A PERFORMANCE REPORTING TOOL FOR ELECTRICITY SERVICE DELIVERY FOR SELECTED LOCAL SOUTH AFRICAN MUNICIPALITIES

By

Oluyomi Ajayi

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Department of Industrial and Systems Engineering
Faculty of Engineering, Built Environment, and Information Technology
University of Pretoria
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Supervisor: Professor Marne De Vries

ABSTRACT

Basic services such as sanitation, waste removal, water, and electricity supplies are necessary for life, well-being, and human dignity. In South Africa, municipalities are the sphere of government constitutionally designated to provide these services. With months of rolling blackouts and volatile operating performance, Electricity Service Delivery (ESD) deserves some attention and improvement because it is setting the country on a pathway to national emergency, weakening investors' confidence and stagnating the country's already problematic economic growth prospects. Since improvement does not materialise spontaneously, deliberate and purposeful actions are required to understand the current state of ESD, extract stakeholders' intentions for an improved ESD (diagnosis), and then devise means to operationalise the intentions. This study focuses on performance assessment with initial reporting capabilities to provide adequate information and insight for diagnosis of ESD within South African local municipalities. It starts by exploring a systematic literature review of available tools for diagnostic service performance assessment. Then, it extracts and validates, through a focus group session, the criteria which such tools must satisfy to be considered useful in the South African context.

The study is based on a Design Science Research (DSR) methodology and follows an inquisitive process of multi-stakeholder engagement to extract evidence about existing functional and constructional ESD areas of concern/requirements. The study inductively develops an artefact, the ESD Performance Reporting Tool (ESD-PRT) to guide improvement in electricity service delivery in South African local municipalities. The ESD-PRT continuously extracts performance metrics from Power System Resources (PSR), citizens, and organisational competencies of the municipalities, with provisions for emerging areas of concern and requirements within design domains and sub-domains. It was evaluated for practicality and usefulness based on the DSR iterative approach and compared to the closest available similar solution.

This entry point solution to an optimised local municipality ESD would guide the redesign of ESD and potentially save South Africa billions of Rands currently lost to energy losses, downtime in economic activities and social discontent occasioned by power outages and rolling blackouts. The study was demonstrated in three local municipalities geo-located in two different provinces. The researcher believes that the study outcome would apply to most local municipalities in South Africa. However, its applicability to metropolitan municipalities still needs to be tested.

DEDICATION

To the only wise God

ACKNOWLEDGEMENTS

It always seems impossible until it is done – Nelson Mandela

This study took me on a very involving journey from many perspectives. However, it was made possible by the support of certain people, to whom I am very grateful.

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- **Municipal Managers**; to the three municipal managers, thank you for allowing me to use your municipalities as pilot municipalities, giving me access to your people, data and power system infrastructure.
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LIST OF ABBREVIATIONS

Abbreviation	Description
ADR	Action Design Research
AHP	Analytic Hierarchy Process
COGTA	Cooperative Governance and Traditional Affairs
DCM	Demonstration Case Municipality
ESD-PRT	Electricity Service Delivery Performance Reporting Tool
DRS	Diagnostic Reasoning System
DSPA	Diagnostic Service Performance Assessment
DSR	Design Science Research
DSRM	Design Science Research Methodology
DSRPM	Design Science Research Process Model
EE	Enterprise Engineering
ESD	Electricity Service Delivery
FEDS	Framework for Evaluation in Design Science Research
FGD	Focus Group Discussion
FGP	Focus Group Participants
GDP	Gross Domestic Product
IEA	International Energy Agency
IS	Information Systems
ISO	International Organisation for Standardisation
KPIs	Key Performance Indicators
MCDM	Multi-criteria decision-making
MDB	Municipality Databases
NERSA	National Energy Regulator of South Africa
NGO	Non-Governmental Organisation
PADR	Participatory Action Design Research
PSR	Power System Resources
RE	Requirements Elicitation
SALGA	South African Local Government Association
SDRM	Systems Development Research Methodology
SDSRM	Soft Design Science Research Methodology
SLR	Systematic Literature Review
STATS SA	Statistics South Africa
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development.
UUT	Unit Under Test

PREFACE

Firstly, this thesis mostly applies active voice rather than passive voice, as Hofstee (2006) advised in his book, *Constructing a good dissertation*. Abbreviations are declared when they are used for the first time, whereafter the abbreviation is used. A list of abbreviations (preceding this section) is included for the reader's convenience.

Secondly, it should be noted that this study already produced some journal and conference proceedings before the final compilation of this thesis. The articles published or accepted by accredited journals include:

- Ajayi, O.B. and De Vries, M. (2019), Diagnostic Assessment of Service Delivery Health in South Africa: A Systematic Literature Review, *South African Journal of Industrial Engineering*, Vol. 30 Issue 1, pp.24-36.
- Ajayi, O.B. and De Vries, M. (2021), Selecting a Public Service Delivery Assessment Tool, *South African Journal of Industrial Engineering,* Vol. XX Issue YY, pp. (Accepted).

Articles published in conference proceedings include:

- Ajayi, O.B. and De Vries, M. (2018), Validation of Criteria for Service Delivery Performance Assessment Tools, *Paper presented at the International Conference on Industrial Engineering and Operations Management,* 29 October – 1 November 2018, Johannesburg, South Africa.
- Ajayi, O.B. and De Vries, M. (2020), Diagnostic Assessment of Electricity Service Delivery at a Local Municipality, *Paper presented at the Southern African Institute for Industrial Engineering,* 5 – 7 October 2020, Virtual Event, South Africa.

A compact disk (CD) that contains the appendices and the abovementioned articles published during the study is included with the thesis

Chapter 1. Introduction

Collectively, the public sector is the largest service provider globally. With the social media explosion and increasing social activism, public sector customers (citizens) have become more aware of their rights. As a result, there is heightened expectations of public service performance, accountability, and transparency, an expectation which now forces governments all over the world to seek means to improve service delivery, and performance (Fiszbein, 2011; Olusola, 2011). While this dilemma is true for developed economies, Africa is no exception as agitations for improved public service performance levels are well publicised (Manning, 2006; Olusola, 2011; Tirivangasi, 2016).

In South Africa, access to cost-effective, high quality and speedy public services is a legitimate expectation of all citizens as the Constitution (1996) makes provision for the government to provide these services. As a boost to this provision, the government adopted the White Paper on Transforming Public Service Delivery (WPTPSD), generally referred to as the *Batho Pele* (1997) white paper in recognition of the need to run an effective and efficient public service. Furthermore, specific government organs and departments such as the Department of Planning, Monitoring and Evaluation (2014), the Public Service Commission (2014), the Department of Public Service and Administration (2016), and the office of the Auditor-General, South Africa (2004b) have been designated to provide oversight role for government's services, programs and projects. Notwithstanding these efforts, Mdlongwa (2014) and Tirivangasi and Mugambiwa (2016) believe that the Public Service still struggles with the basics, causing service delivery backlogs arising from unascertained reasons to continue to grow. However, the consequences of these backlogs are not pleasant because in addition to poor living conditions and economic losses to businesses, they often cause social unrest leading to the destruction of public infrastructure and properties, police brutality and sometimes loss of innocent lives. The term *service delivery* itself is not universally defined. In the South African context and vernacular, it is understood to mean the provision of sustainable services by the local government to citizens (R.S.A, 1996) or the rendering of services needed to ensure an acceptable and reasonable quality of life (R.S.A, 2000). Outside government, the notion of citizens' satisfaction is included in the definition to include the provision of both tangible and intangible public services (Akinboade, Mokwena, & Kinfack, 2014; Nealer, 2014). These services include education, healthcare, electricity supply, sanitation, waste removal and water supply. Focusing on *Electricity Service Delivery* (ESD), schedule 4B of the constitution, the South African government (R.S.A, 1996) designates municipalities as the distributor of

electricity, with Eskom – the national utility - as the generator. Although there are locations where distribution is shared between municipalities and Eskom, these are few and non-significant in the global context of ESD.

Uncertainties surrounding the future of electricity supply, declining business confidence, constrained economic performance, and social discomforts arising from ESD issues are now posing fundamental questions which are best answered through scientific means such as presented in this study.

Just as in Diagnostic Reasoning Systems (DRS), the *diagnostic problem* in this study is to determine the design domains (or sub-domains) of municipality electricity service delivery which, when observed to be functioning abnormally or below expectation, will explain the gaps between the observed and expected/intended electricity service delivery performance. Without this first order, evidence-based diagnosis, a solution pathway cannot be successfully designed and executed. Through well-grounded theories, this research focuses on the design and development of a performance assessment and reporting tool for some local South African municipalities, aimed at providing insight into poor ESD performance, and guiding diagnostic and redesign efforts of the ESD. It concludes by presenting arguments for establishing a new sub-discipline – ESD Diagnostician – an artisan/technician equipped with insight from the ESD performance reporting tool (an artefact developed in this study), in maintaining power system resources (PSR) and responding to PSR disruptions. Although the ESD Diagnosticians' job is to a large extent independent of the actual implementation of the object system (just as the radiologist or pathologist's work is independent of treatment but referred to the physician, with no decision on course of treatment yet), their work is nevertheless the foundation for an effective change of ESD to a desired future state (design implementation). It is proposed as a sub-discipline as it builds on and extends the *employee-centric* theories of enterprise governance and engineering (Hoogervorst, 2017, 2018). Notwithstanding the socio-economic and industrial growth necessities for ESD (Ahmad & Othman, 2014; Aladejare, 2014; Mahfoudh, 2014; Stern, 2019; Zhang, 2017), and the fact that South Africa currently struggles with ESD (De Beer, 2016; De Ruyter, 2021; Eberhard, 2012; Palmer, 2016; SALGA, 2018; StatsSA, 2020), a review of the list of occupations in high demand (DHET, 2020), and their job descriptions published by the government precludes an occupation with the envisaged competencies of the ESD Diagnostician.

1.1 Problem context

Electricity supply is the backbone of almost all economic activities, powering critical systems and infrastructures required for the functioning of our modern economies and societies. It is a necessity for people's well-being, comfort of life and civilisation, and if disrupted may lead to devastating economic and social consequences. In general, electricity is deemed the most demanded commodity in the world (Ahmad & Othman, 2014), while its steady supply is strongly correlated with economic development and industrial growth (Aladejare, 2014; Mahfoudh, 2014; Stern, 2019; Zhang, 2017). Although energy exists in several forms, electricity is considered to have a causal relationship with the prosperity of commercial and industrial enterprises and economic growth in general (Mawejje, 2016). Other intellectual explorations have established mutual relationships between electricity supply (or lack of it) and the quality of elections (Penar, 2016), the quality of healthcare (Laher, 2019), construction (Coetzee, 2016), observance of human rights (González-Eguino, 2015), and poverty (Sovacool, 2012). The term "energy poverty" has now become an acceptable vocabulary for lack of energy access (Pachauri, 2004). Although the need to build carbon resilient economies subsists, electricity supply remains essential for development and poverty elimination (Li, 2019), especially in developing economies such as South Africa. The good news is that the world can now generate *green* (low or no carbon) electricity viably and commercially.

Notwithstanding the acclaimed importance and necessity of electricity supply, the International Energy Agency (IEA) (2020) indicates that more than 1 billion people in the world are still without access to electricity, 700 million of which are from Africa. In South Africa, many households, especially those in local municipalities and rural areas, still do not have access to electricity - Umhlabuyalingana (81,5%), Jozini (58,4%), Ntabankulu (47,2%), Maphumulo (43,0%), Emadlangeni (42,8%) and Msinga (42,7%) - (Lehohla, 2017). Although the country has made substantial progress in improving access to electricity, backlogs still persist, and reliability of supply is threatened. With years of rolling blackouts (generally referred to as *load shedding*) and the volatile operating performance of Eskom and municipalities, ESD deserves some attention because backlogs in the sector is having adverse socio-economic impact on the country, and the country does not seem to have a solution or timeline on when the backlogs would be fully addressed. Therefore, the steady supply of quality electricity at an affordable cost to an average South African is inevitable if the country is to reach its National Development Plan goal of sustainable electricity for all by the year 2030 (Manuel, 2012) and create an environment conducive for investors and economic growth. Figure 1 indicates the decline (percentage points) in key sectors of the economy before the Covid-19 lockdowns, which started in March 2020.

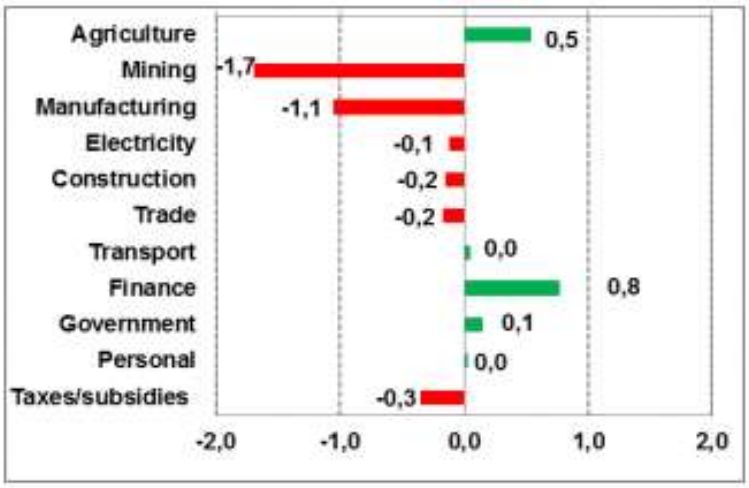


Figure 1: Contributions to Growth in GDP, Q1 2020

(StatsSA, 2020)

Constrained power supply through load reduction (load shedding and load curtailment) and localised outages (mostly from the municipalities' side) play significant roles in the economic outlook shown in Wright (2020). This is a matter of national significance and emergency. Apart from municipalities' ageing distribution infrastructure, colossal debt owed to Eskom and general shortage of skills, Eskom has warned that load reduction would continue for another five years (until 2026), and may be extended, should the economy grow (De Ruyter, 2021).

At the municipality level, Power System Resources (PSR) for electricity distribution are very old (SALGA, 2018), while investments are grossly inadequate, with investment backlogs of more than 40% (Palmer, 2016). While it is recommended that municipalities should invest 10% of the total PSR value per year, only about 2% is currently being invested (De Beer, 2016), leading to an investment deficit of approximately R2.5 billion per year (Eberhard, 2012). In addition to these challenges, municipalities lack the requisite skills for planned maintenance, ad-hoc repairs and scheduled refurbishment of electricity distribution assets (De Beer, 2016). All these often lead to localised power outages that negatively impact socio-economic activities in the country. Furthermore, a compliance audit (NERSA, 2020a) of electricity distribution performance conducted by the national regulator (NERSA – National Energy Regulator of South Africa) on 18 municipalities reveals the poor state of health of ESD at the municipality level, i.e. staff and skills shortages, lack of accredited personnel for Occupational Health and Safety, poor maintenance practices, shortage of critical spare parts, lack of load forecasting capabilities, and unfunded budgets. Also, the audit report indicates that up to 92% of some of the distribution networks were older than 30 years. The report concluded that *none of the audited licensees complied fully with the licence conditions.* This is the same conclusion for the

previous audit (NERSA, 2018). Although these audits are credible, they are incomplete. They fail to address critical areas of concern raised by other stakeholders (Akinboade et al., 2014; Maluleke, 2019; Mangxamba, 2013; Nealer, 2014) and do not guide improvement of ESD. The same issue goes for performance assessment and tracking of electricity service delivery. Although the kWh (kilowatt-hour) of electricity delivered is partly metered (see Figure 2), the South African Local Government Association (SALGA) (SALGA, 2014) points out that municipalities do not have service delivery agreements in place. This makes electricity accounting, service performance assessment/tracking and energy reconciliations to be very problematic. A service delivery agreement for electricity service delivery should be a jointly agreed performance document between relevant stakeholders (providers, consumers, and regulators), indicating performance areas to be measured, the key performance indicators, expected output, budget and timelines (SALGA, 2014). In fact, the World Bank report (The World Bank Group, 2011) on accountability in South Africa's Public Services, confirms that one of the major reasons for service delivery issues is inadequate assessment (including monitoring and feedback) of the health of service delivery. According to the Cooperative Governance and Traditional Affairs (COGTA) Department (COGTA, 2019), the inability of municipalities to effectively assess, track and manage performance of the distribution network is largely responsible for municipalities' R26.5 billion debt owed to Eskom as the network continues to suffer from technical losses, non-technical losses, and inaccurate indigent accounting.

Given the complexity of electrical power distribution networks, the strict regulatory environment, the multi-faceted nature of its stakeholders, and the peculiar operating environment of South African municipalities, a systems and design thinking approach is adopted in this study for the effective performance reporting of ESD, and to guide a future diagnosis and design for optimised ESD performance.

1.2 Research Boundary

Eskom has three licensed businesses, namely generation, transmission, and distribution (R.S.A, 2004a). The distribution arm mainly covers the transportation of bulk electricity from the transmission sub-stations to the municipality step down sub-stations from where the municipalities begin their distribution mandate (R.S.A, 2000), as shown in Figure 2.

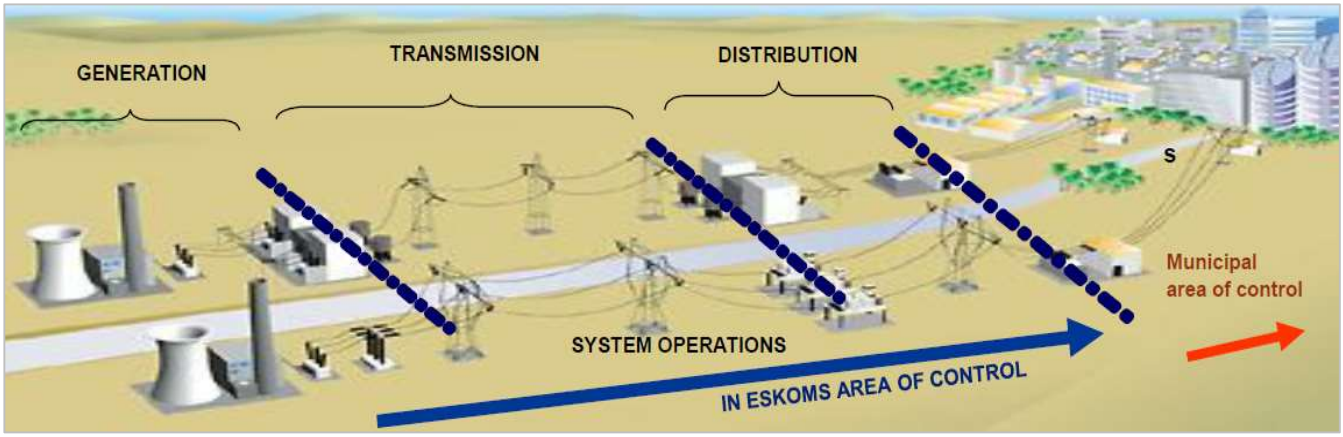


Figure 2: Eskom's Licensed Businesses

Notwithstanding the regulatory authority (R.S.A, 2000) for municipalities to distribute electricity within their geography, the *Electricity Regulation Act* (2006) provides for other licensees (e.g. Eskom) to distribute electricity within the geographical boundary of municipalities. This means that the constitutional powers of the municipality only grant *executive authority* and not *exclusive authority*. Therefore, historically Eskom has supplied electricity to areas not supplied by the municipalities in the country in general. Sometimes, these areas fall within the municipality, but they are often separated physically, with each focusing on different locations. However, the bulk of electricity (and gas) reticulation, as well as other basic service delivery functions rest with the municipality as stipulated in Section 156(1), Schedule 4, Part B of the Constitution (R.S.A, 1996), partly because of their closeness to the grassroots, but also because of the notion of forming a developmental local government.

In summary, while the impasse of constitutional powers for electricity distribution between Eskom and municipalities continues (COGTA, 2019; Eskom, 2018; NERSA, 2020b; SALGA, 2017), both are allowed by law to distribute electricity. Currently, the municipalities distribute power to the majority of customers. In contrast, Eskom distributes a higher percentage of electricity driven mainly by the energy intensive users it directly supplies, such as the mining and heavy manufacturing industries. A NERSA report (NERSA, 2012) indicates that although municipalities distributed electricity to 85% of total customers in the country, the quantum of electricity distributed was only 30%, while the balance was distributed by Eskom to energy intensive consumers.

As shown in Figure 3, this study focuses on the municipality constitutional and physical boundary of electricity distribution to the industrial, commercial, and residential (households) consumers.

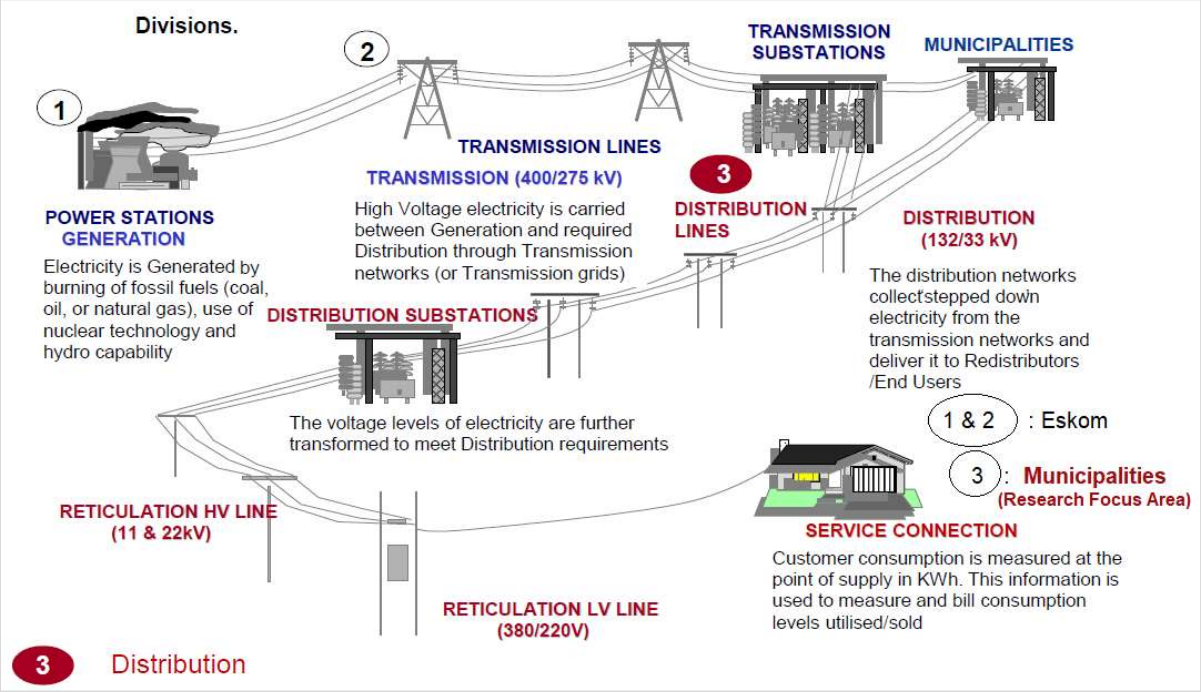


Figure 3: Research Boundary

(Eskom, 2018)

(Modified to show municipalities' domain of operation & research focus area)

1.3 Electricity Service Delivery

Many factors are responsible for the effective distribution of electricity, but any assessment, design or re(design) of the value chain that precludes the humans (authorised social individuals) that operate the value chain (socio-technical systems) and consumers' perception of services provided, are problematic. Therefore, key gaps in knowledge exist in how ESD is currently performance reported, assessed, and diagnosed, where the researcher claims that electricity service delivery transcends mere access to the national grid. For instance, while the percentage of households with access to electricity has increased in the country (76.7% in 2002 to 84.7% in 2018), recent reports by the Statistics South Africa (Stats SA) indicate that users are less happy about electricity services (Maluleke, 2019). The survey found that households' satisfaction with electricity supply declined between 2010 and 2018 from 67.5% to 65.7%, meaning there are other practical and functional areas of electricity services beyond access. Although quantitative impact of the decline in household satisfaction is not estimated, the fact that municipalities depend on sales of electricity for revenue calls for every cause of citizens' (consumer/customer) dissatisfaction to be addressed. If things must change for the better, a paradigm shift is imperative. A media release by the Stats SA, six years before the one above echoed the same sentiment: "…….*the report shows an increase in the number of households*

who had access to….electricity…..however, Stats SA says the improvements in the access to basic services were stained by an increasing dissatisfaction with the quality of services" (Mangxamba, 2013). While most efforts are currently geared towards restoring Eskom, urgent interventions are needed at the municipalities level. In addition to their electricity service delivery obligations, municipalities make their second-largest income from electricity sales (COGTA, 2019; StatsSA, 2019), as shown in Figure 4.

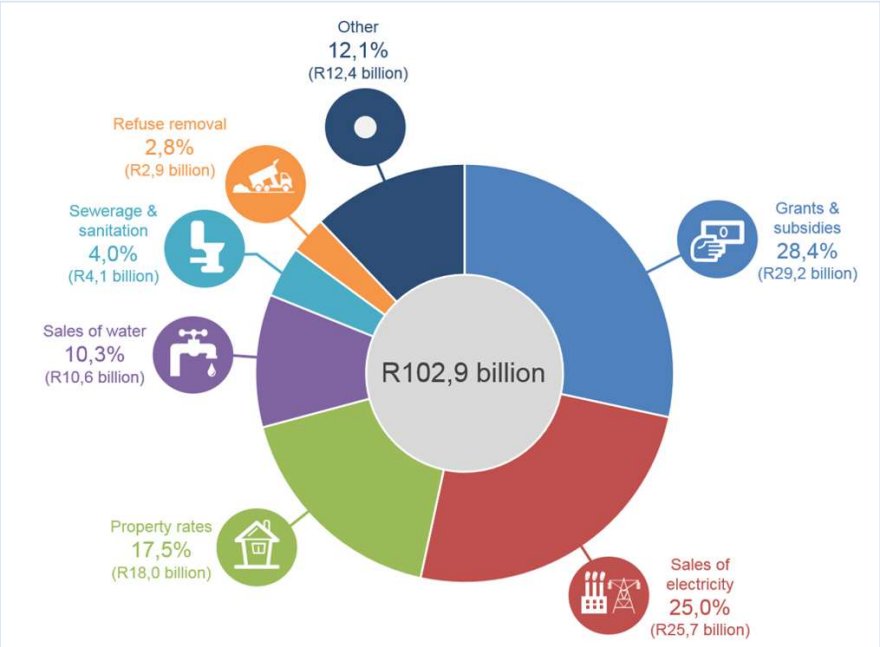


Figure 4: Municipalities Revenues

(StatsSA, 2019)

A good example is the Greater Kokstad municipality, where 93% (93 cents of every R1) of its entire revenue was from electricity sales (StatsSA, 2019), yet municipalities bleed from the inability to optimise this opportunity. Three local municipalities are used as pilot case municipalities (DCMs: DCM 1, DCM 2, DCM 3) in this study. Table 1 outlines partial (distribution) financial losses arising from underperforming ESD. Due to capacity constraints and avoidable ad-hoc maintenance costs, there are more opportunity costs, but these are not accounted for in DCMs financials.

Table 1: Losses for Financial Year 2017/2018

	DCM 1	DCM 2	DCM 2
Units Purchased from Eskom (kWh)	48,119,089	517,078,114	260,934,884
Units Sold (kWh)	39,999,963	408,491,710	231,814,551
Units Lost in Distribution (kWh)	8,119,153	108,586,404	29,120,333
Total Losses in Rands*	**R 8,195,089**	**R 99,423,320**	**R 26,922,405**

These amounts are significant for local municipalities*

A new, theoretically grounded way of looking at ESD is needed as no sustainable improvement can be achieved without a holistic performance reporting, diagnosis of the current state and a coherent (re)design for the future.

Based on definitions by the government (R.S.A, 1996, 2000) and private authors (Akinboade *et al*., 2014; Chen, 2014; Nealer, 2014), this study defines *electricity service delivery* as:

Government's provision of affordable, reliable, safe, and high-quality electricity with associated support services to the citizens.

1.4 Enterprise Engineering - Introduction

A new paradigm to address enterprise *changes* and *adaptation*, EE is a theory-based discipline that provides holistic approaches for analysing and designing enterprises (Dietz et al., 2013; Dietz & Mulder, 2020), i.e. *changes*, in terms of designing a previously non-existing enterprise, or by redesigning an existing one, and *adaptive* because the key role players (humans), act with free will. In this context, enterprises are deemed as goal-oriented, emergent social entities created to achieve pre-determined strategic objectives. At the same time, design refers to the coherent ordering of all its facets into a unified and integrated whole (Aveiro, Pergl, & Gouveia, 2016).

