getting a bit difficult because you are getting young people, they don’t want to become artisans you know. They don’t want to work in the machines and stuff like that so that becomes a little bit of a challenge” (Respondent 5, personal communication, September 30, 2016). Respondent 7 believed that Company 7 had the requisite skills to execute maintenance effectively, “the maintenance, these are guys that are trained, they are skilled. I mean it is foremen, guys that are professional boilermakers. So the guys definitely from a qualifications and a training point of view, they have it” (personal communication, September 26, 2016). Respondent 7 believed that the issue was not a lack of skills but rather process inefficiencies, “I definitely believe we do. I think the biggest issue there is not necessarily the skills, it is more inefficiencies” (personal communication, September 26, 2016). Respondent 8 mentioned that the maintenance department has very experienced team members, “I have got my engineering guy who has been here for 25 years. So a lot of guys have been here for a very long time. So they are experienced” (personal communication, September 6, 2016). A lack of skills was reported at Company 2. Respondent 3 mentioned that the skills base of maintenance staff at Company 2 was growing but this was starting at a low base, “The skill base is growing in the last two years we have more engineers than the organisation has ever had in the last ten years so that is growing under my structure I need sixty people I think I am sitting at 30%” (personal communication, September 14, 2016). Respondent 3 attributed the low skills base due to Company 2’s inability, being a government department, to attract the right skills, “Yes, to attract somebody from a consulting company like yours to come and join us a challenge. Sometime we can’t even match the salary. Even also the quality of the type of work that they do. It is job satisfaction” (personal communication, September 14, 2016).

The respondents that felt that their maintenance departments had the requisite skills and capacity to execute maintenance effectively attributed this to the investment their companies had made into training their staff. At two out of five of the companies there were training academies that had been set up to train maintenance staff members. Company 1 was one of the companies that had a training academy, “There is an academy. They are training practitioners. They are certified by DoL. It is an in-house thing” (Respondent 1, personal communication, September 26, 2016). Company 3 had a training academy that catered not only for the organisation, but for the municipalities as well, “Then you getting the new young people that are coming in and then at the same time Rand Water has created their own academy. So that academy now is catering for them. Not just Rand Water, but the municipalities as well” (Respondent 5, personal communication, September 30, 2016).

According to the literature, a lack of experienced personnel to implement and manage maintenance can lead to insufficient maintenance of assets (Too, 2012). Company 2 was one of the organisations that had the least effective maintenance of their infrastructure and this was highly attributed to the lack of skills in its maintenance department. Conversely, one of the key factors for the success of implementation of maintenance strategy is to ensure that the right skilled personnel are in place to execute maintenance activities. Companies that had the right skills, and invested heavily in the skills development of their staff, had better performance when it came to maintenance of their assets. Companies that were exemplary in this regard were Company 1 and Company 3.

6.2.9 Turnover of Staff

Turnover was not highlighted as a significant factor that negatively affected the effective delivery of maintenance. Respondent 2 reported that there was low turnover in the maintenance division at Company 1, “Ja, it is less than 7%. Inside in this position, I have only lost 3 people who like resigned and then I have got only one who took retirement...Yes it's a big group I have got 26 people” (personal communication, October 6, 2016). There were contradictory statements from Respondent 3 and Respondent 4 regarding staff turnover at Company 2. Respondent 5 noted that staff turnover was not an issue at Company 3, “No not really Rand Water their rewards and you know and so on there is not a very high turnover. I mean I am here 20 years I have got people working here there are 4 ladies here, Victoria is 12 years, Hardin is about 18 years” (personal communication, September 30, 2016). Respondent 7 mentioned that the issue at Company 4 was the staff turnover that happens internally (personal communication, September 26, 2016). Respondent 8 mentioned that staff are retained for a long duration of time to a point that it becomes difficult to appoint people from outside the company, “Because the team has been here for a long time, it is a lot more difficult for an outsider to get recognition and be fully functional. So we find it easier to get people from within the system” (personal communication, September 6, 2016).