Due to increasing customers' expectations, new disruptive forces in the market, rapid technology changes, and globalisation in general, many enterprises are re-evaluating their ability to compete, adapt and achieve strategic success. A direct outcome of such re-evaluation is the introduction and implementation of many business improvement initiatives and approaches in enterprises worldwide. These approaches generally sit within traditional disciplines (such as business and scientific management and organisational sciences) that focus on enterprise changes, development, productivity, and performance improvements. However, records show that they often fall short in bringing to realisation defined enterprise strategic intent. According to research by Kotter (1995), which was later corroborated by a McKinsey Company study (Aronowitz, 2015), and Keller and Schaninger (2019), many modern corporations today are in a repeated cycle of organisational redesign/improvement programs, but with an appalling outcome, indicating less than 25% success. A review of such interventions by enterprises reveals an impressive list of sub-disciplines and approaches for enterprise redesign and performance optimisation such as supply chain management, enterprise architecture and modelling, business process re-engineering, right sizing, operational excellence, restructuring, lean philosophy, total quality management and balanced scorecard, yet with very low success rates (Hoogervorst, 2016; J. Kotter, 2007). Sadly, the confirmation by Aronowitz (2015) and Keller and Schaninger (2019) of the failure of business and scientific

management approaches to bring about enterprise success came some two decades after Kotter's (1995) study, meaning the situation remains unchanged and the trend will likely continue (Sushil, 2012). In general, authors (Kaplan, 2001; Nutt, 1999; Sirkin, Keenan, & Jackson, 2005) estimate that between 50% and 90% of all enterprise strategic initiatives fail, meaning either the strategy was not implemented, or it was implemented with poor results. Although many researchers (Abrahamson, 2000; Bhasin, 2012; Cândido, 2001; Christensen, 2000; Gandolfi, 2011; Gijo, 2011; T. J. Green, 2012; Pascale, 1997) have tried to adduce reasons for these enterprise failures since Kotter's (1995) work, an overbearing theme is a *lack of coherence and unity* among the various component parts of the enterprise. The evolution of the EE discipline, therefore, is a direct response to this gap, a discipline that takes a holistic approach, considering multiple facets of the enterprise to address enterprise change and create a unified, integrated enterprise (Dietz et al., 2013). Considering the DCMs as the *enterprise*, this study therefore adopts the EE approach, on the one hand, building onto some of the enterprise engineering theories, and on the other hand providing the much-needed practical test case scenario, ensuring that the EE discipline delivers evidence about the benefits that it claims to deliver. In this research context, enterprises are considered human endeavours, intentionally created to achieve specific goals and purposes. The entity, given its multi-level divers operating components, is complex and requires considerable *design* efforts to change it from an existing state to a new or preferred state, in a holistic, all-encompassing way, while ensuring the unity and integration of all component parts (Hoogervorst, 2016). The DCM therefore is considered an enterprise

Although the systems engineering discipline has some similarities with the EE discipline, its focus is primarily on technical systems. In contrast, the EE is concerned with socio-technical systems, viewing the enterprise as an adaptive social system with human (social) role players (Aveiro et al., 2016).

1.5 Problem Statement

Municipalities have a constitutional mandate for electricity reticulation to households, industrial and commercial consumers within their jurisdictions. However, due to ageing electricity distribution infrastructure, refurbishments and maintenance backlogs, deficits in investments, lack of skills and human capital, poor asset management practices, localised disruptions to electricity supply have become common.

The problem is that these disruptions and blackouts are setting the country on a pathway to national emergency, weakening investors' confidence and stagnating South Africa's already problematic economic growth prospects. Therefore, this study presents a scientific method of

reporting ESD performance, providing insights into poor ESD performance which may guide the closing of ESD performance gaps in South African municipalities. Although demonstrated in a local context, the researcher believes that the suggested solution can also be used within similar ESD contexts.

1.6 Research Questions

The following sections outline the primary and secondary research questions.

1.6.1 Primary Research Question

Based on the challenges described above, the primary research question is:

*What **user-friendly** performance reporting tool (PRT) for obtaining inputs from various stakeholders will be **useful** to initiate diagnosis of electricity service delivery at some local South African municipalities?*

Usefulness in this context refers to the ability of the tool to meet its objective (Amrina, 2010; Höber, 2015; Uy et al, 2016). That is, it is able to obtain inputs from various stakeholders, and provide insight into the performance of electricity service delivery

1.6.2 Secondary Research Questions

This study addresses the following secondary research questions:

RQ1: What diagnostic service performance assessment (DSPA) tools are available in general?

RQ2: Which of these DSPA tools are used within the service delivery domain?

RQ3: What criteria must these DSPA tools satisfy to be selected and considered effective in addressing service delivery performance gaps?

RQ4: What software tool functions are needed (i.e. software tool requirements) to support the identification of areas of concern & critical failure factors of electricity service delivery?

RQ 5: What are the constructional components of the new performance assessment/reporting tool?

RQ 6: To what extent does a demonstration of the performance assessment/reporting tool partially demonstrate the usefulness and user-friendliness of the tool?

RQ 7: How useful and user-friendly is the new performance assessment/reporting tool?

1.7 Thesis Statement

A ***user-friendly*** performance reporting tool (PRT) for obtaining inputs from various stakeholders *is* ***useful*** to initiate diagnosis of electricity service delivery at some local South African municipalities.

1.8 Significance

This research addresses a matter of national significance by inductively developing an ESD-PRT for some local South African municipalities. The purpose is not to present a cure for the existing challenges within ESD, but rather to identify those performance areas problematic prior to curing them by means of enterprise re-design. Applying a Design Science Research (DSR) approach, the design and development of the ESD-PRT offer a *theoretical contribution*, drawing guidance from existing enterprise engineering theories and a derived methodology that currently lacks many real-world demonstrations and case studies. The baseline diagnostic reasoning (section 2.1), and inquisitive process (section 2.4.1) provide new insights into the *areas of concern* and *critical failure factors* (extracted as part of section 4.4) of this under-explored problem domain, providing new understanding of how the ESD design domains and sub-domains may operate as a unified and integrated whole, effectively addressing key performance areas. This research has significant implications for providers (practitioners) of ESD and researchers, as additional areas of incremental improvement to ESD are brought to the fore by extracting the areas of concern and factors for critical failure. Following the work of Hoogevorst (2018), the researcher believes that enterprise governance should be an inquisitive process, iteratively re-designing enterprise design domains as new areas of concern emerge. Currently, a theory-ingrained software tool, ESD-PRT, does not exist to support the iterative and inquisitive process presented by Hoogervorst (2018).

Although ESD primarily focuses on the citizens, benefits arising from this research are mutual. In addition to fiscal transfers, municipalities in the country make their second largest revenue from the sale of electricity (COGTA, 2019; StatsSA, 2019).

1.9 Brief Thesis Overview

This section discusses the different chapters that make up this thesis.

Chapter 1: Introduction: Background to the *research problem* is articulated in this chapter, while the research domain and boundary are discussed briefly. Also, the body of knowledge for the theoretical foundation is introduced, highlighting the significance of the study. The chapter concludes with an introduction of subsequent chapters after defining the research primary and secondary questions.

Chapter 2: Literature Review: Chapter 2 provides a *theoretical context* for the entire research project. It initiates with a review of the theories of diagnosis, followed by a systematic search for existing diagnostic tools related to service delivery. Since the tools must satisfy specific service delivery needs, an additional search for tools criteria was conducted, and the outcome is presented in the chapter. A focus group later validates the criteria. The existing enterprise engineering theories and approaches are also reviewed, while observed research gaps are highlighted.

Chapter 3: Methodology: Chapter 3 initiates with a paradigmatic exploration to understand available philosophical dimensions applicable to the grand challenge. On acceptance of the applicable paradigm, *relevant methodological perspectives* were examined, out of which the most appropriate methodology and methods were chosen. These chosen perspectives are motivated for in the concluding sections of the chapter.

Chapter 4: Requirements for ESD-PRT: The Performance Reporting Tool is motivated for in Chapter 4, while all design considerations and model development parameters are presented.

Chapter 5: Constructional Components for ESD-PRT: Constructional components of ESD-PRT are presented while their clustering into design domains is equally explained.

Chapter 6: Demonstration of ESD-PRT: The tool, ESD-PRT, is piloted at three municipalities. Procedures for the demonstration and the outcome of the exercise are presented in this chapter.

Chapter 7: Evaluation of ESD-PRT: ESD-PRT is evaluated for specific criteria, including usefulness and ease of use. All test cases and user acceptance test scenarios are also presented. The result of ESD-PRT's evaluation is presented in this chapter.

Chapter 8: Contributions: The research contributions are presented and structured into focused areas of the body of knowledge, provider, and consumer.

Chapter 9: Conclusion: This chapter summarises the research work by linking the results to the research objectives and theoretical foundations. An extension to the research is recommended, which closes the final chapter of the study.

1.10 Chapter Conclusion

The introductory section of the thesis has shown that the need for improved service delivery exists globally. South Africa is not an exception, where agitations over the deficit in service delivery often led to social unrests with undesirable consequences. South Africa currently reels under a power (ESD) crisis which is projected to exist for at least another half a decade.

Therefore, a new way of thinking to aid diagnostic assessment of ESD is needed as it will enable informed actions necessary to close ESD gaps.

Chapter 2. Literature Review

This chapter is an evaluative report of other studies in the literature related to the area of study, extracted through a systematic review of the literature. The chapter answers RQ1, RQ2 and RQ3, which are repeated here:

RQ1: What DSPA tools are available in general?

RQ2: Which of these DSPA tools are used within the service delivery domain?

RQ3: What criteria must these DSPA tools satisfy to be selected and considered effective in addressing service delivery performance gaps?

The chapter aims to:

a. Provide a theoretical context for this research, exploring systems thinking, and a design sciences approach towards ESD.
b. Provide a coherent, focused summary of work already done in the research problem area and what still needs to be done, i.e. show where this research fits into the existing body of knowledge.
c. Depict the significance of the grand challenge (research problem).

2.1 Diagnostic Reasoning

Many diagnostic approaches exist, but the logical sequence remains the same. Whether it is in medicine, evaluation of a production system, digital/analogue circuits testing, or assessing the health of an enterprise, they follow a process of observation, and multiple analysis, ahead of post diagnosis decision making/therapy (De Kleer, 1987; Groopman, 2008; Reggia, 1985). For instance, in medicine it involves identifying a disease by the symptoms, signs and test results of a patient (Berner, 2007; Croskerry, 2009) and exits into decision making (recommendation of a treatment plan) which may follow an *intuitive* or *analytical* approach. A process of diagnostic refinement (multiple analysis, tests and information gathering) is followed until such a time that clinicians are satisfied that they have enough information on the case, to make optimal decisions. This is the scope of diagnosis. Should the diagnosticians not be satisfied about the quality or accuracy of information gathered during the diagnostic refinement process, another iteration is initiated with the aim of minimizing diagnosis inaccuracy or uncertainty. Once a satisfactory level of diagnosis is obtained, care (treatment) may begin. Many models of clinical diagnostic reasoning (Rajkomar, 2011; Yazdani, 2017) exist, but the goals are the same. According to Bowen (2006), key elements of clinical diagnostic reasoning include interviews

with patients, data gathering, analysis, which are later used by the clinician for decision making on care. These are illustrated in Figure 5.

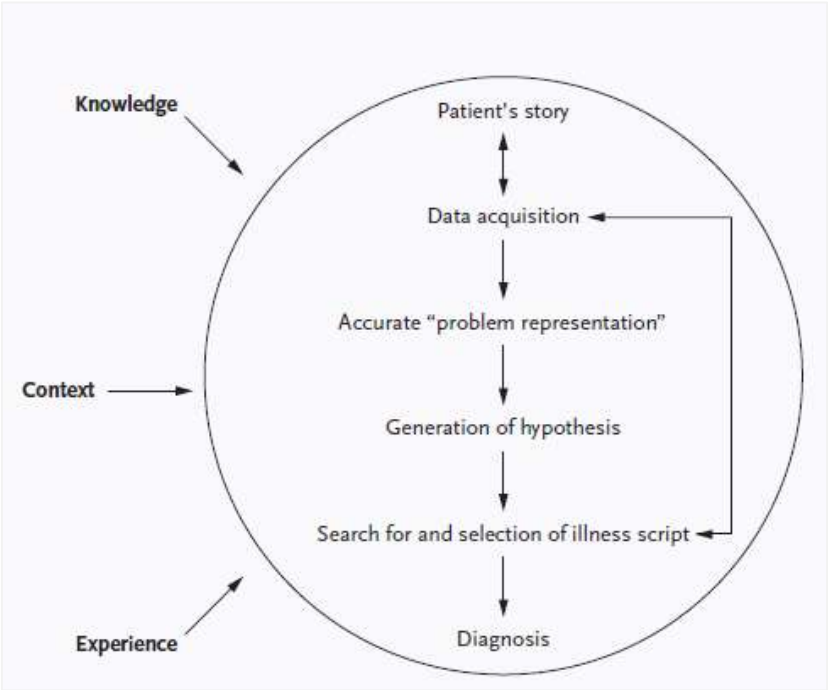


Figure 5: Key Elements of the Clinical Diagnostic Reasoning Process

(Bowen, 2006)

The sequence and functions of diagnostic reasoning are not heavily deviated for electronic circuitry and expert systems (Luo, 2018; Yang, 2011). The process seeks to determine the faulty component/s responsible for an undesired output (or behaviour) of a given circuit for a specific input set. It includes observations (tests), parameter identification, fault verification and knowledge engineering (information gathering). Ahead of actual problem solving (intervention), multiple iterations to improve diagnostic accuracy, as in medicine, are conducted since the initial information gathered are generally not sufficient for precise diagnosis. However, in addition to information saturation, the exit point (of diagnosis) in this case includes the economics of further iterations as continued diagnostic iterations can be costly. While socio-technical systems are dynamic and unpredictable, a diagnostic approach to track individual input parameters into a system, which may inadvertently impact the global system's behaviour, is deemed valuable.

For example, given a *UUT* (unit under test), the *diagnostic problem* is illustrated below (Lirov, 1989):

Circuit pack $P = P(S,B)$ where S is the circuit structure and B its behaviour.

The structure $S = S(C,T)$ is defined by the circuit components C and topology T on the set S.

The behaviour $B = B(IO,R)$ is defined by two mathematical equations:

a. The *IO* model represents the input/output relationships of every component $c \varepsilon C$.
b. R represents the reliability of every component $c \varepsilon C$.

Component $c \varepsilon C$ (i.e. c is an element of the set C) will be deemed faulty should its observed behaviour (b_o) differ from the expected input/output (*I/O*) expected behaviour (b_e), where $b_e \varepsilon IO$.

In this instance, given a multicomponent circuit pack P and symptom/s showing abnormal (unexpected) *IO* behaviour, the *diagnostic problem* is to identify the subset $C_f \varepsilon C$ of faulty component/s.

For this study, the *diagnostic problem* is to identify the ESD for d design domains or sub-domains within n municipalities ($ESD_d \varepsilon ESD_n$) which will explain the gaps (ESD_g) between the observed (P_o) and expected (P_e) performance, given the complexity & multi-level stakeholder nature of the ESD, i.e. n electricity-delivering municipalities (ESD_n), and results showing the foundering performance (P_f). It is intended that the ESD_g will inform the re(design) of ESD. Yet, as briefly outlined in section 1.4, the approach followed in the study is to view the ESD value chain as a complex adaptive social system with human role players, meaning one cannot fully predict or control its entire operational reality (Aveiro et al., 2016). All enterprises are established to achieve specific purposes. However, many factors exist why the majority fail to achieve their purposes and strategic intent (a gap between the observed P_o and expected performance P_e). Not being able to or capable of diagnosing these conditions, identifying the faulty/dysfunctional component or subsystem is problematic and jeopardises the operations and existence of the enterprise (Fernandes & Tribolet, 2019). According to Fernandes and Tribolet (2019), using the Viable System Model (VSM) of Beer (1985) to model an enterprise as a viable system, an enterprise is only viable if the interrelated components and functional subsystems (operational units) meet the condition for expected organisational performance P_e, hence methods and *control* systems to diagnose the state and activities of the operational units on an on-going basis are critical. The specific methodology (techniques, methods, strategy, procedures) adopted in dealing with the diagnostic problem is outlined in Chapter 3.

2.2 Diagnostic Service Performance Assessment Tools

Having adopted the policy on service delivery improvements (Skweyiya, 1997), the government has set up a few oversight departments to monitor its programs, projects and services (DPSA, 2016; Madale, 2014; PSC, 2014). Backed by relevant laws and national policy frameworks, these oversight institutions adopt many tools and performance assessment methodologies to carry out their designated mandates. Notwithstanding these efforts, Tirivangasi and Mugambiwa (2016) contend that service delivery gaps continue to be a problem, leading to protests that paint a negative picture of South Africa, locally and internationally. While it may be argued that there are other driving forces in the configuration of these protests, such as the prevailing economic and political situations, the triple challenge of poverty, inequality and unemployment, a diagnostic assessment of the health of service delivery (electricity provision, water supply, sanitation, waste removal, and housing) is required to determine the extent of their contribution to these unrests amongst other things.

Apart from these protests, the direct economic impact of deficits in service delivery, such as electricity blackouts, has been outlined in Chapter 1. Given the crippling effect that these service delivery gaps have on our society, both government and many authors (Alexander, 2010; Mdlongwa, 2014; Nleya, 2011; Shaidi, 2013; L. Thompson, and Nleya, N., 2010) have focused attention on the causes of the issues, and how they may be resolved. There is some consensus that the key to any solution is a diagnostic assessment of the performance of electricity service delivery. For example, Makanyeza (2013) believes that regular assessment and monitoring of service delivery health (as an early warning system to trigger corrective actions) is desirable. Sibanda (2012) agrees and recommends quality assessment of service delivery health using International Organisation for Standardisation (ISO) standards, international benchmarking and balanced scorecards. Taking a global perspective, The World Bank Group reports on accountability in South Africa's Public Services (2011) confirms that one of the major reasons for service delivery issues is inadequate assessment (including monitoring and feedback) of the health of service delivery.

2.2.1 Objectives and Protocol for a Systematic Literature Review

Given the agreement on the need for performance assessment/monitoring of service delivery, this sub-section conducts a systematic exploration of the literature with some objectives that are also aligned to RQ1, RQ2 and RQ3.

a. SLR_{O1}: Identify DSPA tools in general (aligned with RQ1).
b. SLR_{O2}: Identify DSPA tools used within the service delivery domain and select eligible tools for the research context (aligned with RQ2).

c. SLR_{O3}: Discover criteria that may be considered for DSPA tools to be effective (aligned with RQ3).

The systematic exploration of the literature is guided to a considerable extent by the *eight-step guide to conducting a systematic literature review* given by Okoli and Schabram (2012) and Okoli (2015). According to them, Systematic Literature Review (SLR) is a systematic, structured, all-inclusive effort for critically assessing, extracting, and integrating empirical evidence that meet pre-defined eligibility criteria in a complete, scientifically rigorous, and reproducible manner. Their definition is supported by Kwan (2006) and Tranfield et al. (2003). To date, no systematic review on relevant criteria for a service delivery diagnostic tool has been published. Given government expenditures on service delivery and the continued deficit with its consequential impacts, it is timely that a consolidated effort is made to systematically put together all works published around the subject. This study does precisely that by reviewing all published works in relevant academic journal databases and some secondary information repositories. Table 2 outlines the steps followed for conducting the review. While the steps are adapted from Okoli and Schabram (2012), the interpretation is specific to this study.

Table 2: Review Steps and Definitions

(C. Okoli, and Schabram, K. , 2012)

	Steps from Okoli & Schabram (2012)	**Interpretation for this research**
1	Purpose of the literature review	Specify the purpose and intention of the study.
2	Protocol and training	Stipulate the boundary of the study, conditions, and procedure to ensure consistency during the review.
3	Searching for the literature	Execute defined search criteria for both electronic and physical materials included. Specify the extensiveness of the study (knowledge repositories that were included) and keywords that were used.
4	Practical screen	Apply inclusion criteria to filter all materials acquired during the search.
5	Quality appraisal	Apply exclusion criteria to eliminate materials based on lower than acceptable quality.
6	Data extraction	Systematically extract relevant information from all included materials.
7	Synthesis of studies	Combine facts from all included studies and synthesise/summarise the facts based on qualitative and quantitative means.
8	Writing the review	Report on the findings of the study to enable reproducibility.

The review objectives were stated at the start of this section. Although used mainly in the medical fields, the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analysis) (Moher, 2009; Page et al., 2020) checklist guided this review protocol. Table 3 summarises the protocol, i.e. elaborating on the execution of Steps 2 and 3 of Table 2.

Table 3: Review Protocol

	Items	Protocol used for this study
1	Protocol	PRISMA guideline (Moher, 2009; Page et al., 2020), providing guidelines on including/excluding primary sources.
2	Eligibility criteria	Year 1987 to 2017. The constraint on the search period ensures that we adequately captured all service delivery performance publications before and after the white paper on service delivery improvement (Batho Pele) was adopted by the government in 1997.
3	Information sources	Google Scholar, ProQuest, Scopus, Science Direct, Emerald Insight, some physical reference libraries and general internet search.
4	Search strategy and keywords	First, search for existing systematic literature reviews in the subject area, test searches using combinations of keywords and consultation with subject matter experts and domain experts. The specific keywords are specified in Section 2.2.2.
5	Document Management System (DMS)	Microsoft SharePoint, backed by Microsoft SQL Server, was used as DMS for the search. Version control capable content libraries were created not only to store information but also to keep event/activities log and date/time stamps. Atlas.ti was used later, only for thematic and content analyses.
6	Additional data and analysis	Secondary data were sourced from International Political Bodies (e.g. the World Bank), public entities, state-owned companies, and provincial governments.

Table 4 shows the search scope and inclusion/exclusion criteria, i.e. elaborating on the execution of Steps 4 and 5 of Table 2.

Table 4: Practical Screening and Quality Evaluation

Selection basis	Inclusion criteria	Exclusion criteria
Geographical coverage	Global.	None.
Language	English.	Non-English (except if translations can be obtained).
Publication date	Year 1987 and above (Please see item 2 of Table 3).	Articles published before 1987.
Cost	Services subscribed to by the University of Pretoria (UP) and those available via inter-library arrangements.	Databases not subscribed to by the UP and requiring very costly individual subscriptions to access.
Scope of interest	Materials covering exact or related diagnostic /performance assessment pools in general, such tools used within the public service delivery domain and criteria that the tools must satisfy to be considered effective.	Same as inclusion criteria but in non-democratic societies.
Quality of publications	All peer-reviewed records or approved government policy documents that are unclassified. It must be clear that a knowledgeable individual reviewed the publication. This is further explained in section 2.2.2.2	Blogs, websites and commercial prints whose credibility cannot be easily ascertained.

For the execution of Steps 6 and 7 of Table 2, ATLAS.ti is used to extract data from the knowledge repositories (Microsoft SharePoint) and table the results as per the three main objectives of the SLR.

2.2.2 Results from Systematic Literature Review

A total of 2377 publications were found, of which only 64 were evaluated for eligibility. Out of the eligible 64, only 29 made it to the final inclusion stage. However, not one of the included materials deals with the focus of this exploration, i.e. the search did not identify an SLR that synthesises the criteria that a diagnostic tool must satisfy to be considered effective in closing service delivery gaps. Although a plethora of published works exists around (public) service delivery in general, there is a dearth of an investigation into the criteria which an assessment tool must possess to diminish service delivery deficits. Figures 6 and 7 and Table 5 outline the initial counts of publications from some well-known databases, from inception to data extraction. Boolean logical operators were used to link the search terms in a way that ensures focus.

The next search phrase indicates the intent of our search to address SLR_{O1} and SLR_{O2} of the review:

["diagnostic tools" NOT ("health" OR "hospital")] AND "for assessing public service delivery".

Synonym phrases for "diagnostic tools" were also included in the comprehensive search string that was used, e.g. "survey tools", "survey mechanisms", "survey models", "survey methodologies", "survey frameworks", "survey systems", and "survey approaches".

Some databases & search engines vary in the way that words and phrases are nested, but the inclusion and exclusion logic (use of Boolean operators) generally remain the same. The challenge is, to get the qualifying criteria of a diagnostic service performance assessment tool, the tool must have been empirically tested, evaluated, and validated by its developers (or others) for specific performance criteria. This is lacking in all but 7 of the entire diagnostic/survey tools covered, 13 of which focus on public services, 4 on the general service industry and 2 on the manufacturing sector (included because of their closeness to service quality and performance assessments).

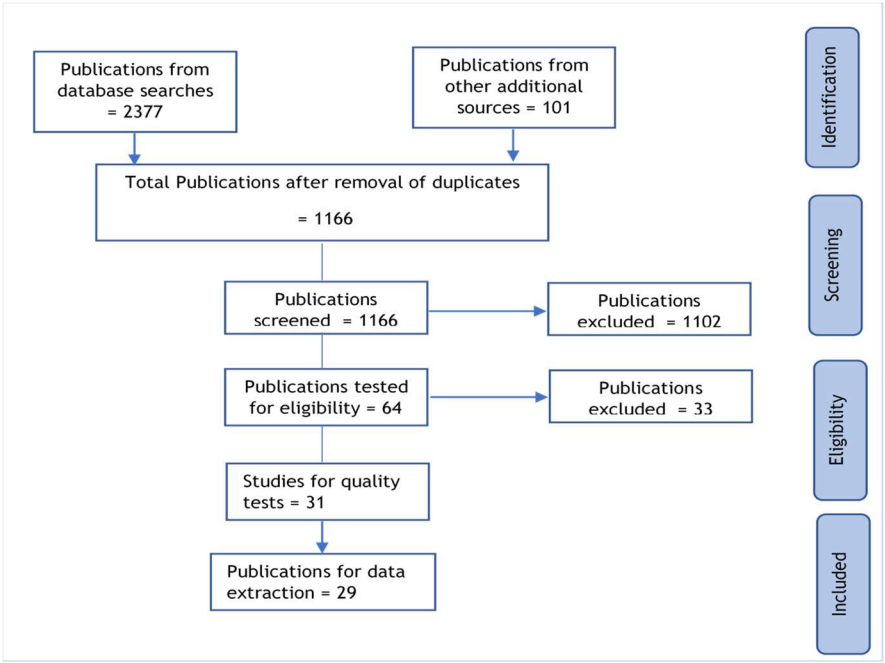


Figure 6: Search Outcome

(Page et al., 2020)

To ensure that the search strategy delivers quality results for SLR_{O1} to SLR_{O3}, a complementary search using the snowballing procedure outlined by Wohlin (2014), was adopted. This led to multiple iterations and the exclusion of 1135 publications, streamlining the final publications for data extraction.

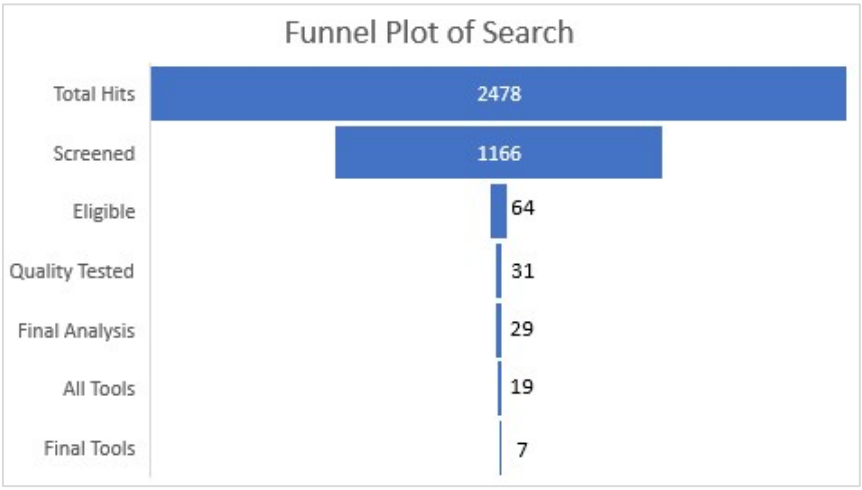


Figure 7: Search Outcome Visualisation (Developed by Author)

Table 5 outlines search hits by databases, duplicate counts, and the number considered relevant in this study.

Table 5: Information Sources and Hits

Source	Number of Hits	Duplicates	Number Relevant
Google Scholar	4	2	2
ProQuest	30	9	1
Scopus	78	34	1
Science Direct	592	201	1
Emerald Insight	367	112	6
Taylor and Francis	1306	899	2
Others*	101	55	16
Total	2478	1312	29

*The World Bank, World Health Organisation, UNICEF, USAID, Government Departments and other journals.

In summary, sources have been excluded (or included) based on the criteria defined in Table 3 (eligibility criteria), Table 4 and section 2.2.2.2 (quality assessment for tools eligibility).

2.2.2.1 Spread and Attributes of Tools

Table 6 indicates the distribution and spread of the tools included, addressing SLR_{O1} of this review.

Table 6: Spread and Attributes of Diagnostic Service Performance Assessment Tools

Tool	Year of publication	Country of application	Theoretical approach/technique	Reference
FSDM	2015	South Africa	Qualitative	(FSDM., 2015)
DEA	2016	South Africa	Quantitative	(Brettenny, 2015)
Citydex	2009	South Africa	Quantitative	(Steven, 2009)
SERVICOM	2006	Nigeria	Quantitative	(SERVICOM, 2006)
SERVQUAL	1988, 1991, 1994	United States	Qualitative	(Parasuraman, 1988, 1991, 1994)
PETS & QSDS	2002	United States	Both	(Reinikka, 2002)
D-Tree	2007	United States	Qualitative	(Wallace, 2007)
Livingstone	2004	United States	Quantitative	(Siamak, 2004)
ESTP	2007	United Kingdom	Qualitative	(Williams, 2007)
SARA	2013	Switzerland	Qualitative	(O'Neill, 2013)
SERVPERF-M	2000	Australia	Quantitative	(Fogarty, 2000)
ASPIRE	2016	Australia	Qualitative	(Uy, Lizarondo, & Atlas, 2016)
PJM	2015	Austria	Qualitative	(Höber, 2015)
EGPE	2015	China	Qualitative	(Yu, 2016)
SCPAT	2011	Thailand	Quantitative	(Banomyong, 2011)
CSDA & SDAF	2016	Multiple	Qualitative	(Ross, 2016)
BSC & GEE	2011	Afghanistan	Qualitative	(Edward, 2011)
MP	2010	Malaysia	Quantitative	(Amrina, 2010)
CEMATT	2013	Romania	Quantitative	(Alexa, 2013)

Although there are many related service quality assessment tools, e.g. ESQ Model (Santos, 2003), Antecedents and Mediator Model (Dabholkar, 2000), INTSERVQUAL Model (Frost, 2000), DEA Model (Soteriou, 1997), and the IT-Based Model (Zhu, 2002), SERVQUAL (Parasuraman, 1988) meets the initial eligibility criteria for inclusion, firstly because, in

addition to general quality metrics, it measures service performances. In addition, it is widely applied in the public sector, and finally, because most other service assessment tools discovered are a variation or adaptation of SERVQUAL. It is deemed the most widely applied, followed by PETS and QSDS (Reinikka, 2002) of the World Bank Research Group.

SERVQUAL has been modified/customised to form other assessment tools and serves as a diagnostic methodology to uncover broad areas of an organisation's quality and performance deficits. It has been applied extensively to many services sectors and in many countries, some of which are outlined in Tables 7 and 8.

Table 7:Some sectors where SERVQUAL has been applied

Sector of application	References
Public service delivery	(Alexandria, 2001; Ali, 2014; Brysland, 2001; Ilhaamie, 2010; Iyikal, 2016; Martinovic, 2017; Mik, 2001; Prodromos, 2014; Ramseook-Munhurrun, 2010)
Public transportation	(Barabino, 2012; Luke, 2017; Muthupandian, 2012; Ojo, 2014; Randheer, 2011; Sam, 2017)
Public and private healthcare	(Butt, 2010; Chakraborty, 2011; Kalaja, 2016; Pekkaya, İmamoğlu, & Koca, 2017; Peprah, 2014; Purcărea, 2013)
Information Systems	(James, 2012; Landrum, 2009; Leyland, 1995; Roses, 2016; Whitten, 2004)
Education	(Abili, 2012; Đonlagić, 2015; Galeeva, 2016; P. Green, 2014; Krsmanovic, 2014; Yousapronpaiboon, 2014)
Hospitality	(Al-Ababneh, 2017; Amballoor, 2015; Kalotra, 2017; Markovi´c, 2010; Mazumder, 2014; Mei, 1999)

Not only has SERVQUAL been applied to many services sectors, its application cuts across many countries, as shown in Table 8.

Table 8: Some countries where SERVQUAL has been applied

Country of application	References
South Africa	(P. Green, 2014; Luke, 2017; Pitt, 2015; Simpson, 2015; Van der Wal, 2002)
Bangladesh	(Amballoor, 2015; Kalotra, 2017; Mazumder, 2014)
Croatia	(Markovi´c, 2010)
United Kingdom & United States	(Lai, 2006)
Thailand	(Yousapronpaiboon, 2014)
Russia	(Galeeva, 2016)
Ghana	(Ojo, 2014; Peprah, 2014; Sam, 2017)
Malaysia	(Ilhaamie, 2010)
Egypt	(Ali, 2014)
Cyprus	(Iyikal, 2016)

Even though SERVQUAL is widely applied, the next section elaborates on whether this tool should be further considered in the study, based on identified criteria to assess tool eligibility.

2.2.2.2 Quality Assessment for Tools Eligibility

In accordance with SLR_{O2}, additional quality assessment criteria were suggested to select eligible tools for the research context and only short-list a tool if it met all quality criteria. The following quality assessment criteria were applied:

a. Has the tool been tested in real life? Motivation: *It is assumed that tools that have been used by practitioners would have been refined, increasing their usability.*

b. Has the tool been evaluated against key performance metrics? Motivation: *It is assumed that the evaluation process would have helped improve the performance of the tool before it is used to assess the health of service delivery.*

c. Are the performance metrics clearly defined? Motivation: *Ambiguous performance metrics will have a negative effect on the reliability of the measurement outcome.*

d. Is the evaluation outcome documented? Motivation: *Authors occasionally allude to evaluations they have conducted without publishing the full outcome. Transparent evaluation outcome is considered vital.*

e. Are independent persons (not the tools developers only) involved in the tool evaluation? Motivation: *The purpose of this criterion is to eliminate potential bias regarding the evaluation of the tool.*

Seven eligible tools meet the quality criteria and are shown in Table 9.

Table 9: Tools that meet quality criteria

Tool name	Abbreviation	Reference
Extended service template process	ESTP	(Williams, 2007)
Area for evaluation, Set goals, Performance indicators, Information sources, Report results, Evaluate	ASPIRE	(Uy et al., 2016)
Balanced Score Card & Generalised Estimating Equation	BSC & GEE	(Edward, 2011)
City Service Delivery Assessment	CSDA	(Ross, 2016)
Performance Journey Mapping	PJM	(Höber, 2015)
External Government Performance Evaluation	EGPE	(Yu, 2016)
Manufacturing Performance	MP	(Amrina, 2010)

Although SERVQUAL has been widely applied and met the initial eligibility criteria for inclusion in this research, as shown in Tables 7 and 8, it fell short of the *documented independent evaluation* criterion of the additional quality filter. The SERVQUAL projects of sectors (Table 7) and countries (Table 8) reviewed showed practical application of SERVQUAL and the before and after scenarios of its application, not independent evaluation.

2.2.2.3 Evaluation Criteria for Effective Tools

For SLR_{O3}, the objective is to discover criteria that DSPA tools must satisfy to be considered effective. Table 10 provides a summary of criteria extracted from the literature.

Table 10: Evaluation Criteria for DSPA Tools

Evaluation criterion, identified as a theme in literature	References where theme occurs
Criteria related to the tool-as-a-construct	
Independence – Administering personnel must be independent and free of financial inducement.	(Edward, 2011; Yu, 2016)
Relevance – The evaluation project must be practically significant and reflect important public issues. The tool must possess metrics relevant to the outcome of interest.	(Uy et al., 2016; Yu, 2016)
Validity – The tool measures what it is supposed to: It possesses fitting and adequate metrics to measure service delivery health.	(Amrina, 2010; Yu, 2016)
Reliability – Tool must be consistent when used to measure (service delivery performance) repeatedly, with fairly comparable results.	(Yu, 2016)
Comprehensibility – The outcome provided by the tool must be easily digested and understood by its users. Graphs and tables can be used to facilitate public comprehension.	(Amrina, 2010; Edward, 2011; Höber, 2015; Uy et al., 2016; Williams, 2007; Yu, 2016)
Comparability – Both the tool, its methodology and results must be in such a way that it can be compared with similar tools.	(Höber, 2015)
Objectiveness – Subjective metrics should be avoided	(Edward, 2011; Höber, 2015; Ross, 2016)
Predictive ability – It must estimate or project what service delivery performance would look like in the near future based on historical and current data.	(Ross, 2016; Williams, 2007)
Diagnostic ability – Tool must identify specific issues regarding specific performance areas affecting service delivery.	(Williams, 2007)
Balance – Tool must cover all relevant areas.	(Höber, 2015)
Conflicts avoidance – Metrics used by the tool must not conflict with one another.	(Höber, 2015; Ross, 2016)
Engagement – Involve stakeholders in the design and development of the tools.	(Ross, 2016)
Focus – Only deal with what is important.	(Ross, 2016; Uy et al., 2016)
Ease of Use – The assessment tool should be easy, flexible to interact with, and uncomplicated to learn and operate.	(Amrina, 2010; Höber, 2015; Uy et al., 2016)
Usefulness – The tool meets its objective. That is, it can effectively and efficiently measure service delivery health and produce valid results. Note that the definition duplicates the definition for "validity" and is therefore removed.	(Amrina, 2010; Höber, 2015; Uy et al., 2016)
Criteria for post-diagnosis practices	
Responsibility – The assessed/evaluated entity should take ownership.	(Höber, 2015)
Impactful – How well the tool's outcome and emanating results lead to improvement in service delivery.	(Amrina, 2010; Ross, 2016; Yu, 2016)
Improvement – Must not only assess but lead to service delivery improvement.	(Amrina, 2010; Edward, 2011; Höber, 2015; Uy et al., 2016; Williams, 2007)

2.2.2.4 Discussion

Despite the acknowledged service delivery surveys/assessments in South Africa, service delivery deficits continue to widen with their socio-economic impacts (Tirivangasi, 2016). A new way/technique of diagnosis, grounded in relevant theories, evaluated for appropriate

performance metrics, and tested for fitness of purpose is therefore needed urgently. As a contribution, this SLR explored the literature to uncover works (if any) by authors and researchers along the same line. Tables 9 and 10 show the extracted tools and criteria, respectively. From Table 10, the most subscribed criterion is *comprehensibility*, i.e. the outcome or results of DSPA tools must be easily understood, simple, and uncomplicated, followed by *improvement*, i.e. must not only assess but lead to service delivery improvement. Given the above, the researcher believes that diagnostic tools are too complicated for the average user and they are often not proven to lead to service delivery improvements.

In respect of South Africa (the focus of this research), all the three extracted native tools (the FSDM, DEA and Citydex) shown in Table 9 did not pass the last quality eligibility tests defined in section 2.2.2.2, suggesting that this is a particularly important subject that suffers considerable neglect at the moment. Although this section identified available DSPA tools and extracted their performance criteria, it is needful to test, verify and validate them for the South African context. Chapter 4 adopts a scientific process to validate the criteria and rank the tools to enable an informed choice of the most suitable tool for South Africa.

2.3 Multi-Criteria Decision Making

As shown in section 2.2 above, there is no scarcity of diagnostic service performance assessment tools (see Table 9) since governments worldwide are keen to understand how well they deliver public services. Citizens' quests for improved services are mounting. This situation presents a serious dilemma of identifying and deciding on the best tool/s for a specific socio-economic, political context. Multi-criteria decision-making (MCDM) is used to determine the performance of decision alternatives across several contradicting qualitative and/or quantitative criteria, resulting in a compromise solution (Scott, 2005; Triantaphyllou, 1998). However, there are many techniques for MCDM, as revealed by Velasque and Hester (2013) and Mardani et al. (2015). This poses an additional challenge of selecting the most suitable MCDM technique to select the best DSPA tool. An investigation of some popular MCDM techniques and their frequency of application by Mardani et al. (2015) resulted in the outcome shown in Table 11. In their analysis, the Analytic Hierarchy Process (AHP) is the most frequently applied method (33%), followed by hybridised AHP at 16%.

Table 11: Summary of MCDM techniques & frequency of application

MCDM Techniques	Frequency of Application	Percentages
AHP	128	32.57
Hybrid MCDM	64	16.28
AGGREGATION DM Methods	46	11.70
TOPSIS	45	11.4
ELECTRE	34	8.64
ANP	29	7.38
PROMETHEE	26	6.62
VIKOR	14	3.56
DEMATEL	7	1.78
Total	393	100

Given the necessity to match a method to the appropriate problem class, the researcher compares the MCDM methods based on earlier works in section 2.3.1 and motivates for the closest to the problem class explored in this research in sections 2.3.2 to 2.3.4.

2.3.1 MCDMs: Comparative Analysis

Velasque and Hester (2013) compare 9 MCDM methods based on areas of application, and suitable problem class. For performance problem types, public policy and decision making, and political strategy, their choice is the AHP. Their position is further echoed and strengthened by Kraujaliene (2019) in his comparative analysis of MCDM methods to evaluate the efficiency of technology transfer that also fits into our problem domain. On the practical application of the AHP to similar problem areas such as this research, Prusak et al. (2015) built the model of assessment of public services in Poland using the same method, while others applied it to the selection of tools, software, models and products (N. Ahmad, and Laplante, P. A, 2006; Bataineh, 2018; Dorado, 2014; Godse, 2009; Hell, 2013; V. Lai, Wong, B.k, and Cheung, W, 2002; Pekin, 2006; Venkatamuni, 2011; Wei, 2005) as intended in this study. Notwithstanding the popularity of the AHP as an MCDM technique in public service and information systems domains, it is not without critiques. Shin (2017) and Barzilai (1998) warn users of the AHP about the risk of inconsistent scoring and rankings. However, this risk was played down by Velasque and Hester (2013) and Gavade (2014), who posited that inconsistencies could be easily managed given that the AHP can handle multiple decision-makers and capture the way people think. Supporting the standpoint that the AHP risk of inconsistent scoring and rankings can be easily mitigated, Whitaker (2007) believes the AHP will always produce expected results if the priorities are correctly structured. Other criticisms of the AHP have been duly addressed by Forman (1993).

2.3.2 AHP: Traditional AHP, Fuzzy AHP and the ANP

Although section 2.3.2 matches the AHP to the problem domain considered in this research, which may be the reason for its popular use as shown in Table 11, the AHP is not without its variants, i.e. the Fuzzy AHP and the Analytic Network Process (ANP). Whereas the traditional AHP requires crisp knowledge and assumes experts' judgement to be exact, the fuzzy AHP (FAHP) is a synthetic extension developed to handle fuzzy comparison matrices, with considerations for the fuzziness of the decision-makers. The ANP on the other hand, is a direct extension of the AHP where elements are grouped into clusters of related factors/networks rather than hierarchical levels. Whereas the AHP represents a model with a linear hierarchical relationship, the ANP enables complex interrelationships among decision levels and attributes (Misra, 2012; T. L. Saaty, 2004b; Yildiz, 2015).

2.3.3 AHP: Motivation for Inclusion

Given the problem domain and attributes discussed in section 2.2, and a review of the literature (Mardani, 2015), the AHP method is deemed to be most appropriate to be included as part of the tool selection process for this study (see Chapter 4) due to the following reasons:

a. Successful practical application to similar problem areas.
b. Simplicity (explanation of concept to local municipal officers is relatively easy).
c. Controlled consistency.
d. Plausible result (decision-makers in agreement with outcoming priorities).
e. The calculation is possible with an MS Excel electronic spreadsheet.

These are contrasted to the ANP whereby the concept is difficult to explain to local municipal officials, verification of results due to interrelationships is impossible, specialised software is required for calculations, and the software is too complex to be used as a normal day to day tool for practical decision making (Goepel, 2013). On the FAHP, Mukherjee (2017) reviewed and analysed three different FAHP models, and concluded that the FAHP spoils rather than improve outcomes due to the complexity and fuzziness that the method brings into the decision-making process.

2.3.4 AHP: Brief Theoretical Review

Organising objectives, alternatives, and criteria into a multi-level hierarchical structure, the AHP was developed by Saaty (1980, 1988, 2008) and enjoys popular application as a decision support system (Harker, 1989). Saaty and Vargas (2001) defined four axioms as conditions for using the AHP:

1. The decision-maker can conduct a pairwise comparison a_{ij} of two alternatives i and j.
2. One alternative is not infinitely better than another relative to a criterion: aij $\neq \infty$.
3. The model can be built into a hierarchy.
4. The goal, criteria, sub-criteria, and alternatives fit into the hierarchy.

Considering m evaluation criteria and n options to be assessed, the pairwise comparison matrix A is an m x m real matrix. The matrix can be defined as:

$$A = \begin{pmatrix} a_{11} & a_{12} \cdots & a_{1m} \\ a_{21} & a_{22} \cdots & a_{2m} \\ \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} \cdots & a_{mm} \end{pmatrix} \quad (1)$$

According to Saaty (1980), for each entry in the criterion comparison matrix:

a. a_{jk} of matrix A is the weight of the j^{th} criterion relative to the k^{th} criterion
b. j^{th} criterion is more important than the k^{th} criterion if $a_{jk} > 1$
c. j^{th} criterion is less important than the k^{th} criterion if $a_{jk} < 1$
d. j^{th} criterion is equally important to k^{th} criterion if $a_{jk} = 1$

The normalised pairwise comparison matrix is averaged by m to derive the criteria weight vector where:

$$W_j = \sum_{l=1}^{m} a_{jl}/m \quad (2)$$

Practical steps for concluding the AHP have been given by Saaty (1994) and Mu (2017).

2.4 Theories and Concepts of Enterprise Engineering

The fact that enterprises constantly implement programs and interventions to achieve and improve their institutional objectives is no longer news, and the fact that they struggle to achieve them is also well published (Aronowitz, 2015; Bhasin, 2012; T. J. Green, 2012; J. P. Kotter, 1995; Sushil, 2012; Todd, 2015).

It is a matter of concern seeing that the health of a nation is strongly correlated to the performance of its organisations (Singh, 2016), and people's day to day lives depend largely on their existence. In this research context, enterprises are goal-oriented cooperatives/businesses (public or private, profit making or non-profit making), established to achieve set performances (Dietz et al., 2013), while performance refers to both financial and non-financial metrics capable of assessing the degree to which enterprise goals and objectives have been met (Almatrooshi, 2016). While many authors have proposed several factors for floundering enterprise performance, and remedial approaches, their propositions are often one-sided and

inadequate to deal with all the facets of an enterprise. For instance, while some (Bhasin, 2012; T. J. Green, 2012) believe that an unconducive environment is mainly responsible for enterprise failure, Gijo (2011) attributes it to poor training programs, Gautam (2015) to management incompetence, Abdul-Rasid et al. (2014) to poor enterprise risk management and Bacha (2010) to how employees perceive their Chief Executive Officer (CEO). In addition, Felicio et al. (2014) attribute it to purely human capital, Fernández-Pérez et al. (2012) to how well connected the CEO is, and Hooi and Ngui (2014) to human resource and knowledge management capacities.

On the contrary, the discipline of EE argues that investigating the health of enterprises, or trying to bring about changes, using management sciences perspectives as outlined above, may assist in the management of an enterprise but will fall short in bringing about any credible change or in giving stakeholders the requisite knowledge of enterprise complexity and enterprise changes (Dietz & Hoogervorst, 2012; Hoogervorst, 2016). Enterprise Engineering is an emerging discipline with a mission to develop and test new theories and approaches that provide evidence-based, multidisciplinary insights into the design and evolution of enterprises (Hoogervorst, 2011). As presented earlier in this section, to avoid enterprise failures, the EE paradigm posits that the enterprise must be viewed as a social-cultural system that must operate as a unified and integrated (congruent) whole through deliberate design decisions (Dietz et al., 2013). Enterprise success is thus consequential to enterprise design (an arrangement of all enterprise parts ensuring congruency and addressing *areas of concern*). Design interfaces between the extraction of strategic intent/desires, and their realisation, clearly defining the *change* required (Giachetti, 2010), i.e. *the what* (requirements elicitation) and *the how* (operationalisation pathways) of enterprise change (Hoogervorst, 2018). Therefore, EE is the generic designation for the theory, methodology, and methods for enterprise design (Dietz et al., 2013).

A scheme of EE theories and generic goals which were set as the bedrock for ongoing research, development and testing are illustrated in Figure 8. Their adopted nomenclature and EE classification are as follows: FI (information theory), MU (model theory), TAO (function-construction theory), PSI (organisational operation theory), DELTA (system theory), OMEGA (organisational construction theory), ALPHA (organisational essence theory), BETA (organisational design theory), IOTA (organisation implementation theory), NU (normalisation theory) and SIGMA (governance and management theory) (Dietz & Mulder, 2020). Notwithstanding this research agenda and underlying theories, there have been suggestions for a broader and more precise scope that clearly demarcate the domain of the EE discipline from

other related bodies of knowledge (De Vries, Gerber, & Van der Merwe, 2014, 2017; Giachetti, 2010; Lapalme, 2012)

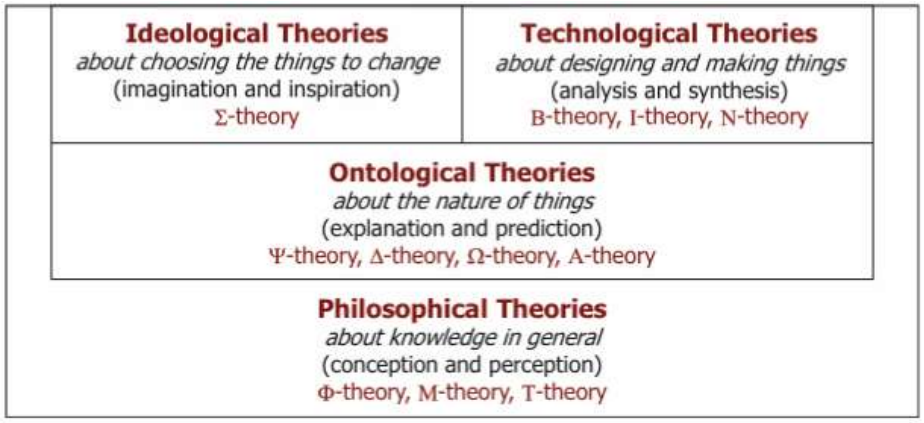


Figure 8: EE set of theories

(Dietz & Mulder, 2020)

As shown in Figure 8, the philosophical theories are the foundation for all other theories, depicting people's perspectives about reality and what is truth in the world around them. The ontological theories form the basis for the technological and ideological theories, addressing the construction and operation of things and the impact of translation from one state to the other. Unlike the ontological theories, which are abstracted from implementation, technological theories are grounded in the practical implementation of things and operationalising them. The process of decision making, and ideation is conceived within the ideological theories. Based on the classifications and definitions by Dietz and Mulder (2020), this study is guided by the TAO (function-construction), PSI (organisational operation), BETA (organisational design) and the SIGMA (governance and management) theories.

a. TAO (Teleology, Affordance, Ontology) theory: As classified within the philosophical theories in the EE classification scheme, TAO is the *function-construction* theory dealing with affordances and their realisation. In this study, the creation of the artefact is based on affordances (functions) derived from socially constructed interactions with subjects of the research environment.
b. PSI (Performing in Social Interaction) theory: Classified within the ontological theory of the EE theory classification scheme, the PSI theory is concerned with the operating construction of the enterprise over time. For this study, a high-level consolidation of the production and coordination acts enables an understanding of the operations of the provider *organisation* where several actors enter into various commitments to perform electricity service delivery.

c. BETA (Building from Essence with Technology and Architecture) theory: The theory is concerned with the activities and process of designing (using both functional and constructional design principles) an artefact (i.e. the object system) to satisfy the requirements of a *using system*. It initiates with the Generic System Development Process (GSDP), which addresses how the function of the *object system* is guided by the construction of the *using system*. The design (and development) process of the research artefact relates to this theory about requirements elicitation, i.e. starting with knowledge about the problem context as the using context and generating the solution architecture of the ESD-PRT to operationalise functional and constructional design principles for the ESD-PRT. Two key design constructs considered in the development of the tool are *areas of concern* and *design domains*. While an area of concern is defined as an attribute or goal that the *black-box* (functional) or *white-box* (constructional) system objects must display or manifest (see section 2.4.2), design domains refer to constructional or functional facets of a system for which design must be carried out (see section 2.4.3). To gain clarity therefore, and to manage design freedom, principles of the BETA theory guided the extraction of *areas of concern*, and classification of performance areas into *design domains*. This is to ensure that the DCMs' (enterprise) strategic intent, also guided by the areas of concerns are systematically addressed within relevant design domains. Having clarity about the design domains helps in defining requirements and in effectively addressing identified areas of concern. These constructs are operationalized in chapters 4 and 5.

d. SIGMA (Socially Inspired Governance and Management Approach) theory: The approach is an employee-centric approach, grounded in the organisational sciences with sharp contrast to the mechanistic view of employees being just an instrument of economic advancement to enterprises. The SIGMA standpoint empowers the employee as an organic part of the enterprise whose opinion and behaviour are essential to the operation and strategic success of the enterprise. Rather than a static top-down approach, a hybrid of bottom-up and top-down approaches was followed in the research artefact design process, drawing from the research organisation's strategic Integrated Development Plan (IDP) and requirements as extracted from the employees through the inquisitive process.

One area not well represented in the approach postulated by Dietz and Mulder (2020) is the diagnostics, underpinned by any form of methodology, technique, framework or tool to extract requirements by design domains in the design process. While socio-technical systems are

dynamic and unpredictable, a diagnostic framework, or tool to understand, and extract functional and construction parameters (design intentions) into a system, which may impact the overall performance, is deemed valuable. Running these diagnostics will enable an enterprise-wide, multi-stakeholder process of sense-making, providing evidence about the existing areas of concern and increasing clarity on the severity of the existing areas of concern. Although the inquisitive process by Hoogervorst (2018), outlined in section 2.4.1, gives an outlook of the diagnosis side, no model or tool was recommended to facilitate the process. However, other works (Gharajedaghi, 2011; Guizzardi, Franch, Guizzardi, & Wieringa, 2013; Horkoff, 2009) exist in guiding stakeholders through extracting these design intentions in a systematic and structured manner, but they are generally silent on how the intentions and concepts are addressed within specific enterprise design domains and constructs. This study contributes to the body of knowledge by developing and demonstrating a rigorous multi-faceted approach within design domains to elicit design-related concepts and intentions that terminates in a cloud-based tool tested in a local environment.

While *social devotion* refers to employee centricity and competent management, *organisational concinnity* refers to constructional congruency, which is a prerequisite to operationalising strategic imperatives as it will not materialise naturally. *Intellectual manageability* is the requirement for mastering the complexities of enterprise construction and operation (Dietz & Hoogervorst, 2012)

Due to the multidisciplinary nature of EE and the contributions from many related disciplines to its knowledge repository, many perspectives and models to enterprise design exist (Lapalme, 2012). Since fragmented schools of thought and approaches are detrimental to local and global enterprise performance, there have been efforts to create a common understanding and minimise ambiguity and inconsistencies in the enterprise design process (De Vries, 2017; De Vries et al., 2017). Just as the enterprise itself must operate as a harmonious, united whole to avoid failure, so should the body of knowledge agree or at least align to achieve results. Arguing against the structural-functionalist approach, which views the enterprise as a mechanised combination of functional components, Hoogervorst proposed an enterprise reality that is emerging, dynamic and complex, yet recognising the place of the functionalist views if located within the confine of an employee-centric theory of enterprise design (Hoogervorst, 2017, 2018). Although there are other enterprise design approaches in the literature (De Vries et al., 2017; Lapalme, 2012), section 1.4 outlines a preference for this organismic, *empowered employee* approach within the global context of this research.

2.4.1 The Inquisitive Process

The functional and constructional design aspects of enterprise realisation are generally embedded in the inquisitive process, i.e. an investigative inquiry to uncover areas of concern, requirements for solutions and identification of practical solutions (Hoogervorst, 2018). Noting that *requirements deal with areas of concern when they are operationalised*, the iterative inquisitive process terminates only when satisfactory understanding is achieved on *how* a defined issue may be resolved (Hoogervorst, 2009, 2017, 2018). The process in itself is creative without a predetermined end, and involves bringing together all relevant stakeholders in a multidisciplinary engagement where *wants* and *needs* are clearly articulated in a naturally emergent fashion, thereby minimising any forms of ambiguity and confusion (Hoogervorst, 2016). This represents enterprise design in a manner that ensures reasonable *consensus* among stakeholders about what needs to change and *clarity* on how the change may be achieved (Dietz et al., 2013). Hoogervorst (2016) believes that the level of agreement among stakeholders (consensus) is what they intend to achieve, and the level of grasp (clarity) on how the achievement will be operationalised can be represented with the matrix shown in Figure 9.