6.2.10 Culture of Maintenance

There were mixed views from the respondents regarding the culture of maintenance in their organisations. Respondent 1 explained that having dedicated maintenance divisions at Company 1 meant that the culture of maintenance was strong, “I would say yes and then just

to support that, I think the fact that there is maintenance departments, people that just basically focus on maintenance, I would say it is” (personal communication, September 26, 2016). There were contradictory opinions from the respondents regarding the culture of maintenance at Company 2. Respondent 3 believed that the culture of maintenance was weak, “I would say this is weak at the moment. On the scale of 1 to 5 we are probably sitting at 2 to 3” (personal communication, September 14, 2016). Respondent 4 had a change of heart from believing that culture of maintenance was engrained in the organisation, to stating that the maintenance department is not where it needs to be from a culture of maintenance perspective, “Ja, we still not there. Even the mentality part of it to say you must maintain it before it fails. It still is not sinking in to everyone. They are used to something down then they jump” (personal communication, September 26, 2016). Respondent 5 explained how garnering a culture of maintenance is an ongoing process that constantly needs to be reviewed, “It is a continuous challenge. Maintenance is not something that you say show it to someone now and they will do it for life” (personal communication, September 30, 2016). Respondent 5 added that the maintenance team at Company 3 meets on a frequent basis to ensure that the maintenance culture ethos is kept intact, “So what we do is we have regular meetings we ensure that we have proper strategies in place” (personal communication, September 30, 2016). Respondent 7 was clear that there was a weak culture of maintenance at Company 4, “No, I don’t think so. I honestly don’t think so. I think the issue is the whole, it goes back down to the issue of the mining culture that I mentioned earlier. I think we have always had this culture of you run your structure to failure, you run your assets to failure” (personal communication, September 26, 2016). The response from Respondent 8 regarding the culture of maintenance at Company 5 was unclear, “I need to think about this. I guess on our side it is not maintenance culture per say. It is probably more, our culture is centred more around managing downtime” (personal communication, September 6, 2016).

Based on the literature, organisational culture in firms that manage their own assets needs to be strengthened in order to develop a more proactive (as opposed to reactive), risk taking and customer centric culture if these firms are to optimise long-term asset performance (Brunetto et al., 2014). Brunetto et al. (2014) attribute a weak correlation between organisational culture and employee engagement for the lack of success that most firms have in achieving this goal. The literature aligned with the outcome of the case studies because organisations whereby the respondents felt there was a strong culture of maintenance (i.e. Company 1 and Company 3) had better maintenance outcomes compared to organisations whereby respondents felt had a weak culture of maintenance (i.e. Company 2 and 4). Another important observation is that a strong culture of maintenance does not necessarily have to stem from privately run companies. Company 3, which was a public entity, had a strong culture of maintenance, as

opposed to Company 4, a privately run mining company, which had a weak culture of maintenance.

6.2.11 Linkage between Financing Models, Maintenance Structures and Life Cycle Costing

Respondents from Company 1 and Company 3 stated that there was a linkage between financing models, maintenance structures and life cycle costing in their organisation. This linkage was ensured due to the close interface of the maintenance departments and other departments in the organisation. Respondent 1 explained how the maintenance department at Company 1 worked with the various departments in the organisation, “So there is a link between the various departments, more specifically the asset management. It is unlike the one department is doing their own thing” (personal communication, September 26, 2016). Respondent 2 mentioned that maintenance department works closely with the asset management department, “Okay, that asset management department is mainly, we call it a Reliability department where they look at the resources, what we are doing, if it is effective enough” (Respondent 2, personal communication, October 6, 2016). In the case of Company 3, reference was made to the asset management division which works closely with the maintenance team, “So remember, we have an asset management team who is now embarking on a life cycle management on the assets so basically we are looking at an entire life now of the asset for the next 20 years for each asset” (Respondent 5, personal communication, September 30, 2016). Respondent 6 mentioned how the maintenance division supplies the asset management department with information that is used for life cycle costing purpose, “Maintenance you know if – like I was saying that we use certain outputs from maintenance to plan accordingly and one of those things is planned versus unplanned maintenance” (Respondent 6, personal communication, October 1, 2016).

Respondents from Company 2 and Company 4 felt strongly that this linkage was weak in their organisations. Respondent 4 mentioned how there was no tracking of maintenance expenditure at Company 2, “For example we have this equipment in this hospital. Can you tell me how much you have spent in that? They can’t” (personal communication, September 26, 2016). Respondent 7 explained the frustration at Company 4, “I don’t see it within our organisation. I honestly don’t see it. In fact that is the one thing that we keep debating. The maintenance work that we are doing, how does it affect the overall risk on the business, how does it affect the bottom line, how does it affect the way we plan our budgets going forward in the next say 5 years or whatever the case may be” (personal communication, September 26, 2016). The feedback from the respondent speaking on Company 5 was unclear to ascertain

the state of the linkage. It is important to note that the companies whereby respondents did not believe that there was a linkage between financing models, maintenance structures and life cycle costing did not have an asset management division within their company. These organisations had a reactive, in lieu of proactive, maintenance department.

7 CONCLUSION AND RECOMMENDATIONS

7.1 Background and Objective of the Study

The aim of the research was firstly to establish the factors that lead to a lack of infrastructure maintenance, and secondly to determine viable mechanisms to deliver effective maintenance of infrastructure assets. The case study method was adopted as a research strategy. Five cases were selected in total. Semi-structured interviews were used to collect data. A single and multiple case study method was used for analysis purposes. A review of the cross-case analysis is summarised in the sections below.

This section summarises the key findings. A discussion of how the key findings addresses the research questions follows thereafter. Recommendations for future research are also discussed.

7.2 Summary of Key Findings

The cross-case analysis revealed factors that lead to a lack of infrastructure maintenance, and determined potential viable mechanisms to deliver effective maintenance of infrastructure assets. Some of the factors were more influential than others. A summary of the outcomes of the analysis from the study is provided below.

The interview questions were based on the themes that emanated from the literature review. The questionnaire for the semi-structured interviews is shown in Annexure 1 of this report. The themes that were selected were as follows:

- 1) Maintenance as a core business activity
- 2) Maintenance techniques
- 3) Outsourcing of maintenance activities
- 4) Maintenance performance indicators (MPI's)
- 5) Linkage of MPI's with organisation vision, objectives and strategy
- 6) Funding of maintenance
- 7) Use of technologies to supplement human personnel
- 8) Skills and capacity
- 9) Turnover of staff
- 10) Culture of maintenance

11) Linkage between financing models, maintenance structures and life cycle costing

The coding frame is shown in Annexure 2 of this research report.

7.2.1 Maintenance as a Core Business Activity

The research has shown that having a technical departments that provides support to the maintenance department is critical for the delivery of effective maintenance in emerging markets. The two essential departments that provide the most needed support are the engineering support department, and the asset management department. The purpose of the engineering department is to offer high level technical expertise and oversight. The purpose of the asset management department is to offer proactive interventions that need to be taken at strategic points during the life cycle of the asset in order to reap full benefit of the asset during its life. These are expertise that are generally lacking within maintenance departments. A procurement department within the organisation can also work closely with the maintenance department on procurement related matters.

The findings of the study show that the management structure needs to be closely evaluated in order to deliver maintenance effectively. The organisation that had the highest maintenance performance, Company 1, had a structure whereby maintenance management reported directly to the top structures of the company. This meant the maintenance was intentionally made a core business activity in terms of priority, rather than being a mere oversight. Company 1 was an example of a company where top management understands the risk implications associated with unreliable equipment.

The findings shed some light on how a lack of political will in a public institution can frustrate the maintenance management process. This was evident at company 2 whereby the meddling of politicians into maintenance matters made the maintenance managers despondent and demotivated. Politicians need to create an environment whereby the maintenance function is supported fully, and not interfered by bureaucracy.

For private companies, executing an effective maintenance program in order to mitigate production losses and increase revenues proved to a motivator. The delivery of a strategic service like water supply also seemed to be a driving factor for delivering effective maintenance for public entities. Political will, as stated above, can however erode any gains to deliver maintenance effectively.

7.2.2 Maintenance Techniques

The research highlighted the importance of having formal maintenance guidelines that are adopted by a maintenance department. These can either be standard or generic maintenance guidelines (e.g. SAMI STAR, Infrastructure Delivery Management System), or they can be bespoke and made in-house specifically for the organisation's requirements (e.g. SIMS).