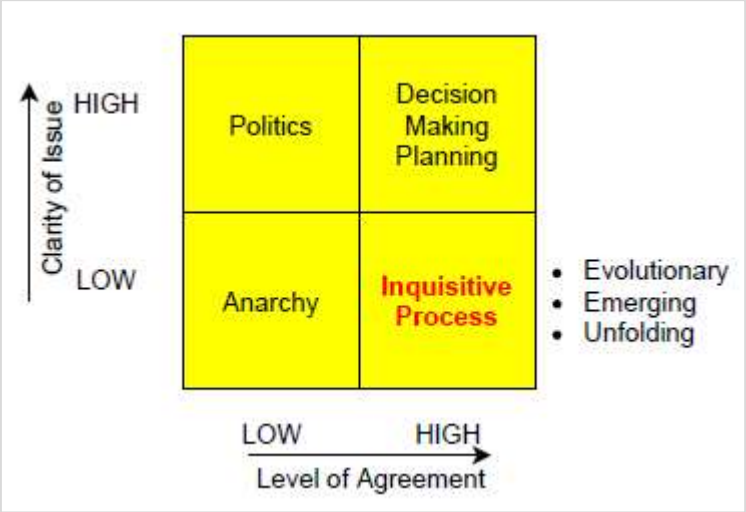


Figure 9: Clarity and Agreement

(Hoogervorst, 2018)

A chaotic solution without consensus on what to achieve or how to go about achieving it has been termed as *anarchy*, while the *politics* quadrant refers to the high level of clarity on issues but general disagreement or low level of consensus about priorities. The *decision-making* quadrant is the relatively straightforward option, where both consensus and understanding are high. Mostly, enterprise issues are locked in the high agreement, low clarity quadrant, signaling the need to gain clarity, i.e. the *inquisitive process*. Although Hoogervorst (2018) did not recommend specific models to go about the evolutionary inquisitive process, many approaches

exist in literature and practice (De Vries, 2020) to guide stakeholders in going through the process to reach consensus and gain clarity. For this study, as shown in section 4.4, a codebook is used to guide this process and conduct rigorous requirements elicitation to provide evidence and clarity about the existing areas of concern. According to Saldaña (2016), using a codebook is a multi-step *sense-making* venture that helps to capture insights and complex assumptions from a specific group or stakeholders.

2.4.2 Design Domains

The inquisitive process needs to be organised in a way that helps the central enterprise governance function to operate effectively with design teams of various competencies. These design teams operate within various facets of an enterprise to define design aspects which are translated to areas of concern and requirements (see section 2.4.3). As stated in section 2.4.1, requirements deal with areas of concern when they are operationalised. Two broad classes of such enterprise design domains have been identified, namely functional (business) and constructional (organisation, information and information technology) enterprise design domains, leading to four domains in general (Hoogervorst, 2018). While the functional design domain relates to the interconnection of functional relationships between an enterprise and its environment, i.e. between the *using* and *provisioning (object)* system, the constructional design domain concerns mostly the operationalisation of the needs and wants of the functional design domain.

Although Hoogervorst (2018) emphasised the need for enterprise design domains to be complete in definition and application, there are concerns that additional classification or additional design domains might be necessary to address other areas of practical applications, systems and subsystems, which have a considerable footprint on enterprise design and performance (Bernus, Nemes, & Schmidt, 2003; J. Dietz & Albani, 2005; Nightingale, 2004). Hoogervorst indicated that additional design domains might be identified in future exploration and research (Hoogervorst, 2016). De Vries *et al.* (2017) already considered contextualising seven different enterprise design approaches for consistency and found that only two of seven approaches considered could be contextualised consistently using their newly developed model called the EECM (Enterprise Evolution Contextualisation Model). The continued absence of shared meaning is partly due to lack of a universally agreed framework for enterprise domain classification. Without standardisation, there is bound to be ambiguity, overlaps in definition, classification issues, and confusion about what constitutes a design domain. Also, a comparative study of all the design approaches would be problematic.

Approaching the demarcation of enterprise design domains using *constructs* with functional and constructional relationships, and building on Hoogervorst's initial work, De Vries (2017) demarcated four main design domains, namely the Organisation, ICT, Human skills and know-how, and Infrastructure domains. Another design domain, the Product design domain, is currently not actively developed within the enterprise engineering discipline. The four main domains have already been used to classify *performance areas* (that are of concern) that need to be addressed at a public enterprise, i.e. a local municipality (Ajayi & De Vries, 2020). In general, these design domains are essential for effectively defining *requirements and architecture*, as well as for effectively addressing system *areas of concern* (Hoogervorst, 2016).

2.4.3 Areas of Concern, Requirements and Architecture

The inquisitive process, as indicated in section 2.4.1 and depicted by Hoogervorst (2018), is a prerogative of the central enterprise governance function, which initiates with the definition of strategic deliverables and desirables, defining *design aspects* which are translated into *areas of concern* and *requirements*. These areas of concern, such as safety, quality, productivity, profitability and customer satisfaction, are addressed by architecture, i.e. design principles to govern enterprise concinnity and congruency *(*Hoogervorst, 2017*)*. Whereas *areas of concern* are defined within *strategic contexts,* addressing them entails a *comprehensive* requirements definition (De Vries, 2020). Yet, the requirements are also addressed by design in specific functional and constructional design domains. To realise the enterprise concinnity and congruency, and addressing areas of concern, enterprise architecture is relied upon for design guidance within one or more design domains. This means effective resolution of areas of concern requires matching/fitting enterprise architecture principles. Conceptually, these enterprise design and governance functions can be represented as shown in Figure 10.

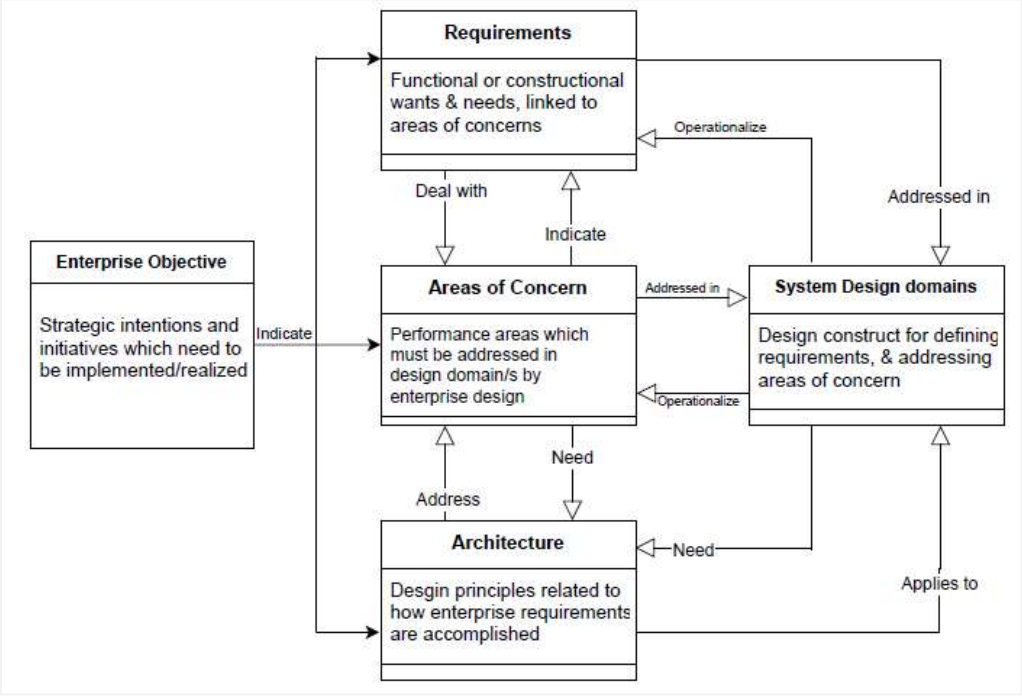


Figure 10: Core Aspects of Enterprise Design

Based on Hoogervorst (2018)

Enterprise design is embedded and is a major activity within the enterprise governance function which defines the direction and provides guidance for enterprise change (future enterprise development and state), while ensuring unification and integration of the enterprise. Hence, from the enterprise objectives *box* of Figure 10, enterprise governance safeguards all activities from the definition of strategic intents, through to its final operationalization. Beyond the objective, the core design aspects (functional and constructional requirements, areas of concern, functional and constructional architecture) are outlined, which must be translated into definite statements, and addressed within specific design domain/s (system design domain *box*). These core aspects of enterprise design are crucial as they inform enterprise outlook and ultimately performance, meaning, underperforming enterprise can be directly linked to poor enterprise design. In summary, the scope and function of enterprise governance is all-embracing, and integrative, ensuring that all change and adaptive initiatives (including operationalization and continuous improvements) to change current enterprise manifestation to a preferred one, is carried out in a concise and unifying manner.

2.4.4 User Requirements Elicitation

One of the most critical phases of engineering and information systems design is requirements elicitation (RE). RE is defined as the process to extract a comprehensive understanding of stakeholders' requirements (needs, wants and wishes), and it is relatively complex as it involves

uncovering, analysing, verifying, and documenting the requirements of diverse stakeholders (Mulla & Girase, 2012; Sharmila & Umarani, 2011). One key challenge of *Business-IT* alignment, often leading to constrained enterprise performance, relates to lack of clarity between the requirements (*needs, demands, goals, objectives*) of Business and IT (M. De Vries, 2013). It is well publicised that poorly executed RE has been identified as the greatest contributor for most software engineering project failure (Briggs & Gruenbacher, 2002; Eberlein & Leite, 2002; Hofmann & F. Lehner., 2001; Nuseibeh & Easterbrook, 2000; Playle & Schroeder, 1996). While identifying other reasons for systems failure such as cost overruns, missed deadlines, and bad technology, Davis et al. (2006) suggest that extracting requirements is responsible for 90% of failure while poor management of requirements is responsible for 71%.

As shown in Figure 10, Hoogervorst's approach tested and demonstrated in this study, requires the identification of functional and construction requirements. His approach focuses mainly on the architecture to achieve enterprise unity and integration as these are deemed essential for translating enterprise intention into reality. Yet, there are other critical issues in extracting design intentions for the construction and evolution of the enterprise, which may call for the use of more than one method for requirements elicitation. *Communication is* key among these issues, often leading to ambiguity and obscurity in RE. Barriers to consistent, complete and intelligible/unambiguous communication among stakeholders include, humans' cognitive limitation (Pitts & Browne, 2007), cultural differences and multifarious stakeholders' backgrounds (Zowghi & Coulin, 2005), and *wicked problems* (difficult to define with human language) (Briggs & Gruenbacher, 2002).

Although there are established methodologies for extracting design intentions, they differ in the classification of design concepts and how these may translate into enterprise construction. To minimise ambiguity, and before extracting design intentions, De Vries (2020) emphasised the need to distinguish and clarify between intention related design concepts, using her newly developed model that incorporates a codebook. The same approach is followed in this study to distinguish between enterprise design concepts.

2.5 Chapter Conclusion

This chapter focused on reviewing publications on three areas that are key to this study: (1) diagnostic reasoning for problem understanding, (2) diagnostic tools for problem solving and (3) design approaches for change to a preferred state. A diagnostic assessment method and tool/s for electricity service delivery with an enterprise-wide perspective remain a gap in literature and practice. An application of some of Dietz and Mulder's (2020) theories is

desirable with tools or methodologies to extract, model and address various stakeholders' intentions in a rigorous but managed fashion. Hoogervorst's (2018) approach, classified within specific enterprise design domains should enable traceability of design intentions and design related concepts and guide how these concepts are translated into enterprise constructions. The methods used and artefact developed as part of this study provide an extension to the initial knowledge developed within the enterprise engineering discipline.

The next chapter reviews relevant research methodologies and motivates for the most suitable methodology in the context of this study.

Chapter 3. Research Methodology

This study applies a DSR methodology to inductively develop an ESD-PRT to provide improved insight into poor ESD performance, which guides diagnostics and redesign of ESD in local South African municipalities. The requirement elicitation process and constructional aspects of ESD-PRT are covered in Chapters 4 and 5, respectively. Furthermore, as indicated in section 2.4, the EE discipline claims it offers solutions to enterprise (e.g. the ESD enterprise) failure, based on some theoretical propositions as illustrated in Figure 8. This claim is deductively investigated by using aspects of ESD-PRT to test a specific extant approach of enterprise design, as proposed by Hoogervorst (2017, 2018). Therefore, this section describes the systematic and practical approach followed in conducting the research, data collection tools and instruments, as well as techniques for data analysis.

3.1 Research Paradigms

Based on ontological, epistemological, methodological and axiological assumptions, a paradigm may be described as an essential collection of beliefs (or metaphysics) about how problems are to be viewed and understood, thus guiding research enquiries for a specific problem (Guba & Lincoln, 2005b; Mackenzie & Knipe, 2006). It is an overarching philosophical or ideological stance, representing a *worldview* of the assumptive base from which researchers go about producing knowledge (H. Rubin & Rubin, 2005). In agreement with Babbie (2020) and Rubin and Babbie (2016), Kekeya (2019) refers to it as a complete system of thinking, school of thought, accepted theories, traditions, and frame of reference of a particular body of knowledge or discipline. A paradigm may therefore be referred to as an anthology of beliefs that guides the inquirer. Notwithstanding the above, Guba and Lincoln (2005a) view paradigms as human construction, arguing that they are all conceptions of human inquiry and therefore subject to misconceptions. None can consequently be said to be incontestably precise. According to Tuli (2010), the ontological and epistemological constructs relate to the researcher's *worldview,* which may be aligned to any paradigmatic perspective, and although both worldviews have considerable influence on research work, none is considered to be superior to the other.

In addition to a lack of consensus among proponents of different paradigms, demarcation and classification also pose significant challenges to researchers. For instance, while Fazlıoğullari (2012), Mackenzie (2006) and Scotland (2012) classify research paradigms into three categories, i.e. positivism, interpretivism and critical theory, Guba and Lincoln (1994) added

post-positivism to the list. Other classifications include post-positivism, interpretivism, participatory action and critical theory (Gringeri, Barusch, & Cambron, 2013), and positivism, interpretivism, transformative and pragmatism (Mackenzie & Knipe, 2006; Tashakkori & Teddlie, 2003). However, recently Saunders et al. (2019) suggested a five-model classification that includes positivism, critical realism, interpretivism (which includes constructivism), post-modernism and pragmatism. According to Holden and Lynch (2004), the choice of a research methodology should be aligned to the researcher's philosophical position. Yet, this position should be guided by the nature of the phenomenon, epistemological matters and previous work in the subject domain (Buchanan, 2007). This implies that the decision on a philosophical approach (and hence methodological choice) to an investigation should be guided by the nature and requirement of the research, rather than a desire to fixate fanatically on one particular philosophical ideology or creed. This decision should be stated as it influences the research methodology and results (Gringeri et al., 2013).

3.1.1 Review of Familiar Research Paradigms

Given the preceding discussion and the submissions by Guba and Lincoln (2005a), and Tuli (2010), the researcher agrees that each classification model is driven by the proponents' most informed perspective and worldview of knowledge. Four of the identified paradigms, considered to be popular, are hereby discussed.

Positivist Paradigm

This paradigm holds a worldview incubated in the scientific method of inquiry, with cause-and-effect relationships (causes which influence outcomes) that interpret observations in terms of facts and measurable parameters. The view prefers real experiments to subjective inquiries and aims to formulate laws, thereby creating a pathway for patterns, prediction and generalisation (Creswell, 2009; Fadhel, 2002). It is entrenched in the notion that a single reality exists and can be known by an objective observer, meaning objects exist independent of the knower (Cohen, Manion, & Morrison, 2007). In Pring's (2000) term, a *discoverable reality* exists independent of the researcher, i.e. the researcher and the researched are independent units. This assumption is a key ontological position of positivism. Since reality is context free (and value neutral), different researchers working on a given phenomenon in different locations and at different times will converge to the same results (Davies, 2018; Ryan, 2018), thus satisfying the conditions of validity (internal and external), and reliability. Because the philosophical stance uses scientific approaches to produce absolute and factual knowledge, it is generally referred to as scientific method or empirical science (Cohen et al., 2007; Rahi, 2017).

Cohen et al. (2007) define four underpinning assumptions to assist researchers using this paradigm to understand its meaning and expected outcome better. They are empiricism, determinism, parsimony, and generalisability. Briefly explained, *empiricism* requires the collection of verifiable empirical data used to test the researcher's hypothesis in conducting a scientific inquiry. *Determinism* refers mostly to cause-and-effect relationships, which may only be uncovered with an ability to make predictions and control the potential impacts of experimental factors. They described the *parsimony* assumption as the researcher's efforts to conduct the scientific inquiry and investigation in the most economically viable way possible. Finally, g*eneralisability* assumes that an investigation carried out within the positivist paradigm in one context should be achievable in other situations by inductive inferences, generally meaning that different researchers working on a given phenomenon in different locations and at different times converge to the same results. In summary, while the ontological position of the positivist is realism, its epistemology is one of objectivism.

The positivist standpoint is not without its critiques. Its insistence on methodological absoluteness, especially to explore social phenomena, has been termed naïve by many researchers since social systems and episodes are far too intricate and complicated to be scientifically investigated in their totality (Cohen et al., 2007; M. Hammersley, 2013; Purnamasari, 2016). According to critics (Marsh & Furlong, 2002; Marsh & Smith, 2001; Shah & Al-Bargi, 2013), another weakness of the positivist standpoint is its lack of empathy for the subjective and hermeneutic aspects of social systems. Given a positivist's failure to address human social phenomena effectively, the critics gave one condition under which social scientists may apply positivism, namely, to hybridise, i.e. *adopt positivism but with subjectivism.*

According to Fadhel (2002), some basic characteristics of research located within positivism include the following:

a. The theory is inevitable, and generalisation can be applied across multiple constructs.
b. Context is less important.
c. Quantification of parameters in any inquiry is possible.
d. Hypothesis testing and formulations are important.
e. Objectivity in inquiries is key.
f. Scientific method is applied.

Interpretivist Paradigm and Constructivist Ideology

Also tagged to the phenomenological approach is the interpretivist paradigm, which subscribes to constructivism and relativism, aiming to understand people (the subjective world of human experience) and how they perceive, define, interpret, rationalise and give meaning to their daily actions and activities (Babbie, 2020; Collis, 2003; Guba & Lincoln, 2005b; Neuman, 2011). *Relativism* implies that reality varies and differs from one individual to the other, meaning the construction of reality is tied to individuals. In contrast to the positivist, it believes that multiple socially constituted realities exist, and they can only be accessed by subjective observers, making the investigation value-driven, focusing on the interpretation of the phenomenon. Also, the frame of reference of both the researcher and the researched influences data collection and analysis (Neuman, 2011). Interpretivists therefore reject objectivism and *context freeness* as positioned by positivist proponents.

Constructivism is an epistemology, which holds a worldview that reality is socially constructed, meaning, understanding and knowledge of the world is constructed through experience (Fenwick, 2003; Matthews, 2002). From a research perspective, it holds the view that knowledge is socially constructed and the researcher's values cannot be detached from their experience (Avenier, 2010). The constructivist worldview is relevant to this research due to its *learning through building,* which makes it appealing to the exploration of problems that are not completely understood, also applicable to this study. Social systems are influenced by their members, and their construction derived from areas of concerns or requirements that the system must address within one or more design domains. Using a scientific approach to design, develop and evaluate artefacts systematically is well located within the constructivist standpoint (Gregg, Kulkarni, & Vinze, 2001; Nunamaker, Chen, & Purdin, 1990).

On the global scale, the epistemology of interpretivism is one of subjectivism, while the ontology is relativist, aiming to conduct inquiries from individuals' perspectives, bearing in mind their values, beliefs and socio-cultural contexts. The methodology is naturalist while it assumes a balanced axiology. Elicitation of individual constructs occurs through interaction between researcher and research participant, generating insights from actions and behaviours of the participants. Such insights might be gained through structured or unstructured interviews, open-ended observations, or focus group sessions. (Cohen et al., 2007; Creswell, 2009; Guba & Lincoln, 1994; Neuman, 2011). According to Schwandt (2005), the interpretation of reality should follow how people give meanings to their lives, while the said meaning can only be discovered via language and not through some quantitative means.

In summary, interpretivism (including constructivism) assumes socially constructed multiple realities, underpinned by observation and interpretation (Guba & Lincoln, 2005b), contextualises social action and phenomenon (Chowdhury, 2014; Ryan, 2018), extracts understanding of socio-cultural episodes through the perception of research participants, and not the researcher's (Cohen et al., 2007), and emphasises the nature of people's background and participation in both social and cultural endeavours (Goldkuhl, 2012). As posited by Neuman (2011) and Guba and Lincoln (2005b), the interpretivist paradigm is underpinned by three main principles, namely (1) social systems and phenomenon are constructed and given meaning by individuals in a subjective manner, (2) the researcher forms part of the inquiry, (3) the research progresses only by interests.

The interpretivists are also criticised on the ground that the subjective and contextual approaches of the paradigm make a generalisation to different environments and settings, and may affect the outcome of social inquiries (Shah & Al-Bargi, 2013). In addition to generalisation issues, validity and trustworthiness are under scrutiny as consensus among research participants is difficult to obtain, even though those are desired parameters in research.

According to Guba & Lincoln (2005b), some basic characteristics of research located within interpretivism include the following:

a. Unravelling social reality from an individual standpoint is not possible.
b. Realities are multiple, and they are socially constructed.
c. Knowledge and knowing requires context.
d. Individual needs to be understood, not universal laws.
e. Causes and effects are mutually interdependent.
f. Interaction inevitably exists between the researcher and the researched.

Critical Theory Paradigm

The critical theory philosophical perspective emerged from criticisms of positivism and interpretivism paradigms, opposing any forms of a belief system that constrain human freedom and social change (Fazlioğullari, 2012). Advocates of this paradigm believe that people cannot effect positive change in their socio-economic, socio-cultural conditions due to various oppressive social, cultural, and political forces. Therefore, they encourage self-conscious criticism to expose ignored beliefs, values and norms, and the problems and structures behind them (Cohen et al., 2007; Kivunja & Kuyini, 2017). Culturally derived, and politically driven, the critical paradigm is influenced by political ideology and believes that human action can alter reality. Also, knowledge cannot be value free. Some theoretical underpinnings of this perspective include *Marxism, queer theory and feminism* (Siegel, 2006).

Whereas positivism aims at prediction, pattern analysis and control, critical inquiry focuses on challenging the status quo, directing efforts to activities that may bring about socio-cultural and political change that would stop any forms of alienation and political domination, that is to, identify, challenge and address *power imbalances* causing systemic inequalities and economic exclusions (Guba & Lincoln, 2005a).

Ontologically, the position of the critical paradigm is that of historical realism. However, there is no single reality, instead, multiple realities exist, which may be addressed by interactions between the researcher and the researched. Although similar to the interpretivist paradigm in addressing socially constructed realities, it differs in that its primary focus is on exposing hegemony and injustice and addressing power imbalances and oppression in society (Fard, 2012; Siegel, 2006).

On epistemology, the paradigm is that of subjectivism, a culture sensitive philosophical standpoint. It subscribes to the fact that bias is present in social actions and while remaining as objective as possible, researchers must recognise the presence of bias in social inquiry (Fard, 2012; Guba & Lincoln, 1994).

The critical theory is not without its downside like the others. Critics believe that the change promised by this paradigm is not guaranteed, and when it exists, it may be insignificant. Also, since forefront proponents are males, feminists believe it excludes the voice of a marginalised group of social existence (Burbules & Berk, 1999).

In summary, the critical approach focuses mostly on historical and social contexts as a means of sense making of socio-cultural construct and phenomenon. While criticising the positivists of their objectivity and status quo narratives (Cohen et al., 2007), their main disagreement is with the interpretivist's centre on the subjectivity of interpretivism at the expense of the bigger picture. Interpretivists are too relativistic and feelings driven (Neuman, 2011).

Some basic characteristics of research located within critical theory include the following, according to (Guba & Lincoln, 1994):

a. Addressing power dynamics within the social context.
b. Recognition of cultural values.
c. Research is constructed, not discovered.
d. Focus on promoting equality, social justice and economic emancipation.
e. Historical realism.
f. Action and participatory research.

Pragmatic Paradigm

This paradigm emphasises what works best as opposed to engaging in a *war of paradigms* or contentious metaphysical concepts. Proponents of the pragmatic paradigm believe that a single paradigm perspective is inadequate to address social reality, and therefore suggest a worldview that blends multidimensions of ontology, epistemology, and axiology to unravel social phenomenon while urging balance between objectivity and subjectivity. Therefore, pragmatism is *intersubjective*, (objective and subjective within the same investigation), with non-singular reality. Although a single reality exists, in other paradigms such as positivism, it is subject to multiple interpretations (Tashakkori & Teddlie, 2003). Often linked to mixed-method research approaches, pragmatism supports plurality and rejects the notion of singular reality ontology, meaning the methodology is independent of epistemology. Rather than choosing between the positivist or interpretivist, researchers consider what works best under the given condition, meaning the choice of a worldview over another is driven by how well that choice fulfils the objectives of the inquiry. As a worldview, it lends itself as an approach for more practical, real world exploration and enquiries (Creswell, 2009, 2013), indicating a preference for empirical methods above an idealistic approach, yet establishing itself as methods-agnostic from a paradigmatic position. Therefore, the best method of inquiry for a pragmatist, is one that produces the optimal targeted outcome, be it single, multiple, or mixed-methods (Tashakkori & Teddlie, 2003).

Epistemologically, pragmatism is conceptualised as the *double-faced knowledge* – multiple knowledge constructs can be used to achieve research enquiries. However, many researchers believe that the ontological position of the pragmatist is unclear, tagging it *anti-ontological pragmatism* (Lohse, 2017; Pratt, 2016). An ontological position for the pragmatic scholar is needed to clearly guide on the conditions for switching between different ontological positions. A possible way to adopt multiple ontological positions is to locate the inquiry within the *reality cycle*. This standpoint has been detailed by Maarouf (2019).

On the downside, Shah and Al-Bargi (2013) view the blend of objective and subjective epistemology as problematic since no procedural framework for the paradigmatic blending was provided. On her part, Thompson (1997) insists that the practical, contextual, problem-focused nature would limit its ability to analyse structural social problems. Other concerns include the fact that pragmatism appears not to be committed to any particular methodology (Feilzer, 2010; Tashakkori & Teddlie, 2003) and assumes independence of method, making researchers not to show commitments toward any particular research method (Tashakkori & Teddlie, 2003).

Some basic characteristics of research located within pragmatism include (Creswell, 2013; Tashakkori & Teddlie, 2003):

a. Positivist's inquiry is insufficient to address real world reality.
b. Inquiry cannot be simply located within a single paradigmatic perspective.
c. Research approach is driven by the research objective.
d. Investigate and adopt the best form of methods for knowledge and knowing.
e. Apply a worldview or combination of *what works* for a specific inquiry.

3.1.2 Essential Elements and Philosophical Dimensions of a Research Paradigm

According to Kivunja and Kuyini (2017), there are four dimensions and assumptions to a paradigm, namely ontology, epistemology, methodology and axiology. Although, as in the case of paradigmatic classifications, some scholars, notably Saunders et al. (2019), identify only three (ontology, epistemology, and axiology) dimensions. This study adopts the four elements posited by Kivunja and Kuyini (2017) based on the researcher's perspective of the phenomenon under investigation.

Ontology

The ontology of a research paradigm refers to the study of *being* or the *reality* of social phenomenon (Fard, 2012; Fazlioğullari, 2012; Scotland, 2012). According to Saunders *et al.* (2019), researchers must take a position on how they perceive things and how things work, leading to such questions as to whether single or socially constructed multiple realities exist.

Epistemology

Epistemology is concerned with knowledge and knowing, i.e. how truth and reality are known (Guba & Lincoln, 2005b; Saunders et al., 2019), how the researcher uncovers knowledge, the attributes of that knowledge, and how it is communicated to the relevant body of knowledge. According to Cohen et al. (2007), this dimension leads a researcher to negotiate the merit and appropriateness of *objectivity, subjectivity, causality, validity,* and *generalisability*.

Methodology

Methodology is the official pathway or strategy for the researcher to uncover what s/he thinks may be known. Therefore, it is concerned with why, what, from where, when, *and how* data is collected and analysed (Guba & Lincoln, 1994). This validates the question of how a researcher may go about learning what s/he believes may be known.

Axiology

While ontology and epistemology deal with truth, axiology of a research paradigm is concerned with ethics (role of moral) and value (Fard, 2012; Kivunja & Kuyini, 2017). Basically, axiology demands congruence between ontological and epistemological assumptions. Its role is vital in ensuring that the tone and rigour of implementing an inquiry are guided.

To differentiate the paradigms, a comparative analysis based on Saunders et al. (2019), Creswell (2013), Neuman (2011), and Guba and Lincoln (2005b) is presented in Table 12.