The research showed that a majority of the maintenance departments that were being studied used a combination of preventative and condition based maintenance as their primary maintenance techniques. This strategy required the equipment to be categorised via a criticality analysis to determine the type of maintenance technique to be adopted. The criticality analysis was done based on the monetary value of equipment, and the impact that a breakdown could have on the operations. Depending on the criticality, a run-to-failure was also adopted on some of the equipment that falls in the lower tier categories (i.e. low value and low impact on operations).

A reliability centre maintenance approach (RCM) is recommended. Sufficient resources in terms of expertise and time are required to run an RCM program.

7.2.3 Outsourcing of Maintenance Activities

The assessment of the cross-case analysis showed that extensive outsourcing of maintenance activities can be detrimental to a maintenance department if used incorrectly. The bulk of the companies that were studied had limited their use of outsourcing to maintenance on their specialist equipment. The majority of maintenance was done in-house by the maintenance team. The results of the research were in line with the literature regarding the negative impact of extensive outsourcing. Company 2, which outsourced a lot of its maintenance requirements had an inefficient and ineffective maintenance system. The provincial department had lost a lot of its critical skills to the market, and also lost control over its suppliers.

The research also showed that a maintenance department needs to have access to a fully equipped maintenance workshop to execute maintenance effectively. The organisations that ran successful maintenance had their own fully equipped maintenance workshops.

7.2.4 Maintenance Performance Indicators (MPI's)

The learnings from the research show that the adoption of MPI's in the maintenance department is one of the most important factors for the effective delivery of maintenance. As stated in the literature, MPI's help track and monitor the effectiveness and quality of maintenance. This was attested by the interviewees from the companies that had adopted MPI's to assist with the management of their maintenance processes. The prevalent MPI's that were utilised by the well performing maintenance departments (i.e. Company 1 and Company 3), were as follows:

- 1) Availability
- 2) Reliability
- 3) Mean time before failure
- 4) Man power utilisation

The abovementioned MPI's fall into the equipment related indicators (i.e. availability, reliability, mean-time before failure) and the maintenance task related indicators (i.e. man power utilisation). There were however no other MPI's reported in the interviews that fall under the other categories which include (1) impact on customer satisfaction, (2) learning and growth, (3) health, safety, security and environment, and (4) employee satisfaction.

Both Company 1 and Company 3 had adopted cost related indicators. These indicators were critical for their asset management departments in order to make decisions on equipment life cycle related interventions.

It is important to note that the abovementioned MPI's fall under the category of lagging indicators. As indicated in the literature, lagging indicators act as outcome measures that provide the basis for studying deviations after completion of maintenance activities (Parida & Chattopadhyay, 2007, p. 244). The only Company that had adopted leading indicators to monitor or track maintenance was Company 1. These leading indicators were adopted as early warning systems for potential failures of the company's assets. It was therefore not a surprise that Company 1 had the best performing maintenance department based on the feedback from the interviews. By having leading MPI's as an early warning system, maintenance teams can be more proactive in addressing maintenance related issues before they spiral out of control. In summary, MPI's have proved to promote a more proactive, in lieu of reactive, maintenance regime. The result is that maintenance will be better aligned to meet the organisation's strategies and objectives.

7.2.5 Linkage of MPI's with Organisation Vision, Objectives and Strategy

Based on the responses, it was evident that the management of the maintenance departments did not have sufficient knowledge of the linkage between the MPI's and their organisation's vision, objectives and strategy. The maintenance management at the production companies stated that their main prerogative was to ensure that downtime was minimised in order to minimise loss of production and revenues. There was however no appreciation of how other non-equipment and task related MPI's can assist in enhancing the organisation visions, strategies and objectives. As discussed above, the other MPI's that were not mentioned by the maintenance managers included, but were (1) impact on customer satisfaction, (2) learning and growth, (3) health, safety, security and environment, and (4) employee satisfaction.

7.2.6 Funding of Maintenance

Funding of maintenance had the least influence on the delivery of effective maintenance. Most of the interviewees mentioned that an annual maintenance budget was prepared and applied for via internal structures and signed off by top management. A distinction was made in the budget for everyday maintenance which was funded by Opex, and capital related maintenance (e.g. rehabilitation) which was funded by the Capex budget.