Table 12: Comparative Analysis of Research Paradigms

Based on Saunders *et al. (2019)*, Creswell (2013), Neuman (2011), and Guba and Lincoln (2005b)

Elements	**Paradigm**			
	Positivism	**Interpretivism**	**Critical Theory**	**Pragmatism**
Ontology	Naïve realism Single reality	Relativism Multiple realities	Historical realism Multiple realities	Relational Non-singular reality
Epistemology	Objectivist	Subjectivist	Transactional/Subjectivist	Inter-subjectivist
Axiology	Value free	Value bond	Value laden (Culture sensitive)	Value driven (Inter-subjective)
Methodology (Most suited)	Experimental Quasi-experimental Correlational Causal comparative Randomised control trials	Naturalist Narrative inquiry Case study Grounded theory Phenomenology Hermeneutics Ethnography Phenomenography Action research Design Research Action Design Research Heuristic inquiry	Neo-Marxist Feminist Cultural studies Critical race theory Participatory emancipation Queer theory Disability theories Action research	**Mixed methodology**: Naturalist Narrative Case study Phenomenology Ethnography Action research Design Research Action Design Research Quasi-experimental methodology Causal comparative methodology
Design	Explanatory Survey Case study Longitudinal	Exploratory Ethnography Grounded theory Case study	Exploratory Ethnography Grounded theory Case study	Explanatory Exploratory Ethnography Grounded theory
Methods (Mostly used)	Quantitative Very structured questionnaire Tests Observations Document analysis Large samples Hypothesis testing Random sampling Statistical analysis	Qualitative Semi-structured interviews Document analysis Small samples	Qualitative or quantitative Interviews Participants' observation Questionnaires Triangulation of methods	Mixed methods

From Table 12, the choice of a research methodology and method is easily linked to the paradigmatic stance of the researcher. Based on the research inquiry and environment (see section 1.5) and a review of the philosophical dimension of each research paradigm (see sections 3.1.1 & 3.1.2), section 3.1.3 motivates for the chosen paradigm for this research.

3.1.3 Chosen Research Paradigm

The study conducts a diagnostic assessment of critical facets and aspects, such as construction and function, of ESD in South African municipalities in order to close performance gaps. The entire value chain represents a socio-cultural, socio-technical society of multiple realities which must be socially constructed and interpreted. Interactions are required between the researcher and research participants, including citizens and municipality electricity service providers, to understand the phenomenon from the participants' viewpoint. Yet, the researcher bears expertise within the value chain. While quantitative inquiry and analysis of the health of PSR are critical, deep insight is required from research participants into their perception of ESD within their respective environments. As shown in Figure 3 (section 1.2), the research boundary covers the entire ESD value chain, including humans, cultures, equipment, money, materials, socio-technical systems and processes. As the inquiry progresses through these facets, the ontological and epistemological perspectives are bound to change (from humans to machines to intangibles). While aspects of the research deal with standalone socio-technical systems typical of the positivist ontology, exploring the consumers' (citizens) concerns with multiple realities is typical of interpretivism. Therefore, it is clear that the main research question (section 1.6) cannot be investigated and answered solely by using a single method type. Both qualitative and quantitative methods and tools are used, including focus group discussions, semi-structured interviews (qualitative), statistical analysis and power equipment useful life analysis (quantitative).

Based on the aforementioned and a carefully conducted review of different research paradigms (see sections 3.1.1 & 3.1.2), the pragmatist approach (see section 3.1.1D) is deemed most suitable for this study. In addition to applying a paradigmatic standpoint suited to the inquiry, the approach offers philosophical toolsets necessary to address such real-world practical problems as defined in this study. In a nutshell, pragmatism is concerned with knowledge for action and change while considering real life impacts as critical components of both meaning, reality and truth. However, as outlined in section 3.1.1 and argued by Nunamker et al. (1990) and Gregg et al. (2001), aspects of this study (design, development & evaluation of an IT artefact) are suited to the constructivist paradigm. Yet, paradigm pluralism is allowed within the pragmatist paradigm.

Although, like the other paradigms, the pragmatic approach is not without its critics (Feilzer, 2010; Tashakkori & Teddlie, 2003; A. Thompson, 1997). Biesta (2010) and Denzin (2012) outline basic principles that may guide against being *over simplistic* and careless in the choice and application of the paradigm.

The rest of the chapter is structured as follows. In line with the paradigmatic choice of section 3.1.3, section 3.2 reviews compatible research methodologies considered for the study and selects the most appropriate, while section 3.3 validates both the paradigmatic and methodological choices. Sections 3.4 and 3.5 conclude the chapter with the research methods and ethical considerations for responsible research observed during the study.

3.2 Review of Relevant Methodologies

Since order would not evolve spontaneously, deliberate measures are required to ensure a state change, from the *current* to the *preferred*. These measures have been defined by many design-oriented disciplines as a design problem, thus offering several formal design approaches. March and Storey (2008) and Hevner et al. (2004) define design as a purposeful arrangement of the people, structures, processes, work tasks and all component parts of an enterprise to achieve a pre-specified goal. They agree that extensive design actions are needed to transform any strategic intent into reality. According to Hoogervorst (2018), design relates to understanding what change is required and how it will be achieved (operationalised). In his part, Simon (1996) illustrates design from an internal and external environment perspective, arguing that it is the interface between the environments to achieve desired goals.

Given the above understanding, the grand challenge may be classified as a design problem since a need exists to provide the much needed, currently lacking insights into poor electricity service delivery. Such insight would provide guidance into the redesign, and transformation efforts of the ESD. This necessitated the choice of DSR approach (validated in section 3.3), yet the approach has been subject to many interpretations with proposed process models for its implementation. To ease the process of choosing out of the various DSR process models, Venable et al. (2017) developed a comparison framework with a technology rule set. Their intention was to guide users of the DSR approach on how they may choose the most appropriate process model for their problem, nevertheless urging users to consider the specific attributes of their design problem while making use of their comparison framework. Figure 11 is a summary of the DSR process models and their respective authors.

Figure 11: Design Science Research Methodologies

(Based on Venable et al. (2017))

Each of the models is briefly reviewed in the subsequent sections.

3.2.1 Systems Development Research Methodology

Generally, there are 5 phases in Systems Development Research Methodology (SDRM), namely concept design, systems architecture development, prototyping, solutions development, and technology transfer. Although this systems development cycle mirrors development processes in other disciplines and can be used as a research methodology, Nunamaker *et al.* (1990) proposed that a blend of multiple (multimethodological) approaches be preferred as no single methodology can be regarded as one size fits all. They described the 5 *principle parts* of the SDRM as constructing a conceptual framework, developing a system architecture, analysing

and designing the system, building the prototype system, observing and evaluating the system. The argument for adopting the systems development concept hinges on its pivotal role within the confines of complex software engineering research.

3.2.2 Design Science Research Process Model

Citing a need for ICT researchers to have a rigorous understanding of the paradigms relevant to their field since ICT is a *multi-paradigmatic* discipline, Vaishnavi and Kuechler (2008; 2015) proposed the Design Science Research Process Model (DSRPM), stating five iterative steps as *problem awareness, suggestion, development, evaluation, and conclusion.* The logical sequence proposed by the authors bears a resemblance to the SDRM of Nunamaker et al. (1990) in that users of the method can use any problem identified during the process to improve their projects by cycling back to the relevant step/s in the process.

3.2.3 Design Science Research Methodology

Peffers et al. (2008) argue that the information system (IS) discipline requires rigorously applicable research solutions to keep its relevance among other disciplines. Although design science has found its way into the IS research environment, they reason that its adoption has been unconvincing. Therefore, they proposed the Design Science Research Methodology (DSRM), which is a six-step iterative framework to address design problems in IS research: *problem identification and motivation, objectives definition, design and development, demonstration, evaluation, and communication*. According to Cross (2001), this specific approach has been long applied in many disciplines such as engineering, architecture and other traditional technical fields. It entails a creative evolution of innovative methods, models or techniques (artefacts) for dealing with real life challenges and contributing to the knowledge base of such problem areas.

3.2.4 Action Design Research

The Action Design Research (ADR) combines Action Research (AR) with DSR. According to Sein et al. (2011), AR combines the development of theory with the direct involvement and intervention of the researcher to address organisational issues, while DSR aims to build and evaluate innovative artefacts to solve specific types of problems. The knowledge gained through this iterative process may be referred to as design principles (Hevner et al., 2004). This implies that while the AR aims to contribute to both theory and practice simultaneously, DSR focuses on developing prescriptive design knowledge by building and developing artefacts targeted at solving a specific class of problems. Also of note is the fact that while the AR has a specific client working in collaboration with the researcher, the DSR methodology neither

assumes a client nor recognises any specific collaboration between the researcher and the client (J. R. Venable et al., 2017).

While some authors argue against combining both methodologies, many others are proponents to the combination. For example, Cole et al. (2005) believe that AR or DSR as individual methods are not sufficient to solve IS related real world organisational problems. Concurring that both approaches are similar, they suggest that a combination of both is required to meticulously evolve artefacts required to solve organisational complex issues. On the other hand, Iivari and Venable (2009) posit that there are no merits in combining both approaches, as they are *decisively* dissimilar with few *superficial* similarities. On *marrying* both approaches, Cole *et al.* (2005) and Sein et al. (2011) believe they can be combined. Lee (2007) suggests both approaches are similar without taking a methodological position, while Iivari and Venable (2009) insist they should be kept apart, citing differences in paradigmatic assumptions of both approaches. They allow a combined use of both approaches under the condition that DSR adopts paradigmatic beliefs that are compatible with those of AR. Four stages to follow for an ADR are proposed by Sein et al. (2011) as follows: (1) problem formulation, (2) building intervention and evaluation, (3) reflection and, (4) learning and formalisation of outcome.

3.2.5 Soft Design Science Research Methodology

The Soft Design Science Research Methodology (SDSRM) (soft DSR) is an approach that merges the conventional DSR with a soft systems approach and evaluative feedback cycles. According to Baskerville et al. (2009), the DSR process takes repeated iterations until a specific design goal is achieved. They believe this softer approach to DSR encourages creativity and continuous improvements to areas of concern during the feedback cycles. Seven activities are identified by Baskerville et al. (2009) for the SDSRM, namely: (1) problem identification, (2) problem expression as a requirement set, (3) problem translation into general requirements, using socio-technical dimensions, (4) solutions design, (5) comparative analysis of the general design requirements for fit, for the specific problem, (6) solutions search and (7) deployment. At the end of step 7, it is intended that some learnings would have been derived, and the cycle is then repeated until all pre-identified socio-technical problems are solved.

3.2.6 Participatory Action Design Research

Given the cross-disciplinary orientation of research in Urban Informatics, Bilandzic and Venable (2011) identified a few methodological challenges which necessitated their proposal of the Participatory Action Design Research (PADR), a combination of the AR and DSR. Arguing that the SDRSM of Baskerville et al. (2009) and the ADR as proposed by Sein et al. (2011) are inadequate to deal with the peculiar nature of Urban Informatics research, they

outlined five stages for their proposed PADR: (1) problem formulation, (2) action planning, (3) action taking, (4) impact evaluation, and (5) learning. The approach provides for consensus among stakeholders to cycle back to any relevant point in the process should the original design problems not be solved or if new problems arose during the initial implementation.

Given the above propositions by different authors, Venable et al. (2017) then proposed a comparison framework based on the Information Systems Development Methodology Comparison Framework of Avison and Fitzgerald (2006) and a technological rules set to assist design science researchers in choosing a DSR methodology. Venable et al.'s (2017) adapted comparison framework has seven criteria (and some sub-criteria) namely philosophy, model techniques, scope, outputs, practice, and participants.

Based on this adapted comparison framework by Venable et al. (2017), the most suitable DSR process model for this research are the SDRM and DSRPM. The only criterion of contention between the SDRM and DSRPM is the primary paradigm (positivism vs interpretivism), which Venable et al. (2017) attest to as controversial, yet allowing users of the adapted framework (with opposing philosophical beliefs) the freedom to follow their philosophical inclination based on the attributes and dimensions of their class of problem. The technological rule set is not a defining parameter for this research as the rules, apart from the paradigm contention addressed above are almost indistinguishable for all the process models.

In line with the above discussion, the comparison framework (Venable et al.'s) to the choice of DSR methodology, the chosen philosophical stance (see section 3.1.3) and other South African municipalities' considerations (see section 1.1), the DSR methodology (DSRM) as proposed by Peffers et al. (2008) is followed in this study. Additional reasons are outlined below, while section 3.3 validates the standpoint.

a. It is the most aligned to the philosophical stance taken for the research. The stages, as outlined in section 3.2.3 (1. Problem identification 2. Objective/s definition 3. Design and development 4. Demonstration 5. Evaluation 6. Communication) require the application of techniques and perspectives that complement both positivism and interpretivism while placing axiological emphasis on *utility*.
b. The stages outlined above involve rigorous processes to design artefacts, including constructs, models or instantiations.
c. The model allows iterative cycling to previous stages, especially from stage 5 (evaluation) or 6 (communication), back to stage 2 (objective definition).

d. Although the rigorous iteration of the process leads to the creation of innovative artefacts, the prescriptive design knowledge gained can be used to create additional instances of the artefacts for the same class of problems.

3.3 Preferred Methodology and Philosophical Stance for this Study

There have been requests & responses for a consensus to base the DSR upon a paradigmatic foundation (Carlsson, 2010; Livari, 2007; Niehaves, 2007). While Carlsson (2010) views it as appropriate within critical realism, Niehaves (2007) gives the motivation to locate it within the interpretivist worldview. However, Hevner et al. (2004) reject both positions arguing that DSR is best located within the pragmatic paradigm. The focus of pragmatism on relevance to address real world problems make the DSR pragmatic. Many scholars (Hovorka, 2010; A. S. Lee & Nickerson, 2010; J. R. Venable et al., 2017) have towed the line of Hevner et al. in accepting that DSR is best grounded within pragmatism. According to them, the paradigmatic stance of a DSR researcher changes as the inquiry moves from one stage to another within the iterative design process. Initially, a DSR researcher is viewed as creating reality through constructivism (researcher's intervention) and becomes a positivist while observing the performance of the intervention in a bid to evaluate (see if it behaves as intended) based on a theoretical prediction of the intervention. Some of the traits of the DSR that can be located within the epistemological foundation of pragmatism include:

a. Addressing utility and usefulness;
b. Contribution to research and practise;
c. Unlike in the more traditional research scenario, problematic situations drive inquiry and design; and
d. In addition to descriptive contributions, it develops *prospective, normative and prescriptive* knowledge.

The discussion above validates the research paradigmatic (pragmatism) and methodological (DSR) standpoints as posited in sections 3.1 and 3.2.

Design science research has been long applied in many disciplines such as engineering, architecture, information systems, healthcare, and other traditional technical fields (Cross, 2001; V. Vaishnavi & Kuechler, 2015; J. R. Venable et al., 2017). According to Peffers et al. (2008), Gill and Hevner (2011), and Gacenga et al. (2012), the mission of DSR is to develop and evaluate artefacts that are useful and sustainable in solving identified enterprise problems. It is a conscientious process of designing artefacts that address real-life, practical problems. Many authors have proposed several models for conducting DSR, some of which have been reviewed in section 3.2 (R. Baskerville et al., 2009; Bilandzic, 2011; Nunamaker et al., 1990;

Peffers et al., 2008; Sein et al., 2011; V. Vaishnavi & Kuechler, 2015), while others include Hevner et al (2004), Takeda et al. (1990), Ahmed and Sundaram (2011), Alturki and Gable (2014). Although the nomenclature for operationalising their models and processes have some differences, they are mostly from the IS discipline and emphasise rigour.

One critical step across all the propositions is evaluation. To validate the resulting artefact, all the authors agree on some forms of evaluative process or procedures. However, for the evaluation of artifacts to be rigorous and consistent, Venable et al (2016) proposed the FEDS (Framework for Evaluation in Design Science Research), Tremblay et al (2010) the use of focus groups (Exploratory and Confirmatory Focus Groups), while Hevner et al. (2004) proposed five different methods (*observational, analytical, experimental, testing and descriptive*), depending on the applicable business context. The criteria for evaluation were explained by Stufflebeam (2003) as:

a. Reasons for evaluation (WHY): What is the purposive reason and motive behind evaluation?
b. Timing of evaluation (WHEN): At what logical points should evaluation be conducted?
c. Methods of evaluation (HOW): What are the procedures for the evaluation?
d. Points of interest (WHAT): What is the focus of the evaluation?

Evaluation in DSR is not without its challenges as it is prone to different types of errors and risks that are common in day-to-day life.

Baskerville et al. (2008) identified many risks, risk drivers and risk events that require systematic management in DSR. Some of the risks identified are:

a. Selecting or solving the wrong problem.
b. Lack of understanding of the problem domain.
c. Poor problem formulation.
d. Shortage of information about the problem domain.
e. Varying stakeholders' interests.
f. Expectation misalignment.

Peffers et al. (2008) suggested a DSRM model consisting of six phases, as illustrated in Figure 12.

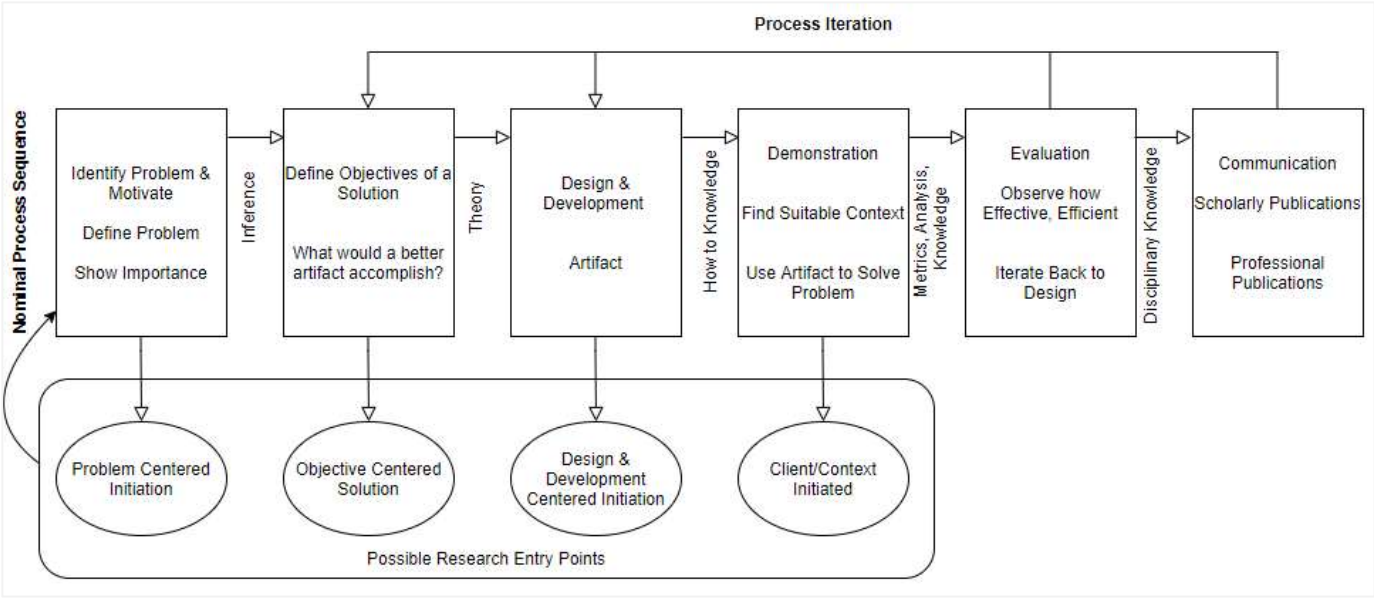


Figure 12: DSRM Process Model

(Peffers et al., 2008)

This study is based on Peffers et al. (2008)'s model , as outlined in Figure 12. Each phase is briefly described below:

a. Problem identification and motivation. This requires defining the specific research challenge while justifying the value of a solution. This problem may be derived from many sources including an organisational setting, new developments in a reference discipline or body of knowledge. It is pertinent to justify the value of a solution as this serves as a motivation for the inquiry while keeping the interest of stakeholders alive.
b. Define the objectives of a solution. Based on the problem definition and motivation, inferences are drawn based on an awareness of the problem domain of prospective solution/s, which may either be qualitative or quantitative. An overview of how the developed artefact would guide the solution to the problem class is also highlighted.
c. Design and Development. Depending on the artefact to be created, this phase refers to the preliminary implementation of the solution, which could be a model, design theory, concepts, construct, architecture, or framework. The specific tool sets and techniques for this implementation phase will depend on the artefact to be developed. Innovation or novelty is built within the design, not necessarily in the construction of the artefact.
d. Demonstration. This involves the practical use of the solution to test certain instances of the problem identified and defined in phase 1 (problem identification). Assuming adequate knowledge of the problem domain and workings of the artefact, the

demonstration may involve a proof-of-concept (PoC) session, experimentation or case study.

e. Evaluation. This phase is key in validating the developed artefact. Observation and measurements (qualitative or quantitative) are carried out to record how well the artefact address the pre-defined problem. During this phase, it is important to define the specific reason for evaluation (WHY), carefully choose the logical point at which to trigger the evaluation process (WHEN), agree on the necessary process for evaluation HOW), and define the boundary and focus of evaluation (WHAT).

Table 13 provides a summary of each phase, its application and reference to chapters of this thesis.

Table 13: Application of Peffers et al. method to this study

(Peffers et al., 2008)

Phase	Application for this study	Chapters
1. Identify the problem and motivate	Localised disruptions to electricity supply have become commonplace in South Africa. They are setting the country on a pathway to national emergency, weakening investors' confidence and stagnating the country's already problematic economic growth prospects.	Ch 1
2. Define objectives of a solution	An ESD-PRT is needed for the holistic performance reporting of electricity service delivery to guide redesign efforts in addressing performance gaps in South African municipalities.	Ch1 and 2
3. Design and development	Design factors and Software Requirement Specification (SRS) for the construction of the ESD-PRT are implemented.	Ch 4 and 5 Appendix 5
4. Demonstration	The artefact is demonstrated at the three Demonstration Case Municipalities (DCMs).	Ch 6
5. Evaluation	The artefact is evaluated at the three DCMs.	Ch 7
6. Communication	Aspects of the design process have been published in academic journals (Ajayi & De Vries, 2019) and academic conference proceedings (Ajayi & De Vries, 2018, 2020). The DCMs will be trained on the artefact which will be deployed to their IT network post evaluation.	Page ix

3.4 Data Sources and Collection Methods

This section outlines the data management approach that was followed in this research. According to Collis and Hussey (2003), such an approach has to include the data sources and data types, motivating their inclusion, and to elaborate on the data collection and analysis methods.

Different groups of participants were involved as data sources via other data collection methods during different phases of the study, as summarised in Table 14.

Table 14: Data Collection, Sources and Methods

Phase	Data source ID	Data Collection Methods
2. Define objectives of a solution		
Criteria validation for solutions (see section 4.2)	FGP (Focus Group Participants)	Focus group discussion. Questionnaires.
Requirements for ESD-PRT (see section 4.3)	DMC 1, DMC 2, DMC 3, Consumers, MDB (Municipal Databases)	Interviews. Workshop. Observations.
5. Evaluation		
User Acceptance Testing (UAT) Functional Non-functional	DCM 1, DCM 2, DCM 3, Consumers	Interviews. A questionnaire with test cases. SUMI (Software Usability Measurement Inventory) survey.

Each of the data sources and motivation for their inclusion are elaborated below.

3.4.1 Data Sources

Focus Group Participants

During the *design and development* phase, two sub-phases of data collection were used. First, a top-down approach was used to validate high-level requirements that were extracted from the literature. A group of purposively recruited participants validated the high-level requirements during a focus group discussion (FGD). A wide range of public participants, including representatives from the national and local governments of the Republic of South Africa were involved in focus group discussions, to ensure contextualisation and validation of requisite criteria for diagnostic service performance assessment tools. Their profile ranges from subject matter experts (SMEs), decision-makers in private and public entities, non-governmental organisations to the municipalities being the bedrock of electricity service delivery. They include:

a. Municipal government (City of Tshwane Municipality, South Africa). Municipalities (section 1.2) are constitutionally designated to distribute electricity; hence their representation is crucial.
b. SALGA is the umbrella body for all the municipalities in the country. They bring a broader, yet deep perspective to the discussion.
c. The Department of Public Service and Administration (DPSA) is the government organ constitutionally responsible for the organisation and administration of the public service. They bring a strategic perspective to the discussion.

d. The Presidency is the ultimate authority in South Africa. Budget owner of fiscal transfers to the municipalities for service delivery and policy decision maker (and enforcer).
e. United States Agency for International Development (USAID) brings an International, independent, global benchmarking perspective.
f. Non-Governmental Organisations (NGOs) are independent, non-partisan participants. They are involved in the Monitoring and Evaluation (M&E) of government service delivery programs. Representatives bring performance monitoring of public programs perspective to the group.
g. Academia (University of Pretoria) as the independent observers, moderators and recorders of events.
h. The general public and consumer representation. Also, a practising Industrial Engineer in the area of performance measurement, targeting and reporting.

Characterised by a series of meetings, participants' in-depth involvement, purpose-driven discussions and focused topic reviews/analysis, focus groups help generate ideas on research problems and phenomenon being studied. According to Brandtner et al. (2014), the processes for conducting focus groups include:

a. Definition of a clear study purpose and research objective
b. Purposeful recruitment of participants
c. Facilitation:
    i. Preparation/Logistics
    ii. Pre-session
    iii. Session
d. Analysis
e. Reporting

Demonstration Case Municipalities (DCM 1, DCM 2, DCM 3)

The research involved participants willing to participate in the study and were recruited from three local municipalities used as pilot cases. The main research participants were thus drawn from the municipalities tagged DCM 1, DCM 2, and DCM 3.

For municipality participants, the stratified random sampling technique was used for their recruitment. This sampling method entails dividing target participants into various sub-groups/strata that share common attributes. According to Acharya et al. (2013), the sampling method minimises variability since the attributes of each stratum is well known. The target

population was divided into two broad strata, namely municipal employees and residents (non-municipal) employees, which was further subdivided into two other sub-strata each, i.e. municipal employees (senior and management staff) and residents (residential and commercial users). The stratified structure is shown in Figure 13.

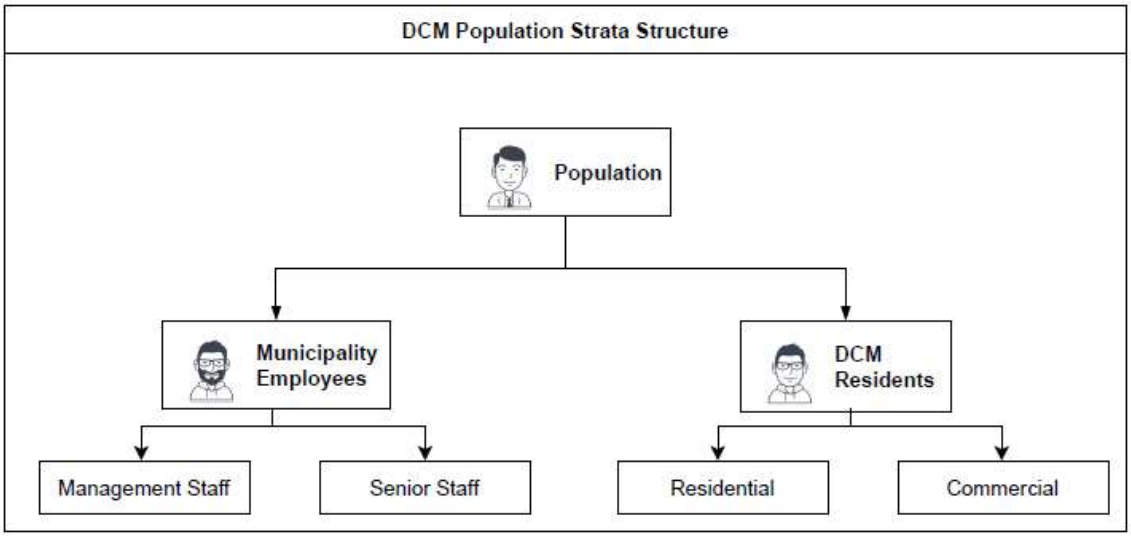


Figure 13: Stratification of Participants

The stratification was necessary to avoid bias as municipal employees may show sympathy or loyalty to the municipality, which may affect their responses to the research questions, even though efforts were made to mitigate this risk by assuring them of confidentiality and anonymity. The notion of taking a stratified random sample to minimise the prospect of human bias is supported by Sharma (2017) and Koyuncu and Kadilar (2010), citing additional benefits as generalisation and external validity. The rationale for each stratum is outlined below:

a. Municipal management staff. This category of people has access to strategic information like budgets, and national government plans, on electricity service delivery which senior staff members may not have access. Also, financial and municipal performance reporting fall within the portfolio of this group.
b. Municipal senior staff. These are the people on the ground. They have hands-on experience with electricity service delivery which management staff members generally don't have access to since this type of work is not part of their job profile. Although the stratum is aimed at providing comprehensive insight into their practical work, and the interface that they have with the general public (e.g. for repair, new connections, or re-connections), an additional intent is to use its consolidated responses to guide verification and validation of management's responses.

c. Residential customers. This is the majority by count for each DCM, although not the majority by the amount of power (kW) or energy (kWh) consumed. As the most populous end-users, and voting citizens of the Republic, their input provide an independent assessment of municipal electricity service delivery performance.
d. Commercial customers. This group is the highest paying stratum. Purposively targeted to provide insight on "value for money" and other service performance metrics, commercial customers' assessment of ESD is critical as many local municipalities depend on them for sustenance (see Figure 4, section 1.3).