7.2.7 Use of Technologies to Supplement Human Personnel

The use of technologies to supplement human personnel was one of the most powerful and influential factors for the delivery of effective maintenance. This was one of the factors that distinguished the average performing maintenance departments from the exceptional ones. The technologies used were in the form of software solutions and automation. The benefits were in line with the literature in that they assisted the maintenance departments to collect better quality data at real time, and have better coverage of their infrastructure. The technologies also reduced the inconsistency and subjectivity brought about from human intervention.

One of the prevalent technologies used was the web-based software applications linked to mobile devices, primarily cellphones. The web-based software solutions were both bespoke

(i.e. made in-house for the organisation's requirements) or generic. Company 1 even had a mobile scanning device that had a questionnaire that prompted the site inspector for information on the piece of equipment during the inspection. A notification with a job card was automatically generated if a fault was detected, and the loop would only be closed once the fault was rectified. There was also a widespread use of SAP as an asset operations and management tool. SAP was used by four out of the five companies that were interviewed. SAP falls under CMMS tools. SAP assisted maintenance and asset management teams to store and analyse vast amount of data, and assisted in decision making. SAP also assisted the maintenance teams for planning maintenance activities, more especially for running a preventative and condition based maintenance programme. The use of automation to monitor performance of equipment via lead indicators such as vibration of equipment was limited primarily to Company 1. The technology also assisted the companies to have a historic register of equipment data. This allowed for better monitoring of trends for future planning purposes.

7.2.8 Skills and Capacity

Having the right skills and capacity was one of the influential factors and prerequisites for the delivery of effective maintenance. The maintenance departments with the least amount of skills and expertise such as Company 2 had the lowest performance in terms of delivery of maintenance. The companies that invested heavily in training of their maintenance personnel (i.e. Company 1 and Company 3) had the best performance in terms of delivery of effective maintenance. These companies also had their own training academies to train their technicians and artisans. In summary, having the right skills and capacity can be the difference between an effective and ineffective maintenance programme.

7.2.9 Turnover of Staff

Turnover of staff was not mentioned as one of the major inhibitors of delivering effective maintenance of infrastructure assets. This meant that turnover of staff was not as influential in delivering effective maintenance in relation to the other factors. Notwithstanding, it is still important to ensure that the right skills and expertise are retained in the maintenance departments.

7.2.10 Culture of maintenance

The feedback from the cases shows that the companies that had a strong culture of maintenance fared better in terms of delivery of effective maintenance compared to the companies with a weak culture of maintenance. A strong culture of maintenance garnered a more proactive, in lieu of reactive, maintenance approach. The feedback from the case studies also showed that a strong maintenance culture can be developed in both private and public entities. A strong maintenance culture has to be driven from top management in the organisation.

7.2.11 Linkage between Financing Models, Maintenance Structures and Life Cycle Costing

The respondents that mentioned that there was a linkage between financing models, maintenance structures and life cycle costing are those who came from organisations that had an asset management division (i.e. Company 1 and Company 3). The respondents who came from organisations without an asset management department mentioned that there was a weak linkage of these factors. Based on the feedback, it can be determined that having an asset management department that works closely with the maintenance department is a prerequisite in terms of establishing this link. The maintenance department needs to supply the asset management department with maintenance outputs, mostly in the form of cost related MPI's. The asset management department can thereafter utilise this information to make strategic decisions on the interventions to be employed during the life-cycle of their assets. These interventions include decisions on whether to conduct repairs, preventative maintenance, rehabilitation, or disposal of assets.

7.3 How Key Findings Answer Research Questions

The summary of the study needs to address the research questions that were posed. The research questions were as follows:

Research Question 1:

What are the factors that lead to a lack of maintenance of infrastructure assets in emerging markets?

Research Question 2:

What are the viable mechanisms to deliver effective maintenance of infrastructure assets in emerging markets?

Research Question 3:

What is a viable way to ensure a linkage between financing models, maintenance structure and life cycle costing of infrastructure assets in emerging markets?

These research questions are addressed below based on the outcome of the research that was conducted.