Municipality Databases

Municipality databases (MDB) that include financial statements, electrical asset register and technical reports, were obtained. As the DCMs are public entities, the information is generally available in the public domain, yet ethical clearance was obtained to cover interactions with human participants at the DCMs. Some of the data extracted include:

a. *Financial performance data.* This data set is necessary to assess the quantity of electricity procured from the national grid (Eskom) versus revenue generated from the sale and distribution of electricity.
b. *Electrical asset register.* This shows not only the asset inventory but their respective age and condition. Combined with the financial data, this information was helpful in estimating impairment, remaining useful life of electrical assets and condition criticality. Some of the assets include medium voltage substations (mini-substations, transformer substations, switching substations), medium voltage (MV) network (MV lines and MV switching equipment), low voltage (LV) network (LV lines and LV switching equipment), service connections (overhead and underground) and electricity meters (conventional and prepaid).
c. *Technical reports.* Maintenance information, distribution losses (technical and non-technical) are derived from this information set (see Table 1). In general, the understanding of losses, i.e. regardless of their origin, is that they represent the difference between all the energy purchased from Eskom and the energy billed by the DCMs. Losses are categorised as shown in Figure 14.

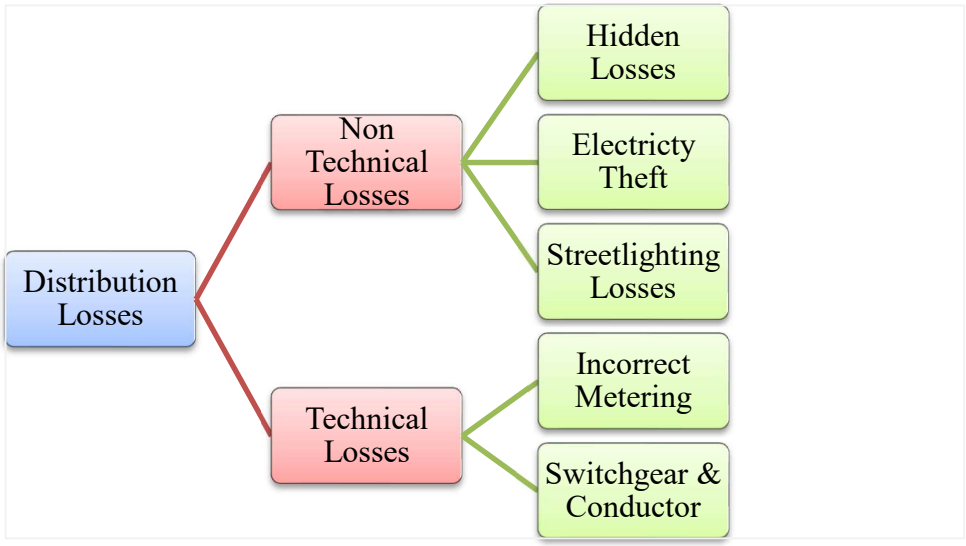


Figure 14: Sources of electricity distribution losses

While there are technical means to read, or estimate these losses, "hidden losses" cannot be directed measured, as they are hidden. This category of distribution loss therefore refers to the difference of deducting all the known distribution losses (technical and non-technical) from the overall distribution losses.

3.4.2 Data Collection Methods and Analysis Methods

The primary data acquisition instruments include semi-structured and structured interviews, questionnaires, focus group discussions and observations. This section introduces each of the techniques and the guidelines (from literature) that guided this study.

Focus Group Discussion

Tremblay *et al.* (2010) argued that the FGD technique is very useful for both exploratory and confirmatory studies, and they suggested the following motivational reason for adopting the FGD:

a. *Flexibility*. The approach is innovative in that a wide range of design issues and problems can be reviewed and debated among participants in an open forum.
b. *Secondary Ideas Generation*. Unlike traditional questionnaires, participants can build on each other's ideas to generate new ideas for the research problem. In addition to increased opportunity for multiple ideas, conflict of opinions would indicate an area for the researcher to further investigate for improvement.
c. *High Data Volume*. Since participants are present simultaneously, large amounts of data are likely to be generated, which gives the researcher an opportunity to get a deeper understanding on how the business environment may view, use, or react to the artefact.

d. *Clarifications.* Because participants are present in the FGD, the researcher can probe and clarify issues during the sessions. This is unlikely with questionnaires that are distributed remotely.

The steps are outlined in Figure 15 below:

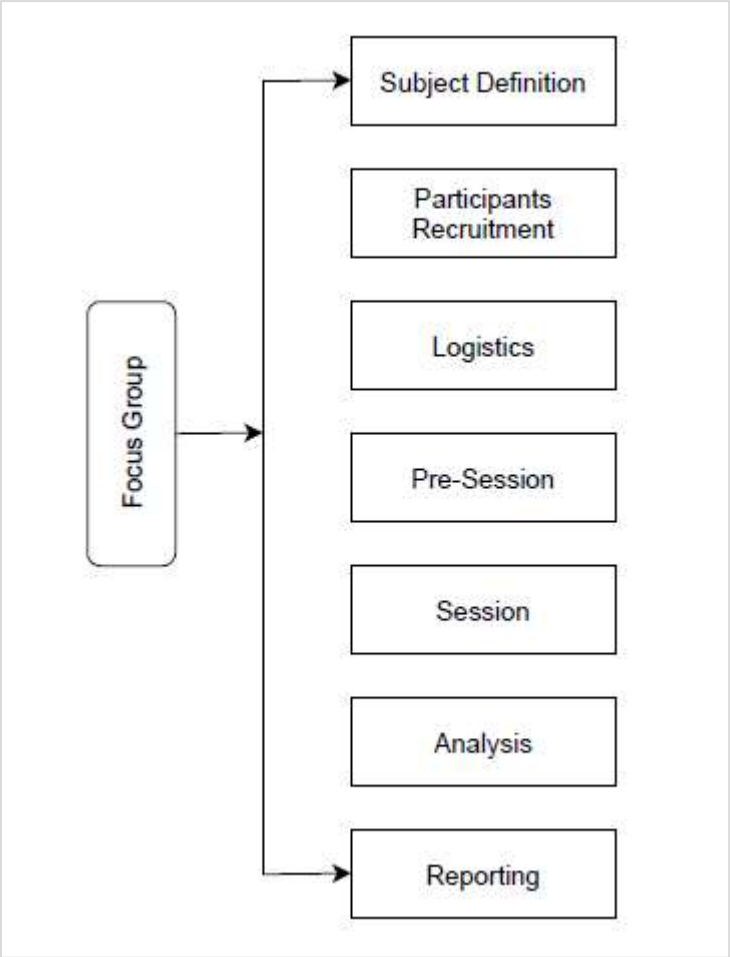


Figure 15: Steps to apply Focus Group

(Brandtner, 2014)

This study used an FGD during phase 2 of the DSR design cycle. As indicated in section 4.2, the focus group consisted of 9 participants, as outlined in section 3.4.1. All the FGD questions that were used during different phases of the project are appended in Appendix 3.

Interviews

Interviews are data acquisition techniques designed to collect rich information from a small number of people about opinions, perceptions, behaviours, events, feelings, or experience. They are typically open ended, enabling the collection of in-depth information (Gill, Stewart, Treasure, & Chadwick, 2008; Knox, 2009; Rosenthal, 2016), and maybe structured (Flick,

1998), semi-structured (Gubrium, 2001), unstructured (Gubrium, 2001; Stuckey, 2013) or via a FGD (Dilshad, 2013; Krueger, 2000). During the latter part of the research, participants were interviewed via telephone and other online platforms, such as Skype or Zoom, as face to face interviews were not practicable due to the COVID-19 pandemic lockdown rules.

This study used interviews during Phase 2 (Define objectives of a solution) of the DSR design cycle and during Phase 5 (Evaluation). During Phase 2, data was collected from the three DCMs as indicated in Figure 13 through the *requirements elicitation process,* as outlined in section 2.4.4. In addition to the ethical clearance from the University of Pretoria for DCMs participants, letters of approval were obtained from each DCM management. Informed consent forms were completed by each non-municipality participant and kept on file. During Phase 5, the same set of participants of Phase 2 were involved with evaluation. All the interview questions that were used during different phases of the project are included in Appendix 1 (consumers) and Appendix 2 (providers). The number of participants is as follows:

Table 15: Participants by Stratum

	DCM 1	**DCM 2**	**DCM 3**
Municipality employees: • Management • Senior staff Response rate Municipality residents: • Commercial • Residential Response rate	**4** (of 4) 2 2 100% **15** (of 22) 5 10 68%	**4** (of 4) 2 2 100% **22** (of 25) 7 15 88%	**3** (of 3) 1 2 100% **18** (of 20) 4 14 90%
Total Participants	19	26	21
Grand Total	**66**		

The low response/return rate from DCM 1 was largely due to the COVID-19 pandemic since that specific DCM was implemented during the *hard lockdowns*, limiting access to strictly remote and virtual engagements. Although the pandemic was still prevalent during DCMs 2 and 3 engagements, the lockdowns have been eased, allowing reasonable access, with observed health and safety guidelines. Non-responses would not have been an issue provided one can be sure that non-respondents are the same in attributes to respondents on all the performance variables scored and investigated, as they would have responded similarly had they participated. When response rates are high, the potential for variances between respondents and non-respondents is lower, thereby increasing the likelihood that the results can be generalised to the population sampled and also reducing the chances of response bias (Johnson & Wislar, 2012).

Welman et al. (2009) gave guidance on maximising response rates by research participants. For this study, the following steps were taken to improve response rates:

a. The questionnaires were short and attractive.
b. The time to complete a questionnaire was between 10 and 15 minutes, while an interview was a maximum of 20 minutes (the municipalities allowed 30 minutes sessions with their employees during workdays).
c. Prior appointments, based on participant's convenience were scheduled.
d. Follow up phone calls and e-mail reminders were made ahead of scheduled sessions.
e. Option for contact or virtual meetings for interviews was made available.
f. Minimal cost and efforts to municipality and private participants.

Questionnaires

While interviews (face to face or remote) have the benefits of customisation and in-depth queries, questionnaires (also called surveys) are more rigid, even though they reach more participants (Rowley, 2014). Depending on the nature of the phenomenon being investigated, questionnaires may be used in conjunction with interviews, especially where the target participants are large in number (Kendall, 2008; E. R. Lai & Waltman, 2008). According to Wilkinson and Birmingham (2003), the design of a questionnaire has considerable influence on the response rate, including the reliability and validity of the data collected. In line with the advice from Wilkinson and Birmingham, the following steps were taken in the design of the questionnaires:

a. Clear layout design of the questionnaire forms.
b. The design ensured anonymity as no traceable personal details were requested.
c. Relevant authorisation letters were attached to the questionnaires.
d. During the informed consent request, a brief summary of the research was given to participants giving them peace of mind about the research objectives. Also, their rights to opt-out at any point should they not wish to continue was highlighted.
e. Pilot testing was conducted. The purpose of this pilot testing was to:
    i. Ensure the questionnaire was fit for purpose.
    ii. Identify and clear any errors.
    iii. Ascertain whether participants can easily understand the entire concept introduced in the questionnaire.
    iv. Determine the ease of completion.
    v. Understand how long it will take to complete the questionnaire.

Some of the principles (Delport & Roestenburg, 2011) that guide the final questionnaire construction include:

a. *The principle of economy.* This is to ensure that participants provide as much information as possible within the shortest possible time.
b. *Concise appearance.* Attention was given to ensure the layout and structure were clear and without ambiguity.
c. *Precise questions.* The questions were formulated to be clear and precise.
d. *Alignment.* The questions were formulated to be aligned to the research purpose, agenda and strategy.

Each section of the questionnaire was designed to achieve a specific purpose. The sections are briefly introduced below:

QUESTIONNAIRE 1: Consumer (Appendix 1)

a. *Section A: Introduction.* A brief overview of the research is presented in this section without going into any technical details that may confuse the participants, i.e. only including what is needed for them to understand and respond to the questions.
b. *Section B: Electricity Service Delivery Performance Assessment.* This section aims to get citizens' performance ratings on availability, quality, cost, and value for money of electricity supply. Also, it elicits perception on the most problematic areas of basic service delivery: electricity, water, sanitation and waste removal.
c. *Section C: Customers Experience.* It is intended to understand customers experience with many areas of ESD in this section.
d. *Section D: Interview Guide.* Provides guide to the interview and requirement elicitation sessions for the ESD-PRT.

QUESTIONNAIRE 2: Provider (Appendix 2)

a. *Section A: Introduction.* A brief overview of the research is presented in this section without going into any technical details that may confuse the participants, i.e. only including what is needed for them to understand and respond to the questions.
b. *Section B: Electricity Service Delivery Performance Assessment.* This section aims at getting performance ratings from the providers on challenges to availability, quality,

ease of connection and of electrical fault resolutions. It also deals with the perceived health of the PSR.

c. *Section C: Interview Guide.* Provides guide to the interview and requirement elicitation sessions for the ESD-PRT.

QUESTIONNAIRE 3: Focus Group Presentation & Service Rating (Appendix 3)

a. *Section A: Introduction.* A brief overview of the research is presented in this section without going into any technical details that may confuse the participants, i.e. including only what is needed for them to understand and respond to the questions.
b. *Section B: Service Ratings.* This section aims at getting performance ratings from the focus group participants on availability, quality, cost, and value for money of electricity supply. Also, it elicits perception on the most problematic areas of basic service delivery, i.e. electricity, water, sanitation and waste removal.

QUESTIONNAIRE 4: Evaluation Guide (Appendix 4)

a. *Section A: Introduction.* A brief overview of the research is presented in this section without going into any technical details that may confuse the participants, i.e. only including what is needed for them to understand and respond to the questions.
b. *Section B: Functionality Testing.* This section allows users to evaluate and test the functionality of the ESD-PRT.
c. *Section C: User Experience Testing.* This section allows users to evaluate and record their experience of the ESD-PRT based on SUMI (1990).

All the questionnaires and interview guides that were used for this research are attached as Appendices 1 to 4.

Since the questions were well-structured, the results could be analysed quantitatively, i.e. most of the questions required fixed responses or responses according to a Likert scale, which facilitated quantitative consolidation of the results.

Observations

For many years, many disciplines have used observation as an instrument of data collection about systems, processes, people, or phenomena. Recently, however, both observation and data collection methods such as interview, and document analysis have been classified as

ethnographic methods/participatory studies (Fine, 2003). As indirect interviews, observation may be structured or unstructured and bears the advantage of giving the researcher direct access to the subject matter. Notwithstanding this benefit, observation has its drawbacks in that longer time is required, and researcher's bias is often of concern (Emerson, Fretz, & Shaw, 2001; M. Hammersley, & Atkinson, P, 2007). Observation in this research context is relatively easy as the researcher observed mainly the health of PSR as a means to validate the parameters recorded in DCMs PSR asset registers. Due to other non-research related activities, which the researcher had to conduct at the DCMs, officials were familiar and at ease with the researcher, making unstructured observation of DCM maintenance practices pain free. Relevant ethical clearances were obtained for the DCMs. Examples of some of the PSRs observed are shown in Figures 16 to 18.

Figure 16: Some PSRs - DCM 1

Figure 17: Some PSRs - DCM 2

Figure 18: Some PSR - DCM 3

3.5 Limitations, Quality and Reliability

The quality of a study is a primary concern of every researcher. This is very important, especially if the artefact is to be deployed and used in practice. While outlining limitations associated with the research, this section describes tactics adopted to ensure the credibility and quality (validity and reliability) of the research. According to Yin (2018), four quality tests are common, especially for qualitative studies, namely *construct validity, internal validity, external validity, and reliability*. Applications to this research are illustrated in section 3.5.2, Table 16 and section 3.5.4.

3.5.1 Limitations

Some of the limitations to this research are outlined below:

a. The inquiry covers three local municipalities, but it is believed that the methods and artefacts are extensible and can be generalised to the larger (metropolitan) municipalities since municipal structures and the laws that set them up are the same.
b. A total of 66 respondents participated in the research. Although the response rates were good, the number of participants would have been more if not for the Covid-19 pandemic.
c. Although the artefact is rigorously evaluated as provided for within the DSR model applied for the study, the long-term impact of the artefact is untested.

3.5.2 Validity

Validity the extent to which an empirical parameter reflects what it was intended to measure. That is the accuracy with which the finding reflects the data. In a sense, it concerns the

acceptability (and appropriateness) of the research and aims to ascertain whether the study evaluates what it is intended to assess, and how well it does it (Ghauri & Gronhaug, 2005). In socially constructed inquiry, it is viewed as the foundation for trustworthiness, utility and dependability (Boesch, Schwaninger, Weber, & Scholz, 2013). The three types of validity suggested are reviewed for this study, in the subsequent sections. Once the theory about validity and reliability is discussed, Table 16 summarises the tactics that were applied for this study.

3.5.2.1 Construct Validity

To avoid subjectivity, especially of the researcher's preconceived ideas on the subject matter, it is important to identify and define adequate operational measures to guard against bias while implementing an inquiry. Construct validity refers to the extent to which a research instrument measures the construct it is intended to measure. In other words, is the test constructed in a way that it accurately tests what it purports to test? It is a measure that is verified by comparing the primary test to other tests that measure similar parameters to verify how highly correlated the two measures are. According to Yin (2018), techniques that may be used to increase construct validity include using *multiple sources of evidence*, establishing a *chain of evidence* and to have the outcome report *reviewed* by key informants.

3.5.2.2 Internal Validity

Internal validity relates to how strong the causal relationship between the independent and dependent variable is. It is concerned with the alignment (congruency) of the research outcome to reality (G. Morse & Graves, 2009). It is necessary to eliminate any other solutions (rival explanations) for the research outcome to ensure internal validity. Some threats to internal validity which may have a considerable impact on the research outcome have been identified (Kaya, 2015), namely *history, maturation, testing, instrumentation, statistical regression, research reactivity, selection biases and attrition*. However, the threats may be controlled if the research inquiry and constructs are planned with the potential threats in mind.

3.5.2.3 External Validity

This test concerns assurance that the research outcome is generalisable to other settings, with different subject matters or to a broader population. While generalisability is relatively easy with quantitative methods, the subjective nature of the qualitative inquiry makes it a bit challenging in the domain (Guba & Lincoln, 1994). Rather than thinking of generalisability from the perspective of generating precisely the same outcome, Imbens and Rubin (2015) argue for the use of credibility earned through a consistent data acquisition process. In general, external validity may be improved by increasing the scenarios of inquiry investigation and also

increasing the diversity of the population (McDermott, 2011). Some threats to external validity include the interaction effect of testing, the effect of selection biases and that of multiple treatment inferences (Imbens & Rubin, 2015).

3.5.3 Reliability

Replicability (of research process and result) is a key criterion of reliability. Reliability is concerned mostly with the consistency of research output, yet a tolerable amount of variability is allowed, provided the methodology and epistemological constructs produce ontologically similar outcomes (Grossoehme, 2015). Some ways to improve the reliability of research outcomes have been suggested by Yin (2018) to include making the research procedures as comprehensive as possible and retaining a consciousness of repeatability throughout the entire research life cycle. The research life cycle includes the investigator's position and explicit explanation of the procedures and stages of the inquiry, triangulation, and an audit trail.

Based on the discussions above, Table 16 outlines the tactics used to improve the quality criteria of validity and reliability.

Table 16: Research Validity and Reliability

Quality Test	Tactics applied for this Study
Construct validity (identifying correct operational measures for concepts being studied)	The key concepts associated with performance assessment within ESD were sourced from *literature*. Data triangulation was used by using a *focus group* with participants from various facets of the population but with knowledge of the problem domain. This ensured multiple sources of evidence while the additional chain of evidence was created by stratifying municipality participants into several strata of common interest and attributes.
Internal validity (making invalid inferences, i.e. indicating x -> y when z -> y)	The study indicates that the designed ESD-PRT provides insight that *guides redesign efforts in addressing performance gaps* through means of *interview feedback* from participants. This study did not evaluate whether the ESD-PRT increases performance gaps when used in practice during the evaluation phase. The researcher acknowledges that future research is needed to fully evaluate the effectiveness of the ESD-PRT in addressing performance gaps.
External validity (knowing that findings can be generalised)	This study demonstrated only one DSR iteration of building, demonstrating and evaluating the ESD-PRT within the ESD context. Three different municipalities were involved during the requirements elicitation phase of the ESD-PRT, increasing the validity in developing a suitable ESD-PRT for the South African context. However, one iteration is not adequate to generalise across other ESD bodies, and future research is needed to apply the ESD-PRT within different ESD contexts.
Reliability (demonstrating the operations of the study can be repeated with the same results)	The study is transparent on the research methodology, keeping all raw data in a retrievable format in Atlas.ti. A chain of evidence was maintained throughout, relating interim findings to sources and to the initial research questions. The DSR guidelines of Hevner et al. were used to systematically design, develop, demonstrate and evaluate the solution. Each phase and guiding procedure are explicitly documented and can be repeated.

3.6 Ethical considerations

Participants in this study are real individuals with their personal attributes, values, and way of life. As outlined in section 3.3.1, they range from residents in the DCMs, DCM officials, to representatives in local and national governments, academia, non-governmental organisations and independent citizens. The researcher interacted with them directly (pre-COVD-19), and remotely during the pandemic. To ensure that the dignity and rights of these participants are observed and respected, the researcher obtained the necessary ethical clearance for all interactions.

Ahead of any interviews or sharing of questionnaires, informed consent of participants was secured. Also, they were made to understand that participation is entirely voluntary, and information from them would be handled with strict confidentiality in line with the University's guidelines for ethical research practices. Pseudo names were used rather than publishing participants' or municipalities' real names. Finally, participants were treated with utmost courtesy, given the opportunity to withdraw from the exercise at any time, and assured of anonymity.

3.7 Chapter Conclusion

This chapter explored the ontological, epistemological, methodological, and axiological foundations of the main research paradigms. Paradigmatic consideration was necessary as it has an immense influence on the methodology, methods, and interpretation of the research outcomes. The interpretive paradigm is deemed most appropriate for this research given the socio-cultural, socio-technical environment of the grand challenge. An artefact for diagnostic assessment of ESD at the municipalities, is an outcome of the study, necessitating the use of the DSR. The DSR is not without process recommendations and models for its use. A review of these models led to the choice of the DSRM, which is motivated for in this chapter. The chapter concludes with the research method and ethical considerations.

Chapter 4. Requirements for ESD-PRT

This chapter provides additional motivation for the design, development, demonstration and evaluation of a solution in line with the World Bank's (2011) position that a study is needed to measure and report on the performance of service delivery in South Africa, the absence of which may perpetuate service delivery deficits. A criterion for identification/validation was implemented for such a solution, while functional requirements for the same solution, the ESD-PRT, were extracted via a requirement elicitation process.

Chapter 4 answers RQ4, which is repeated here:

RQ4: What software tool functions are needed (i.e. software tool requirements) to support the identification of areas of concern & critical failure factors of electricity service delivery?

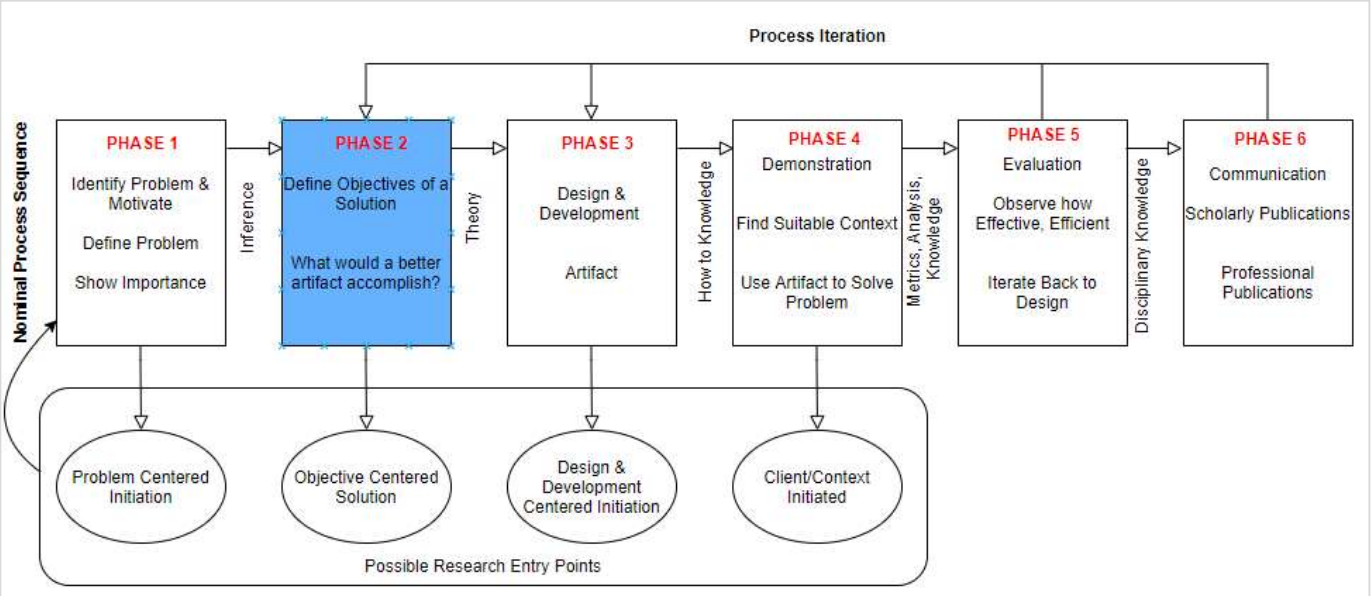


Figure 19: DSRM Process for the ESD-PRT, focusing on Phase 2

(Peffers et al., 2008)

4.1 Introduction

An ESD-PRT for electricity service delivery has become necessary given the state of ESD in South Africa's municipalities. Apart from its socio-economic and socio-cultural impacts, faltering ESD is a major bottleneck for municipalities to fulfil their developmental role as enshrined in the constitution. Many municipalities, mostly the local ones, currently make their largest revenues from electricity sales (section 1.3, Figure 4), making the issue of ESD a double-edged sword, affecting both the provider (municipality) and the consumer (citizens, i.e. residential, commercial, and industrial users). Therefore, a diagnostic tool that performs

evidence-based assessments of the ESD, with considerations for consumer and provider perspectives, and the technical health of PSR (all facets of the value chain, design domains and sub-domains) is inevitable.

Notwithstanding the overwhelming evidence of backlogs and deficits (De Beer, 2016; De Ruyter, 2021; Eberhard, 2012; Palmer, 2016; SALGA, 2018) in ESD in the South Africa of today, the decision to design and develop the ESD-PRT was neither random nor intuitive, but rather driven by evidence, and followed a rigorous scientific process of decision making and design thinking. The focus is on the municipality, the government's main arm responsible for electricity distribution and reticulation within their areas of jurisdiction (COGTA, 2019; Eskom, 2018; SALGA, 2017). At the financial year ended 31 March 2020, 187 municipalities were licenced by Eskom for electricity distribution, and they owe Eskom a cumulative amount of 28 (twenty eight) Billion Rands (Eskom, 2020).

In these municipalities, PSRs are very old (SALGA, 2018), and investments are inadequate (De Beer, 2016; Palmer, 2016), with investment backlog hitting 68 (sixty eight) Billion Rands as at 2018/2019 financial year. To compound the problem of ESD at municipalities, they lack the requisite manpower and skills to carry out effective maintenance of PSRs (De Beer, 2016). NERSA, the authority for regulating electricity in South Africa, has been conducting scheduled and discreet compliance audits of the municipalities. For the years reviewed by this study, the results have been poor (NERSA, 2018, 2020a). Although NERSA's efforts are commendable, the audits fail to address all the design domains necessary to address and bring change to ESD at the municipalities. The audit efforts are discreet, target just about 14 to 20 municipalities at a time, neglect other critical stakeholders of ESD, and lack any design dimension to inform better performance. Their view is strictly compliance, not holistic, in the context of ESD. However, a holistic approach is necessary to address the issue of ESD, since ESD is a multi-stakeholder, multi-level, socio-technical value chain with considerable impact on the health (i.e. social, economic and political) of the entire country.

A holistic approach is currently lacking (see Chapter 2). One of the flaws of taking a partial approach to a problem such as this is manifested in the electricity financial losses which the municipalities cannot accurately account for (section 1.3, Table 1). They are generally classified as technical and non-technical losses by the municipalities, but without an account of the proportions to PSR, poor metering, artificial demands and illegal connections. These losses range from 30% to 53% of the total electricity received from Eskom, as shown for a cross section of municipalities in Figure 20.