7.3.1 What are the factors that lead to a lack of maintenance of infrastructure assets in emerging markets?

The literature attributes the lack of maintenance of infrastructure to a lack of funding, lack of reliable data on existing infrastructure stock, uncoordinated efforts by maintenance departments in government agencies, and lack of life cycle costing at the procurement stage (South African Institution of Civil Engineers, 2011). It is important to note that the literature referred to relates to mostly public infrastructure owners. The literature also states that a lack of maintenance of infrastructure in emerging markets is attributable to a lack of funding due to inadequate billing and collection procedures, low purchase power by users, insufficient attention to operations and maintenance, a lack of experienced personnel to execute maintenance, and a lack of political will (Alm, 2013). The research conducted via the case studies is in line with the literature review and shows that a lack of skilled personnel, political will (at public institutions), life cycle costing, and a general lack of maintenance lead to a lack of maintenance in emerging markets. The study did not however find that a lack of funding attributed to a lack of maintenance. It should be cautioned that this research was limited to only five cases, and therefore this statement needs to be tested via a bigger sample. The author does however believe that a lot of the issues that stem from a lack of maintenance are primarily related to inefficient maintenance processes. The research also highlighted how uncoordinated outsourcing can lead to a lack of effective maintenance. This was a factor that was also highlighted in the literature review.

7.3.2 What are the viable mechanisms to deliver effective maintenance of infrastructure assets in emerging markets?

The research showed that some factors are more influential than others in the delivery of effective maintenance. The factors that were found to be the most influential in the delivery of effective maintenance of infrastructure were as follows:

- 1) Ensuring mechanisms are in place to make maintenance a core business function or activity.
- 2) Use of a combination of maintenance techniques, including run-to-failure, preventative or planned maintenance, and condition based maintenance.
- 3) The use of strategic maintenance guidelines by the maintenance department. These maintenance guidelines can either be generic or developed in-house to align with the organisation's requirements.
- 4) Keeping most of the maintenance work in-house and limiting outsourcing to specialist equipment.
- 5) The use of MPIs to track the effectiveness and quality of maintenance, and its impact on the overall performance of infrastructure assets. The MPI's selected need to be linked with the overall vision, objectives and strategies of the organisation.
- 6) Use of technologies to supplement human personnel in the form of maintenance software solutions (e.g. web-based software applications for mobile devices, CMMS applications such as SAP) and automation for monitoring the performance of equipment and other related assets.
- 7) Continuous investment in training of maintenance personnel, including technicians and artisans. A training academy should be implemented if funding suffices.
- 8) Initiatives should be put in place to retain critical skills.
- 9) A culture of maintenance should be developed in the organisation, starting from top management structures. A strong culture of maintenance will promote a more proactive, rather than reactive, approach to maintenance.
- 10) An asset management division should be put in place to work closely with the maintenance department. The asset management department is a prerequisite to create a strong linkage between financing models, maintenance structures and life cycle costing.

7.3.3 What is a viable way to ensure a linkage between financing models, maintenance structures and life cycle costing of infrastructure assets in emerging markets?

The research showed that a viable way to create a strong linkage between financing models, maintenance structures and life cycle costing is to create an asset management division within the organisation. This division needs to work closely with the maintenance departments to ensure that informed decisions are taken on the type of interventions to be implemented during the life cycle of equipment (e.g. repairs, preventative maintenance, rehabilitation, disposal of assets etc.).

7.4 Research Limitations

The following research limitations have been identified:

- 1) The research was limited to the South Africa.
- 2) The research did not cover all the infrastructure asset types.
- 3) The research was limited to the maintenance management departments.

7.5 Recommendations for Future Research

The author recommends the following areas of study for future research:

- 1) A more detailed research study on one of the case studies selected and analysed in this research report. The study should include discussions with other stakeholders within the organisation that fall outside of the maintenance department.
- 2) A quantitative research study on the impact of maintenance or lack thereof on a company's bottom-line
- 3) A quantitative research study using statistical analysis of the data stored by the maintenance department to establish trends and testing if these trends have any impact on any other of the organisation's KPIs.
- 4) A research study that investigates how an organisation can create and continuously improve on its culture of maintenance.
- 5) A research study on how an organisation can enhance the position and power of its maintenance departments within the organisations; the study can potentially have an emphasis on the asset management department or function.

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APPENDIX 1

QUESTIONNAIRE FOR SEMI-STRUCTURED INTERVIEW

QUESTIONNAIRE FOR SEMI-STRUCTURED INTERVIEWS

1. Please provide an overview of your organisation and the function of your department within the organisation.
2. Please explain your role in the organisation?
3. How long have you been working in this position?
4. What is the relevance of maintenance to your current position in the organisation?
5. Please provide a brief understanding of how infrastructure maintenance plays a role in your organisation.
6. How does your organisation deal with maintenance from a strategic level, i.e. is maintenance management seen as a vital core business activity that is crucial for business survival and success?
7. Please advise of the maintenance techniques adopted by your organisation (e.g. preventative maintenance, condition based maintenance, maintenance outsourcing, total productive maintenance, etc.)
8. In the event that your organisation outsources maintenance, please advise on the type of maintenance contract (i.e. work package contract, performance contract, or facilitator contract) in place and why.
9. Does your organisation or maintenance department utilise performance measurement as part of an asset management strategy? If so, which maintenance performance indicators (MPIs) has your organisation adopted?
10. Are the maintenance performance measures or indicators linked to the organisation's visions, objectives and strategy?
11. What have been the results of the company's maintenance performance measurement (MPM) framework(s) (e.g. cost savings due to operational efficiencies)?
12. What are the mechanisms used to fund maintenance activities in your organisation, e.g. cost-recovery model via user pay systems, subsidies, etc.?
13. Has your organisation adopted the use of technologies to supplement human personnel for maintenance activities?
14. Does your organisation possess the right skills and experience to execute maintenance activities efficiently?
15. Is there a high turnover of maintenance staff in your organisation?
16. Is there a culture of maintenance engrained in your organisation?
17. Is there a linkage between financing models, maintenance structure, and durability or life cycle of assets in your organisation? If so, please elaborate.

18. Has the window of time to carry out inspections and maintenance work affected the delivery of effective maintenance in your organisation? If yes, please describe in more detail.
19. Please advise of the main challenges that hinder the delivery of effective maintenance in your organisation?
20. Please advise on successful maintenance measures your organisation has adopted, and the reasons for the success?
21. Please advise on recommendations to improve maintenance / asset management in your organisation?
22. In your experience, which public infrastructure assets suffer the most from a lack of maintenance?
23. From your experience, does the country have the right skills and experience in organisations that own infrastructure assets to execute maintenance efficiently?



APPENDIX 2

CODING FRAME FOR QUALITATIVE CONTENT ANALYSIS



**CODING FRAME FOR QUALITATIVE
CONTENT ANALYSIS**

CATEGORY NO.	CATEGORY DESCRIPTION	DESCRIPTION
1	Maintenance as a Core Business Activity	
		Unit of coding investigates factors that make maintenance a core business activity
2	Maintenance Techniques / Systems	
		Unit of coding investigates the various maintenance techniques used by the maintenance department.
3	OUTSOURCING OF MAINTENANCE	
		Unit of coding investigates the extent of outsourcing utilised by the maintenance department.
4	Maintenance Performance Indicators (MPIs)	
		Unit of coding investigates the extent of MPI's utilised by the maintenance department
5	LINKAGE OF MPI'S TO ORGANISATION VISION, OBJECTIVES AND STRATEGY	



		Unit of coding investigates the linkage of MPI's to organisation vision, objective, and strategy.
6	FUNDING MAINTENANCE	
		Unit of coding investigates the mechanisms used by the organisation to fund maintenance.
6	TECHNOLOGIES	
		Unit of coding investigates the technologies utilised by the maintenance department.
7	SKILLS AND CAPACITY	
		Unit of coding investigates the level of skills and capacity in the maintenance department.
8	TURNOVER OF STAFF	
		Unit of coding investigates the level of staff turnover in the maintenance department.
9	CULTURE OF MAINTENANCE	
		Unit of coding investigates the level of the culture of maintenance within the organisation.
10	LINKAGE BETWEEN FINANCING MODELS, MAINTENANCE STRUCTURE AND LIFE CYCLE COSTING	



		Unit of coding investigates the linkage between financing models, maintenance structure and life cycle costing.
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APPENDIX 3

CONSOLIDATED TEXT MATRICES FOR QUALITATIVE CONTENT ANALYSIS (QCA)



APPENDIX 4

TURNITIN REPORT



APPENDIX 5

ETHICAL CLEARANCE LETTER