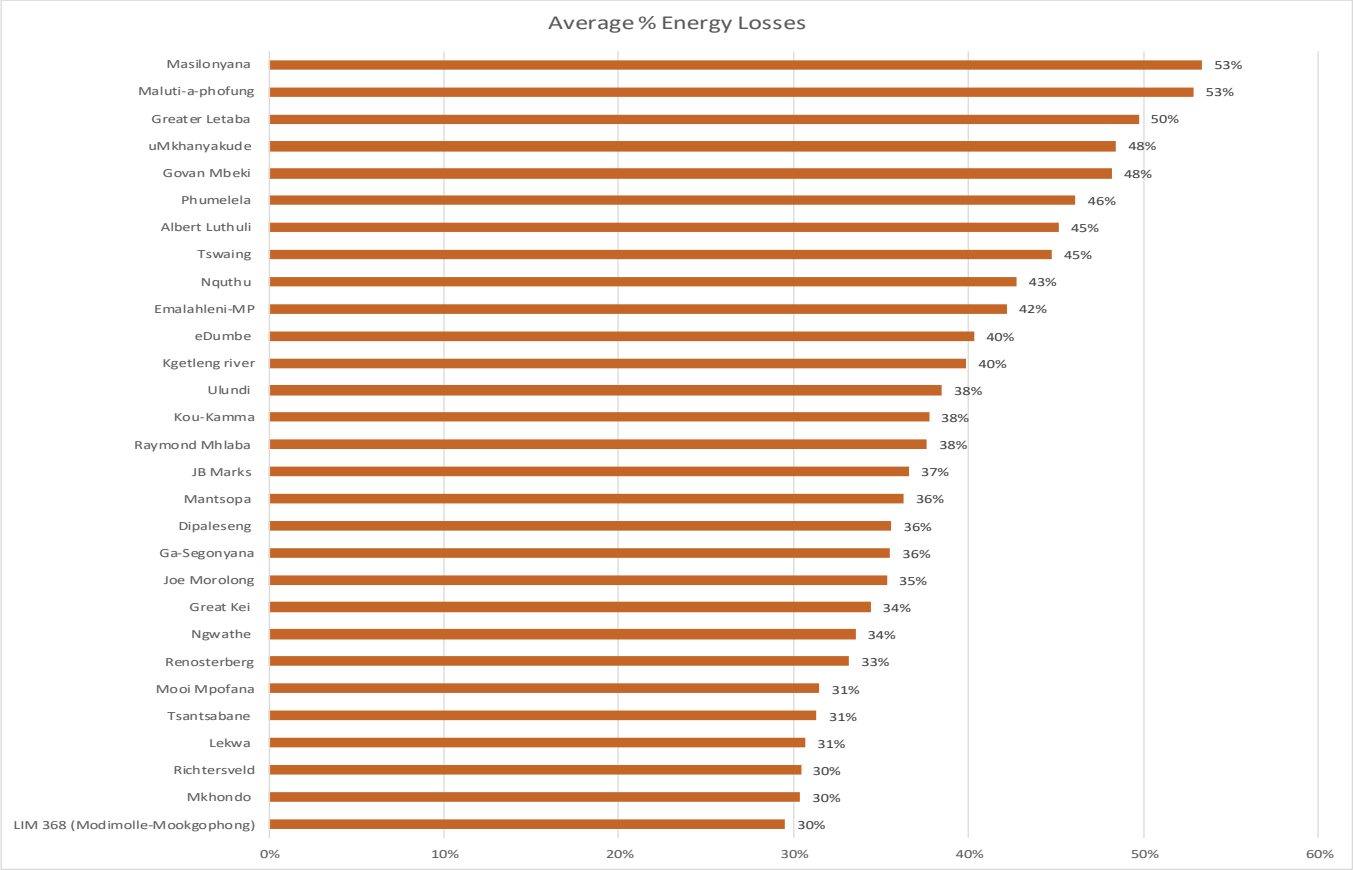
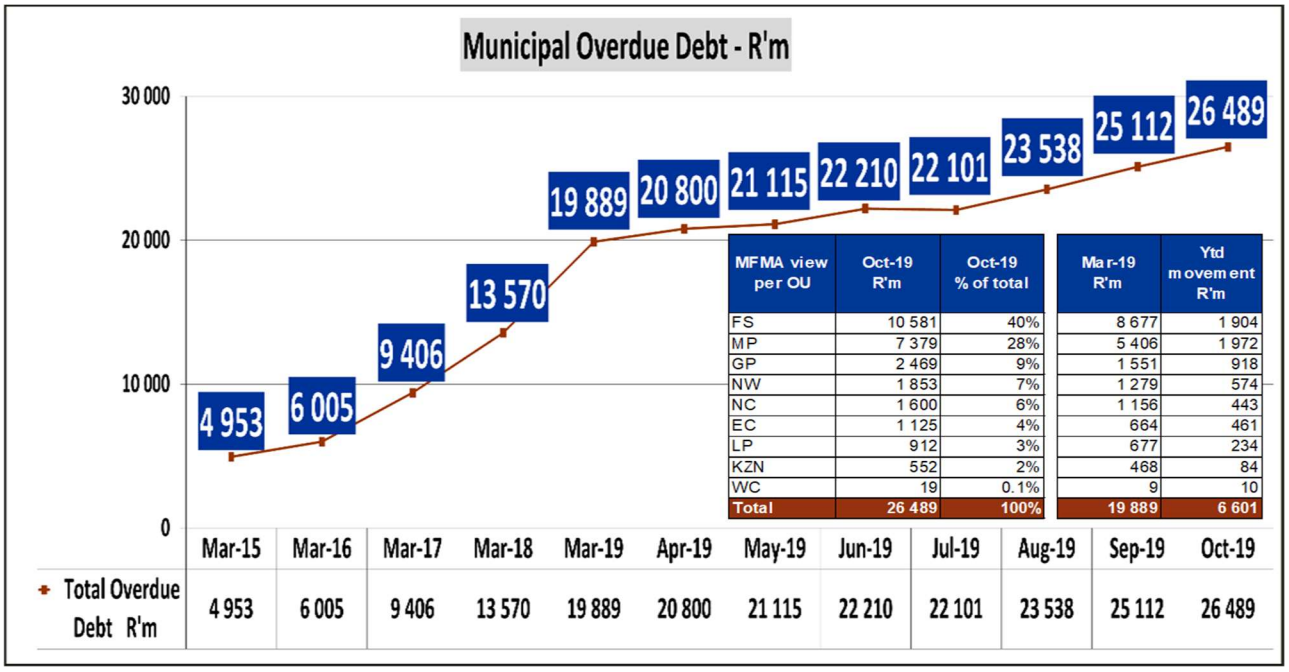


Figure 20: Energy unaccounted for, at a selected set of municipalities

(COGTA, 2019)

The researcher posits that the unaccounted losses are responsible for the climbing municipalities overdue debt to the power supply utility Eskom, as shown in Figure 21.

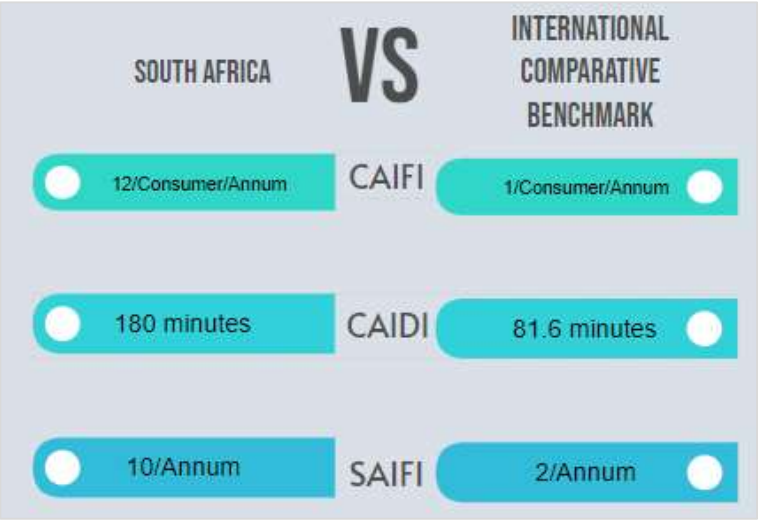


MFMA view per OU	Oct-19 R'm	Oct-19 % of total	Mar-19 R'm	Ytd movement R'm
FS	10 581	40%	8 677	1 904
MP	7 379	28%	5 406	1 972
GP	2 469	9%	1 551	918
NW	1 853	7%	1 279	574
NC	1 600	6%	1 156	443
EC	1 125	4%	664	461
LP	912	3%	677	234
KZN	552	2%	468	84
WC	19	0.1%	9	10
Total	26 489	100%	19 889	6 601

Figure 21: Rising municipalities overdue debt to Eskom

(COGTA, 2019)

Nevertheless, this study takes a global perspective, and assesses how South African municipalities perform with ESD compared to the international community. A benchmark study of this nature is global best practice, but not often conducted in South Africa, meaning very recent data is not available. A previous benchmark study, based on three key performance metrics (*customer average interruption frequency index*, *customer average interruption duration index,* and *system average interruption frequency index)* revealed that consumers within the South African municipality distribution jurisdiction experienced more frequent and longer outages than consumers (citizens, i.e. residential, commercial, and industrial users) in similar context elsewhere in the world. This is summarised in Figure 22.



LEGEND:

CAIFI: Customer Average Interruption Frequency Index.

CAIDI: Customer Average Interruption Duration Index.

SAIFI: System Average Interruption Frequency Index.

Figure 22: ESD benchmarks

Adapted from De Beer (2016)

While not suggesting that a single tool will be the panacea to ESD challenges in South Africa, the study argues that one tool, designed and developed with holistic, integrated perspective is the entry point to, and will guide any credible and sustainable solution. This study suggests that design thinking is applied to develop an ESD-PRT to provide a holistic picture of the current health of ESD in South Africa. This position is supported by the World Bank Group (international) and COGTA (local). According to research by the World Bank Group (2011) on accountability in South Africa's Public Services, their report indicates that one of the major reasons for service delivery issues is inadequate assessment (including monitoring and feedback) of the health of service delivery. Similarly, COGTA (2019) posits that the inability of municipalities to effectively assess, track and manage the performance of the distribution network is mainly responsible for municipalities' 26.5 billion Rands debt owed to Eskom as at 2019, confirming COGTA's belief in such a tool or solution for on-going diagnostic assessment of the ESD value chain, to guide improvement. This same position is echoed by Makanyeza (2013) and Sibanda (2012).

The DSRM phases followed in theory and inductive development of the ESD-PRT are illustrated in Figure 23. Once developed and commissioned, users of the ESD-PRT would include all the groups indicated in Figure 13: municipal employees (management staff and senior staff) and DCM residents (residential and commercial consumers of electricity)

The remaining sections of this chapter deal with *phase 1,* while *phases 2 and 3* are covered in Chapter 5. *Phase 4* (demonstration) is addressed in Chapter 6, while *phase 5* (evaluation of the

ESD-PRT) is addressed in Chapter 7. The entire thesis, as well as scholarly publications, provide evidence for executing *Phase 6*.

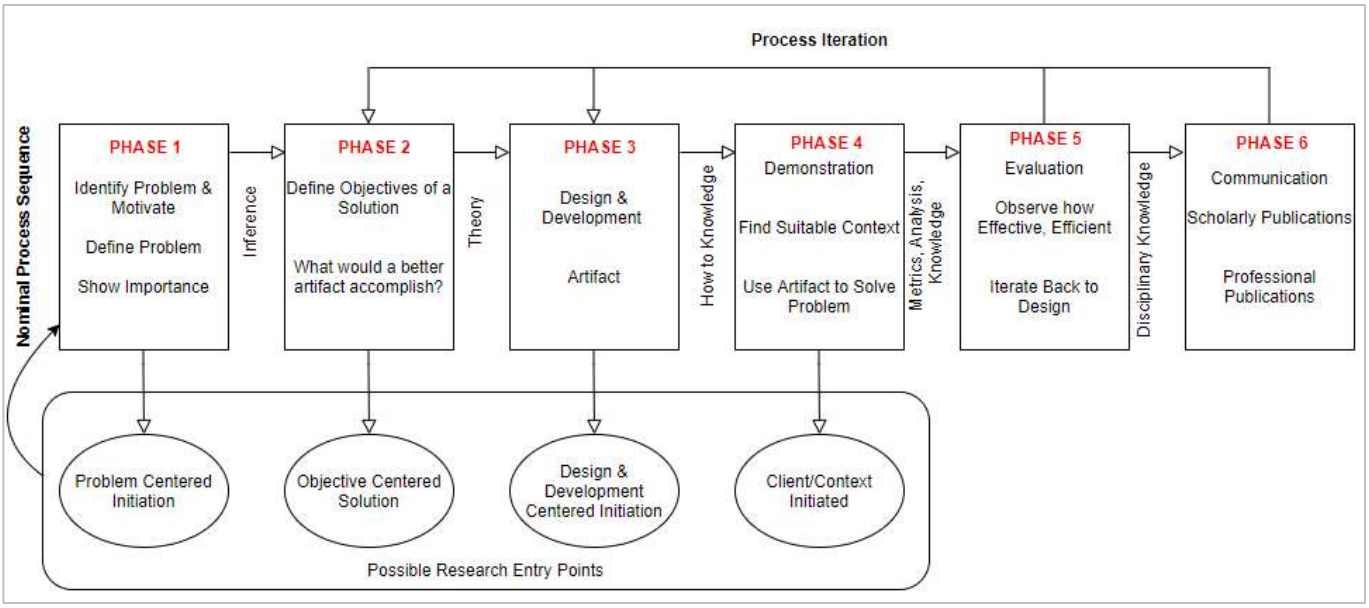


Figure 23: DSRM Process for ESD-PRT

Based on Peffers et al. (2008)

Chapter 1 provided background on the existing problem on ESD and the lack of diagnostic assessment of the entire system. An initial search for a solution, using a SLR (in Chapter 2), indicated that there is no shortage of such diagnostic tools. The challenge is that, notwithstanding these tools, some of which are applied by the government, the service delivery gap continues to widen (Tirivangasi, 2016). On application of relevant inclusion and exclusion criteria and quality parameters, Table 6 is a list of diagnostic service performance assessment tools extracted from the literature. It is represented as Table 17 for convenience.

Table 17: Extracted Diagnostic Service Performance Assessment Tools

Tool	Year of publication	Country of application	Theoretical approach/technique
FSDM	2015	South Africa	Qualitative
DEA	2016	South Africa	Quantitative
Citydex	2009	South Africa	Quantitative
SERVICOM	2006	Nigeria	Quantitative
SERVQUAL	1988, 1991, 1994	United States	Qualitative
PETS & QSDS	2002	United States	Both
D-Tree	2007	United States	Qualitative
Livingstone	2004	United States	Quantitative
ESTP	2007	United Kingdom	Qualitative
SARA	2013	Switzerland	Qualitative
SERVPERF-M	2000	Australia	Quantitative
ASPIRE	2016	Australia	Qualitative

Tool	Year of publication	Country of application	Theoretical approach/technique
PJM	2015	Austria	Qualitative
EGPE	2015	China	Qualitative
SCPAT	2011	Thailand	Quantitative
CSDA & SDAF	2016	Multiple	Qualitative
BSC & GEE	2011	Afghanistan	Qualitative
MP	2010	Malaysia	Quantitative
CEMATT	2013	Romania	Quantitative

Notwithstanding the discovery of the tools outlined in Table 17, an additional exercise was implemented to extract from the literature performance criteria for each one. As reported in Table 10 (with relevant references), the extracted criteria include *independence, relevance, validity, reliability, comprehensibility, comparability, objectiveness, predictive ability, diagnostic ability, balance, conflicts avoidance, engagement, focus, ease of use, responsibility, impactful and improvement*. Since not all the tools were developed in or for the South African context, additional rigour is required to validate necessary criteria that the tools must satisfy to be considered valuable and appropriate in the South African context. The outcome of the exercise is reported in section 4.2.

4.2 Criteria Validation for Solutions

There is need for sufficient rigour in determining which of the tool's criteria in section 2.2.2.3 (Table 10) are relevant in the South African context. To achieve this, a FGD approach was followed with the following objectives:

a. Validate the need for a service delivery diagnostic tool for assessing public service delivery performance.
b. Validate criteria extracted from literature and identify additional criteria to evaluate the performance of existing public service delivery assessment tools.
c. Use the validated criteria to propose a hierarchy of criteria that decision-makers could use to prioritise the criteria.

To achieve the objectives outlined above, a focus group of 9 participants was formed. The FGD consisted of subject matter experts (SMEs), domain experts (DEs), decision makers, related government departments, including the presidency, and the municipal government, being the bedrock of electricity service delivery and the first point of contact to the citizenry. In summary, the following sectors and departments were represented at the FGD:

a. Municipal government (City of Tshwane, South Africa)
b. South African Local Government Association
c. Department of Public Service and Administration
d. The Presidency

e. United States Agency for International Development
f. Non-Governmental Organisations
g. Academia (University of Pretoria)
h. The public

While these cannot be assumed to represent the entire South Africa, they have been purposively identified and recruited for the FGD exercise. Feedback from the session commenced only after informed consent of participants was obtained. The main objective of the FGD was to obtain a list of validated service delivery diagnostic performance criteria.

In summary, the focus group participants redefined and validated 11 criteria, and could not reach consensus on one (comparability) and added two new ones, namely *comprehensiveness* and *accuracy*. The validated criteria are:

a. **Independence**: Administering personnel must be independent and free of financial inducement. (*However, participants argue that this is not feasible on an ongoing basis and Technology Assisted Approaches should be explored*).
b. **Relevance**: The tool must assess practically significant public services and reflect important public issues. It must possess metrics relevant to the outcome of interest. (*Participants indicated that relevance would be driven by legislated sectorial mandate*).
c. **Reliability**: Tool must be consistent when used to measure public service delivery performance repeatedly, with results that are reasonably comparable with similar tools.
d. **Comprehensibility**: The outcome provided by the tool must be easily digested and understood by its users. Graphs and tables can be used to facilitate public comprehension. Interested parties can access the report/publication and make sense of the content. Within certain contexts, the word accessibility is also used, meaning that any individual should be able to interpret and comprehend the results produced by the tool.
e. **Measurement expressiveness**: Both objective and subjective metrics should be used as triggers for action/correction.
f. **Predictive ability**: The tool must be able to estimate or project what public service delivery performance would look like in the near future, based on historical and current data.

g. **Diagnostic ability**: The tool must identify specific issues regarding specific performance areas affecting public service delivery, i.e. the tool should allow data drill down to root causes.
h. **Robustness**: Metrics used by the tool must be robust, i.e. there should be clarity on exactly what is measured.
i. **Engagement**: Stakeholders are involved in the design, development or customisation of the tool, using consultation and a participatory approach.
j. **Customisable**: The tool must be tailored or customised for a specific sector or sub-sector, i.e. the generic components of the tool should be adjustable to be valid for a particular sectoral context.
k. **Ease of use**: The assessment tool should be easy, flexible-to-interact-with and uncomplicated to learn and operate.
l. **Comprehensiveness** (new criterion, added by the focus group participants): The tool must cover all relevant areas, be all-inclusive, all-embracing for the context that is measured.
m. **Accuracy** (new criterion, added by the focus group participants): Output is precise.

Given the ultimate goal of the FGD (to be able to decide on the most suitable service delivery assessment tool), the criteria (defined and validated via the FGD), and the available alternatives (existing diagnostic service performance assessment tools), an AHP hierarchy was developed to enable pairwise comparisons by stakeholders and decision makers. The AHP hierarchy uses validated FGD participants' criteria and additional (post construct) criteria to aid practical comparisons and decision making. The tool selected based on the AHP process for the South African state was the Performance Journey Mapping (PJM) (See Tables 26 and 27).

4.3 Evaluating PJM as a Possible Solution

Using the AHP (see section 2.3), the PJM was selected after rigorous pairwise comparisons by key decision makers at four local municipalities. Based on Saaty (1994) and Mu (2017), steps followed to arrive at that decision are outlined in sections 4.3.1 to 4.3.5.

4.3.1 AHP steps followed:

a. Step 1: Identify the overall objective, i.e. What is the main problem? What is to be achieved?
b. Step 2: Identify criteria (and sub-criteria) that must be met to achieve the desired objective, following a participatory approach whereas many relevant participants as possible are co-opted.

c. Step 3: Identify alternatives, also consolidating Steps 1 to 3 into a hierarchy framework where the lowest level presents the alternatives.
d. Step 4: Derive priorities for all criteria, local priorities (preferences) for the alternatives, and overall priorities (synthesis) for the model. Data is obtained from decision makers, using comparative ratings indicated in Table 18. For this step, data collection is required to inform pairwise comparisons. For this study, the expertise and experience of multiple decision makers that meet the recruitment criteria outlined in section 4.3.3 were relied upon to inform the pairwise comparison process.

Table 18: Pairwise Comparison Scale

(T. L. Saaty, 1994)

Options	**Numerical Values**
Equal Importance	1
Moderate importance	3
Strong importance	5
Very strong importance	7
Extreme importance	9
For a compromise between the above values	2, 4, 6, 8

e. Step 5: Ensure consistency of judgement by calculating the consistency index and consistency ratio CR for the criteria and alternatives matrices. The consistency ratio (CR) of a consistent decision maker should be 0.1 or less (T. L. Saaty, 1980). When multiple decision-makers are involved, a geometric consensus index (GCI) should be used to evaluate the decision-making consistency.
f. Step 6: Perform sensitivity analysis, i.e. determine how changes in the weights of the criteria affect the overall outcome.
g. Step 7: Make the final decision, using the synthesised results and sensitivity analysis to inform the final decision.

4.3.2 Identifying and Validating Appropriate Criteria

Selecting valid criteria (Step 2 in section 4.3.1) is no simple task. Within the context of this study, there are many performance evaluation criteria for diagnostic service performance assessment tools in the literature. Relevant criteria (such as comprehensibility, comparability, and diagnostic ability) were, through a focus group review session, subjected to a relevance analysis (published in 2018 by the authors) to understand whether they are relevant in the South African context. In addition to that, each criterion was now defined (considering the South African context and vernacular), interpreted, and validated. These criteria could be classified as effectiveness criteria.

The researcher believes that two additional criteria categories are needed, namely project criteria (cost, time, warranties) and technical criteria (technology, availability, scalability, fault tolerance, maturity, modularity, and recoverability). Following the advice from Wei et al. (2005), all criteria need to be validated for practicality before pairwise comparative analysis can commence. Saaty (2004a) provides an additional question to assess the validity of the criteria that was incorporated in this study, i.e. *Can I compare the elements on a lower level using some or all of the elements on the next higher level as criteria or attributes of the lower level elements?*

4.3.3 Selected Participants

In South Africa, the Municipal (local) Government is the bedrock of service delivery and the first contact of government with the citizens. Also, it is the sphere of government that can react most speedily to local challenges, being close to the grassroots. As a constitutional democracy, South Africa has a three-tiered system of government (national, provincial, and local) that operates in an interrelated, interdependent manner (Pretorius, 2007). Of these three tiers of government, the constitution of South Africa (R.S.A, 1996) entrusts the role of providing basic services, such as access to water services, sanitation services and waste removals, and electricity, to the municipalities. According to Reddy (2016), this is the sphere/level of government with the designated mandate to provide primary health services, education, housing, electricity, water, sanitation, and an environment that is safe and secure for all local residents. In line with the study objective, participants are, therefore, authorities from the municipal government. To ensure further alignment to the selection process strategy, additional filters were applied as follows:

a. Is the person a senior manager in the municipality?

   Rationale: Only senior management team members participate in budgeting, execution, and evaluation of service delivery performance.

b. Has s/he been in a senior management position for five years or more in one or more municipalities?

   Rationale: It is reckoned that a minimum of 5 years' experience at the senior management level is necessary to have sufficient knowledge about the service delivery concerns.

c. Is their role relevant to service delivery or service delivery monitoring, evaluation, research, and learning (MERL)?

   Rationale: Service delivery is the focus of our study.

Table 19 summarises the number of decision-makers from the four municipalities that participated in the pairwise comparison and decision making.

Table 19: Pairwise Comparison Participants - Key Decision Makers

Municipality	No of Participants
Umvoti	3
Endumeni	3
Umsinga	2
Umzinyathi	2
Total Number of Senior Officials	10

4.3.4 Participants Involvement and Tool Short-Listing Strategy

Multiple sessions were held with the participants to:

a. Review validated criteria for practicality.
b. Conduct pairwise comparisons of criteria and alternatives in terms of criteria.

The Business Performance Management Singapore (BPMSG) tool of Goepel (2013), an electronic Microsoft Excel based AHP software application allows a maximum of 20 decision-makers with the capability to calculate aggregated results for all of them, using the geometric mean of all decision matrices. The tool calculates a consistency ratio (CR) for each decision-maker to evaluate the consistency with which the decision-maker prioritised criteria. In addition to that, and with the possibilities of differing rankings from decision makers, the tool calculates a geometric consistency index (GCI), which indicates the disparity or otherwise of decision-makers rankings. The GCI ranges from 0% (no consensus between decision-makers) to 100% (full consensus between decision-makers). The GCI values calculated for this study were interpreted in accordance with Table 20.

Table 20: Geometric Consensus Indicators

(Goepel, 2013)

Index	Consensus
<=50%	Very Low
50% - 65%	Low
65% - 75%	Moderate
75% - 85%	High
=>85%	Very High

Theoretically, the GCI of the BPMSG tool is calculated using the Row Geometric Mean Method of Thomashevskii (2015). The CRs are calculated (CR = CI/RI) for each decision-maker with the calculated principal eigenvalue based on one of the eigenvectors calculated from the Row Geometric Mean Method from each decision-maker or from the eigenvector method in the aggregated results. The RI is a random-like index where judgements have been randomly entered, tabled in Saaty (2012) per number-of-comparison-criteria.

This selection process is not practically possible to procure all the tools outlined in Table 17, train the decision-makers (top government officials) in all the tools, and allow the use of the tools for a lengthy period to gather enough data to evaluate them. Therefore, a further filter was required to limit the tools to only those that have been rigorously evaluated with documented evidence of evaluation from the literature. The filter is summarised as follows:

a. Has the tool been tested in real life? *Rationale*: The researcher assumes that tools which have been used by practitioners would have been refined, increasing their usability.
b. Has it been evaluated for clear key performance metrics? *Rationale*: Ambiguous performance metrics will have a negative effect on the reliability of the measurement outcome.
c. Is the evaluation outcome documented? *Rationale*: Transparent documentation of evaluation outcomes is key to comparative analysis.
d. Are independent persons (not the tools developers only) involved in the evaluation? *Rationale*: This is necessary to ensure integrity, impartiality, and independence of evaluation outcome.

Table 21 is the outcome of the applied filter, showing that only 5 tools were shortlisted for pairwise comparison.

Table 21: Pre-Evaluated Tools

Performance Assessment Tool / **Performance Metric**	ESTP	ASPIRE*	BSC & GEE	CSDA & SDAF	PJM	EGPE	MP**
Independence			●			●	
Relevance		●				●	
Validity						●	●
Reliability						●	
Comprehensibility	●	●	●		●	●	●
Functionality				●		●	●
Comparability					●		
Responsibility					●		
Objectiveness			●	●	●		
Diagnostic ability	●			●			
Predictive ability	●						
Improvement	●		●		●		●
Balance					●		
Conflicts avoidance					●	●	
Focus	●			●			

*Eliminated for minimal criteria.

**Eliminated being designed & evaluated for manufacturing contexts.

4.3.5 Results of Pairwise Comparisons

Based on the AHP methodology (see section 2.3) and the highlighted steps (see section 4.3.1), results for selecting the tool are outlined below.

4.3.5.1 Initial Criteria for Selecting COTS (Commercial-Off-The-Shelf) candidates

As indicated in section 4.2, the researcher already identified and validated some effectiveness criteria for diagnostic service performance assessment (DSPA) tools via a FGD for the South African context. Two additional categories that are relevant when existing off-the-shelf tools need to be compared were added. Thus, the author believes that three categories of criteria need to be considered:

a. Effectiveness criteria
b. Project criteria
c. Technical criteria

4.3.5.2 Results for Validated Criteria for Practicality

A questionnaire containing all pre-validated criteria and definitions was used to obtain decision makers' judgement on practicality. Below is a summary of the aggregated responses from 10 participating decision makers.

a. *Have all criteria been identified?* 100% indicated Yes.
b. *Should any effectiveness, project or technical criteria be excluded?* 100% indicated No.
c. *Indicate the degree to which each criterion is expressed in practical terms*. When aggregated, all criteria that scored 60% and above are included in the AHP structure (Figure 24) for pairwise comparisons. The consensus was reached with the decision makers to include criteria with above-average scores. Interestingly, two of the criteria have been excluded due to practical evaluation constraints, namely functionality and diagnostic abilities. Since the tools presented in Table 21 have been developed with the main purpose of diagnosing/assessing performance deficits, it is assumed that the DSPA tools incorporate the minimum set of functional features and diagnostic abilities. Yet, a requirement elicitation process is needed to ensure that the selected tool also complies with required functional features and diagnostic abilities.

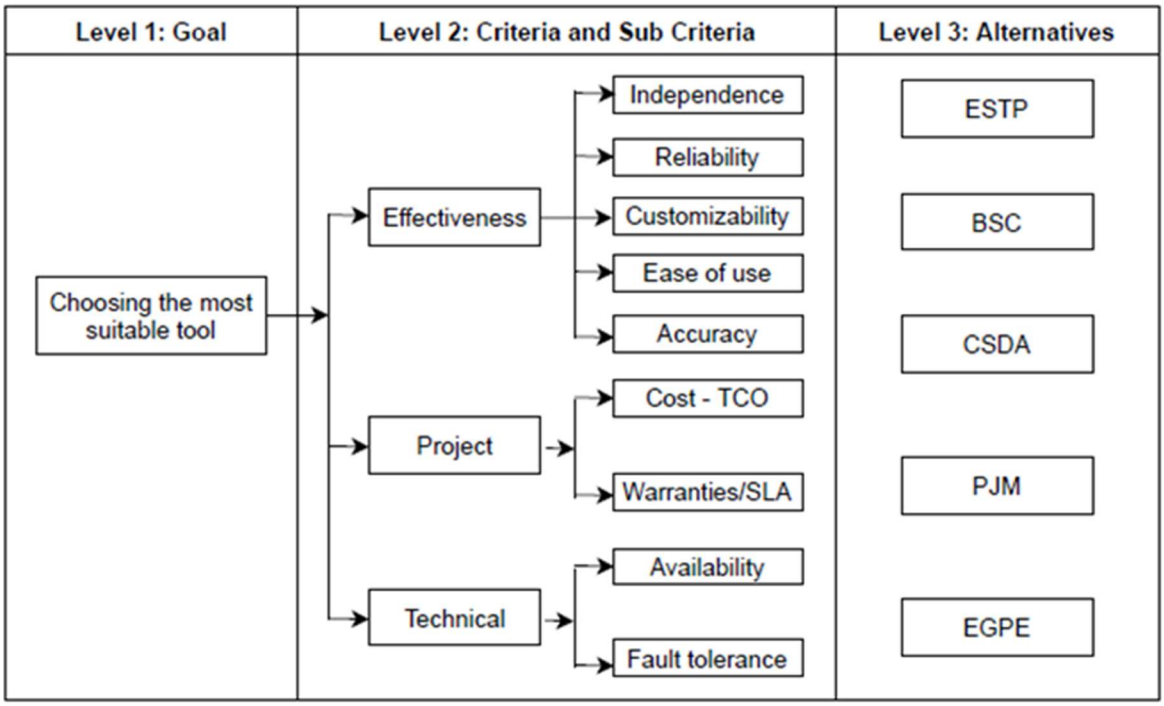


Figure 24: AHP Structure for Choosing the Most Suitable DSPA Tool in South Africa

4.3.5.3 Results for Short-Listed Tools

Based on the list of criteria, key decision makers were involved in prioritising criteria from the list of *effectiveness, project, and technical criteria*, to select the most appropriate DSPA tool for South Africa. They were taken through the description, performance and evaluation results of the pre-selected tools, the AHP structure in Figure 24 and their scorings were obtained. Figure 25 and Tables 22 to 24 show the results of the pairwise comparisons for the criteria. Consolidated results are as follows:

a. Number of decision makers: 10.
b. Number of criteria: 9.
c. Consensus Index (CI): 88.6% (Very high agreement between decision makers - see Table 20).
d. Priorities in order of importance: Ease of use (14.3%), Availability (13%), and Cost (12.9%).

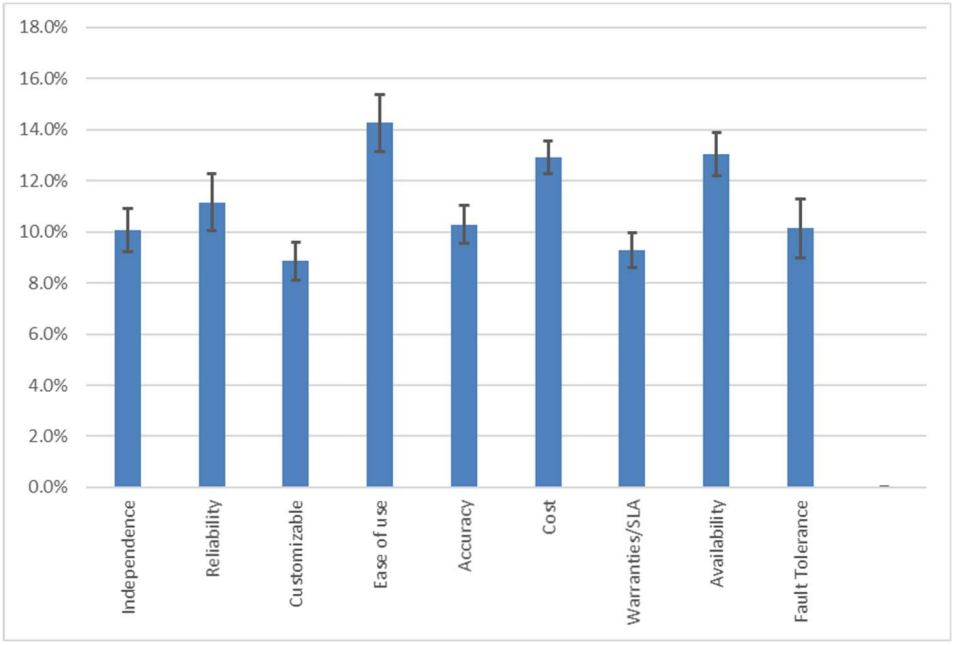


Figure 25: Consolidate Judgements and Priorities

An example of the problem set-up for one of the decision makers is shown in Tables 22 and 23, while Table 24 shows the consolidated matrix for all decision makers. Table 23 also includes one of the decision makers comments, i.e. her interpretation of the criterion.

Table 22: Decision maker 1 scoring

1	Decision Maker 1 - Finance						1		10-09-19	
	1	2	3	4	5	6	7	8	9	10
1	1	1	5	1/9	1	1/5	3	1/5	1	0
2	1	1	5	1/5	1	1	5	1/3	5	0
3	1/5	1/5	1	1/5	1/5	1/5	1/3	1/5	1/5	0
4	9	5	5	1	5	3	5	1	5	0
5	1	1	5	1/5	1	1	3	1/3	5	0
6	5	1	5	1/3	1	1	5	1	5	0
7	1/3	1/5	3	1/5	1/3	1/5	1	1/3	1/3	0
8	5	3	5	1	3	1	3	1	3	0
9	1	1/5	5	1/5	1/5	1/5	3	1/3	1	0
10	0	0	0	0	0	0	0	0	0	1

Table 22 outlines the scoring of decision maker 1. Each decision-maker was interviewed to complete the matrix on a scale of 1 to 9, selecting which is more important on the pair e.g. criterion independence scored against reliability, customisability, and ease of use, stating which is more important relative to independence. The legend for scores and their values is shown in Table 18 as a guide for decision-makers to score between 1 (equal importance) and 9 (extreme importance).

Table 23: Decision maker 1 priorities and interpretation of criteria (CR = 9%)

n	Criteria	Comment	RGMM	+/-
1	Independence	Personnel free of financial inducement	6.1%	3.0%
2	Reliability	Repeated consistency & comparability with similar tools	10.3%	4.7%
3	Customizable	Tools should be adjustable	2.2%	1.2%
4	Ease of use	To learn and use tool should easy & uncomplicated	30.2%	16.0%
5	Accuracy	Output must be precise	9.6%	4.1%
6	Cost	TCO must make sense	14.3%	5.7%
7	Warranties/SLA	Support must be guaranteed	3.3%	1.6%
8	Availability	Tool to be in a functional state for acceptable time period	18.8%	8.2%
9	Fault Tolerance	Even when faulty, tool should maintain a level of performance	5.1%	
10				2.8%

Corresponding priorities of decision-maker 1 is shown in Table 23, with a consistency ratio of 9%. Where the consistency exceeds 10%, the top 3 inconsistent pair-wise comparisons on the input sheets are highlighted to allow the participants an adjustment of their judgments. The judgment resulting in lower inconsistency was proposed, and adjustments were made to improve the consistency.

Table 24: Consolidated matrix for all decision-makers (CI = 88.6%)

C	Consolidated									
	1	2	3	4	5	6	7	8	9	10
1		1	1.175	0.661	1.116	0.725	1.116	0.725	0.896	0
2	1		1.311	0.701	1.116	0.851	1.311	0.763	1.311	0
3	0.851	0.763		0.725	0.851	0.725	0.896	0.725	0.763	0
4	1.513	1.427	1.38		1.38	1.116	1.427	1.175	1.38	0
5	0.896	0.896	1.175	0.725		0.823	1.116	0.763	1.175	0
6	1.38	1.175	1.38	0.896	1.215		1.311	1	1.38	0
7	0.896	0.763	1.116	0.701	0.896	0.763		0.763	0.803	0
8	1.38	1.311	1.38	0.851	1.311	1	1.311		1.311	0
9	1.116	0.763	1.311	0.725	0.851	0.725	1.246	0.763		0
10	0	0	0	0	0	0	0	0	0	

Table 24 shows the consolidated matrix for all the decision makers. These are the final priorities whose calculation is based on the eigenvector method. Although priority criteria have been determined, it was now important to derive relative priorities (preferences) of the alternatives (DSPA tools) with respect to each criterion. In other words, what are the priorities of the alternatives concerning independence, reliability, customisation, ease of use, accuracy, cost, warranty, availability, and fault tolerance, respectively? Table 25 summarises the outcome of local priorities for alternatives.

Table 25: Local Priorities for Alternatives

With respect to criterion….	The preferred tool is….	Consistency ratio
Independence	PJM	0.07
Reliability	PJM	0.04
Customisability	EGPE	0.07
Ease of use	PJM	0.09
Accuracy	BSC	0.03
Cost	PJM	0.02
Warranties	EGPE	0.06
Availability	EGPE	0.07
Fault tolerance	PJM	0.07

Once local priorities were calculated, the overall priority could be calculated, referred to as model synthesis and shown below:

a. PJM: (0.101*0.613) + (0.112*0.359) + (0.088*0.337) + (0.143*0.534) + (0.103*0.193) + (0.129*0.289) + (0.093*0.341) + (0.130*0.297) + (0.101*0.403) = **0.375**
b. EGPE: (0.101*0.165) + (0.112*0.28) + (0.088*0.407) + (0.143*0.225) + (0.103*0.193) + (0.129*0.265) + (0.093*0.361) + (0.130*0.404) + (0.101*0.203) = **0.276**
c. ESTP: (0.101*0.088) + (0.112*0.209) + (0.088*0.111) + (0.143*0.101) + (0.103*0.193) + (0.129*0.265) + (0.093*0.192) + (0.130*0.145) + (0.101*0.100) = **0.156**
d. BSC: (0.101*0.066) + (0.112*0.068) + (0.088*0.083) + (0.143*0.079) + (0.103*0.255) + (0.129*0.114) + (0.093*0.082) + (0.130*0.060) + (0.101*0.22) = **0.112**
e. CSD: (0.101*0.068) + (0.112*0.084) + (0.088*0.062) + (0.143*0.061) + (0.103*0.165) + (0.129*0.067) + (0.093*0.07) + (0.130*0.094) + (0.101*0.074) = **0.081**

In summary, Table 26 shows all the alternatives ordered by their overall priority or preference.

Table 26: Model Synthesis

Alternatives	Overall Priority	Rank
PJM	0.375	1
EGPE	0.276	2
ESTP	0.156	3
BSC	0.112	4
CSD	0.081	5

Since the PJM tool scores the highest (37.5%), given the importance (or weight) of each criterion, the PJM tool is preferable compared to the others.

4.3.5.4 Sensitivity Analysis

The overall priorities calculated in section 4.3.5.3 (and shown in Table 26) are heavily influenced by the weights given to each criterion by the decision-makers. To see how the final results were impacted if the weights of the criteria are different, it was essential to conduct a what-if analysis, generally referred to as Sensitivity Analysis (SA).

The SA helps decision-makers to assess the quality of their decision and understand which criterion/criteria have the most impact on the original result (Banda, 2019; Farahani, 2012; Ivanco, 2017). Several scenarios may be tested by altering the weights of the criteria and observing how they affect the overall priorities of the alternative DSPA tools.

According to Yadav & Sharma (2016) and Kousalya and Supraja (2013) SA actually helps to enhance the final decision-making process, eliminates alternatives, and gives information about the robustness of a decision. For this study, several scenarios were considered, including varying the weights and local priorities to see what the ranking and overall priority would look like for each scenario.

The outcome for one of the tested scenarios is presented in Table 27, answering such question as: What would the ranking look like, if all the criteria have equal weights? With equally weighted criteria, the changes in overall priority are marginal, retaining the ranking order as in the original calculations.

Table 27: Sensitivity Analysis for Scenario Testing

Alternatives	Overall Priority	Rank
PJM	0.374	1
EGPE	0.278	2
ESTP	0.156	3
BSC	0.117	4
CSD	0.083	5

4.3.6 The PJM

The sensitivity analysis indicated that the PJM tool is still the most preferable (see Tables 26 and 27). It is closely followed by the EGPE tool both in the local and global priority rankings. The PJM visualises all performance metrics for a specific service while integrating three critical dimensions in the context of performance assessment of services: (1) the service process, (2) the dimensions of the balanced scorecard, and (3) the service implementers within an organisation; that is, staff members, supervisors, and line managers, who are involved in the service delivery process (Höber, 2015). With specific considerations for small and medium-sized enterprises, the PJM is service -oriented, employing models like the TAM (Technology Acceptance Model) and GST (Goal Setting Theory) for acceptance and targeting, respectively. According to Höber et al. (2015), the three-step model of the PJM framework, is shown in Figure 26. For the study, the key to the review and pairwise comparison process is the documented result of the evaluation conducted on the PJM, which, when reviewed alone, indicated that it performed well on metrics such as comprehensibility, objectiveness, conflict avoidance, balance, and improvement.

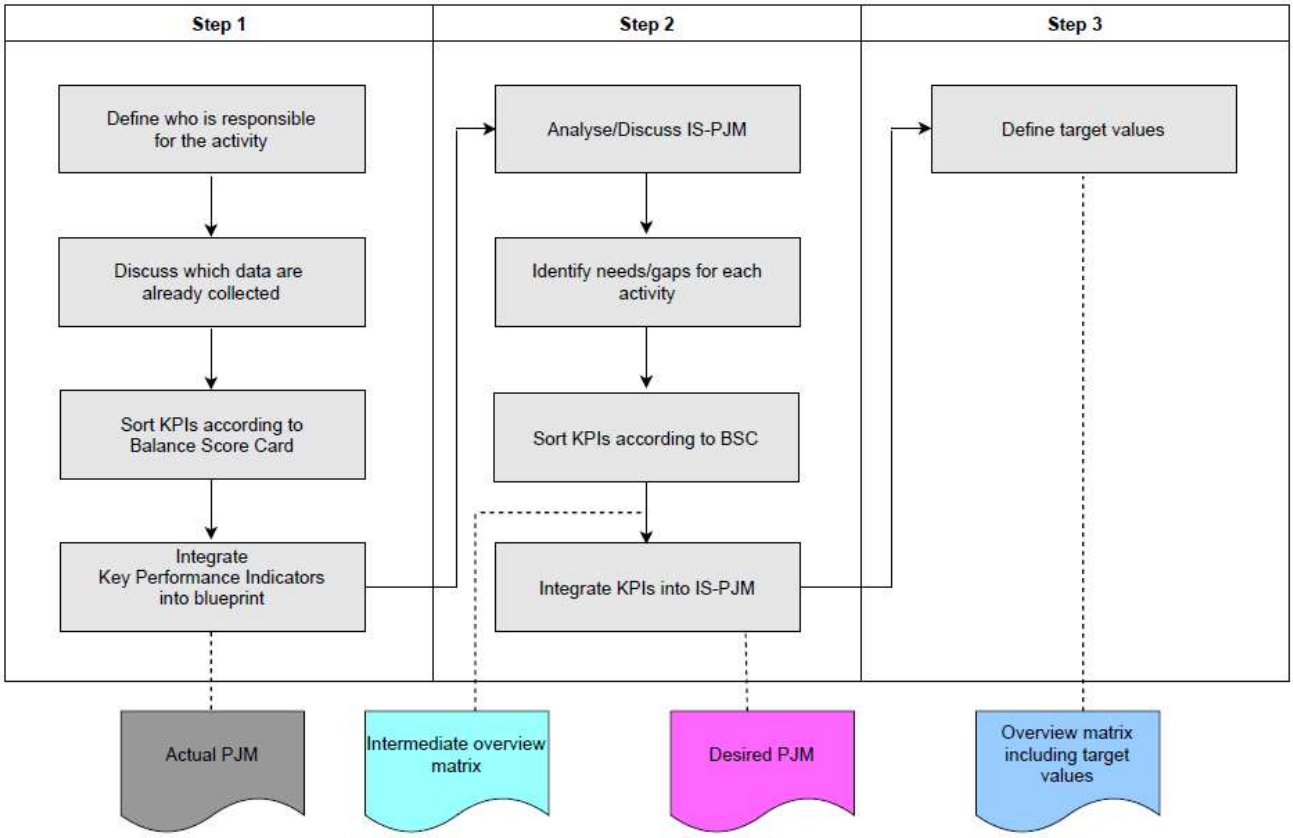


Figure 26: Three-step PJM model

Additional strong points of the PJM include:

a. The GST employed for commitment has the capability to influence staff members towards participating and contributing to overall company goals, as they co-create the performance measurement system.
b. The use of the Balanced Score Card can promote process and information alignment.
c. The iterative process gives the PJM an adaptive tendency, catering for new KPIs as they are discovered in practice and application.

Notwithstanding the above merits of the PJM and the fact that it was ranked as the highest out of all the pre-validated service performance assessment tools and tools criteria by the municipalities' decision makers, it is not without its shortcomings. Although its users (service delivery providers and employees) make input into its build up and application, different classes of consumers of the services are not incorporated into its framework. Also, there are no proper guidelines on how to execute steps 1 to 3 of the model, as depicted by Höber et al. (2015) in Figure 26. In summary, the following *shortfalls* have been noted with the PJM which would potentially affect its usability and performance, especially for the electricity service delivery performance assessment:

a. As an entry point to step 1 (step 0) of Figure 26, the cloud-based application does not provide any model within its framework for requirements elicitation and sense making of the requisite KPIs and business blueprint of the service to be performance-measured.
b. Given the structure of service organisations, the PJM framework does not stipulate a recruitment strategy for participants in an organisation for steps 1 to 3 of Figure 26.
c. On performance targeting, no guideline exists within the framework and software for weighting, prioritisation and targeting of KPIs in step 3.
d. Although the balance scorecards provide management with the alignment of organisational goals and strategy, the knowledge gap in understanding the nature and structure of the BSC by employees can lead to a top-down dominance in the PJM application, negating an all-inclusive employee-centric perspective.
e. The repository of KPIs presented for implementing a PJM at a service organisation has been selected based on a dynamic PI (performance index) which may be problematic for novice practitioners to adapt to.
f. The PJM doesn't show how its performance dimensions can inform or guide the redesign of the enterprise for optimised performance.
g. It is heavily *small and medium sized enterprises* service performance assessment biased.

A further investigation was embarked upon, exploring design science and, in particular, the EE discipline as outlined in sections 1.4 and 2.4 to mitigate these application and performance risks and shortfalls. Based on the extant theories highlighted in Figure 8, the EE discipline provides methods and approaches for *intellectual manageability, organisational concinnity and social devotion*, potentially mitigating most of the aforementioned concerns and limitations of the PJM. For example, the EE discipline (Dietz & Hoogervorst, 2012; Hoogervorst, 2018) provides the missing *step 0* related to Figure 26 by:

a. Setting up a Central Enterprise Governance (CEG) function.
b. The CEG is prescribed to have both operational (running the mill) and governance (changing the mill) competencies.
c. Running the mill entails building (implementing) while changing the mill entails the design function.
d. The CEG initiates, maintains, and manages the Inquisitive Process (IP) (see section 2.4.1).
e. The Inquisitive Process entails:
    i. Defining the strategic desirables and intent.
    ii. Identifying both the functional and constructional requirements.

iii. Discovering both the functional (black box properties or areas of concern) and constructional design (white box properties) of design domains.

Thus, the EE discipline provides an answer to the first and other highlighted issues. To this end, relevant aspects of the EE theories are applied, while other concepts of the same body of knowledge are tested as practical contribution from this study. An outcome is the design, development, and evaluation of the ESD-PRT based on DSR.

4.4 Functional and non-Functional Requirements for the ESD-PRT

As outlined in section 2.4.4 and applying concepts from EE as outlined in section 2.4.1, requirement elicitation sessions were held with research participants in the DCMs. To avoid ambiguity and vagueness, a codebook was incorporated into the elicitation process for clarity purposes. This section outlines the process and outcome of the requirement elicitation process.

4.4.1 Codes, Codebook, and Coding

According to Saldana (2016), using the Codebook is a multi-step *sense-making* venture that helps to capture insights and complex assumptions from a specific group or stakeholders. However, the codebook contains codes, which are tags for allocating units of definitions to distilled topics and excerpts of text extracted during a coding exercise. The codes (or themes) which may be assigned to words, phrases or sentences in a text or transcript, are operationalised by clear definitions to guide their applications (Decuir-Gunby, Marshall, & Mcculloch, 2011). Coding is a generative and iterative process for condensing unstructured data into themes and patterns for analysis (Saldaña, 2016). According to Guest et al. (2014), condensing raw data in this manner to extract both *implicit* and *explicit* ideas that are pertinent to the description of an inquiry is called thematic analysis. Therefore, the iterative development of a codebook provides the rigour and process necessary for consistencies in the description and interpretation of texts within a qualitative inquiry (Decuir-Gunby et al., 2011; A. Tashakkori & Teddlie, 2010). In line with the paradigmatic philosophy (pragmatic epistemology) of this research, a hybrid (dualism) of both the inductive (data driven) and deductive (theory driven) coding process and thematic analysis (Fereday & Muir-Cochrane, 2006) was employed. In addition to this, the critical realism ontological standpoint ensures that while current theoretical understanding provides some foundation through deductive coding, the participants' realities are clearly shown via the inductive coding process. Deductive coding is a top-down, theory driven process that develops themes based on research questions and existing frameworks, while inductive coding is a bottom-up approach whereby themes are derived from raw data (Decuir-Gunby et al., 2011; 2016).

4.4.2 Methods

As indicated in section 3.4.2, the mixed methods used interviews and questionnaires for the requirement elicitation process. The rigorous and comprehensive (though time consuming) procedure and techniques aim to ensure transferability and replicability to other local and metropolitan municipalities. Considering the study to be of importance to the municipalities, the municipal managers of all three DCMs gave approval and moral support to the study, while all participants signed informed consent forms ahead of any form of participation. Ethics approval was also obtained from the faculty of Engineering, Built Environment and Information Technology (EBIT) Committee for Research Ethics and Integrity. Employing a codebook is considered pertinent to remove ambiguity, gain clarity on design intention-related requirements, and ensure consistency in interpreting texts through cycles of coding and text re-examination. In general, the coding strategy and guideline provided by De Vries (2020) was followed.

4.4.3 Participants

As outlined in section 3.4.2, Figure 13 (repeated as Figure 27), and Table 15 (repeated as Table 28), the target population was divided into two broad strata – municipal employees and residents (non-municipal) employees. The stratification was necessary to avoid bias as municipal employees may show sympathy or loyalty to the municipality, which may affect their responses to the requirement elicitation process, even though efforts were made to mitigate this risk by assuring them confidentiality and anonymity.

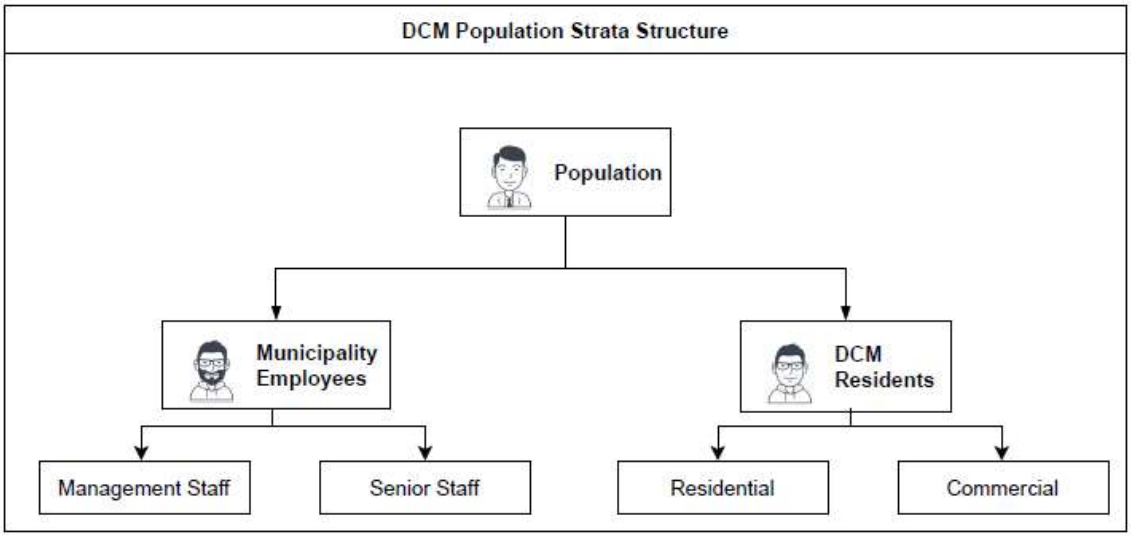


Figure 27: Stratification of Participants

The two strata are further subdivided into two other (sub)-strata each: municipal employees (senior and management staff) and residents (residential and commercial users). In total, over

a cumulative period of approximately 106 hours, 66 DCM respondents participated from the 3 DCMs, while four engineering students familiar with ESD participated in coding and codes validation.

Table 28: Participants by Stratum

	DCM 1	**DCM 2**	**DCM 3**
Municipality employees: • Management • Senior staff Response rate Municipality residents: • Commercial • Residential Response rate	**4** (of 4) 2 2 100% **15** (of 22) 5 10 68%	**4** (of 4) 2 2 100% **22** (of 25) 7 15 88%	**3** (of 3) 1 2 100% **18** (of 20) 4 14 90%
Total Participants	19	26	21
Grand Total	**66**		

Pseudonyms were assigned to all participants based on the following naming convention:

a. Demonstration Case Municipality 1 (Residential Consumer 1): DCM_CR1
b. Demonstration Case Municipality 1 (Commercial Consumer 1): DCM_CC1
c. Demonstration Case Municipality 1 (Provider Management 1): DCM_PM1
d. Demonstration Case Municipality 1 (Provider Senior Staff 1): DCM_PS1

The same convention applies to DCMs 2 and 3.

Although Morse (2000) recommends a minimum of 6 participants when making an inquiry into experience and requirements, Guest (2006) posits that twelve is a good sample size to expect thematic saturation. For this requirements elicitation process, we exceeded the minimum recommended number per DCM.

4.4.4 Developing the Codebook

The hybrid, dualistic approach to developing a codebook followed in this study (section 4.4.1) implies that the first cycle was conducted based on literature and initial research and on initial rounds of reading through the raw data. After the inclusion of initial codes, a priori by the codebook designer, the first *read throughs* of the raw transcripts was carried out, where a decision was made on what to code. Subsequent initial re-reading led to addition of new codes before the processes of collation and grouping of codes into themes, and further iterations. According to Boyatzis (1998), codes should be classified with code label, description, exclusions and examples from the raw data. The four engineering students were trained on how to code data and practised coding. Also, they were trained on how to use the selected Computer Assisted Qualitative Data Analysis Software (CAQDAS), called Delve (Delve, 2021). In

addition to that, and in line with the coding strategy outlined by De Vries (2020), they were re-introduced to the ESD in the context of this study but without over-explaining the concepts.

4.4.5 Results

Creating a codebook from the size of our transcripts is complex and time-consuming, hence the engagement of four engineering students familiar with the ESD but with divergent viewpoints as revealed in the initial coding. Individual codes developed by the coders during the first iteration showed few disparate interpretations for the transcripts leading to inconsistencies in the coding protocol. This was dealt with by making sure that definitions were precise without compromising the constructs that needed to be captured. For example, we had to reduce the definition of "availability" of electricity to household level based on disagreement from the coders on a paragraph of the transcript from DCM1_CR10:

Generally, in my area, electricity is available. It is there. You apply for it at the municipality, you ask them, and they tell you how much. So, it is there.

A coder had excluded this excerpt from any concern since electricity is *available*, while another coder argued that electricity availability at the municipality level does not translate to electricity availability at household level. Upon this argument, the definition of "availability" was reduced to mean availability at the house level since many things may go wrong between the municipality distribution centre (mini substation) and a consumer. Given this and similar experience, the process was then changed to coding as a group during the second iteration, guided by De Vries (2020). Section 4.4.5.1 outlines the outcome of the first iteration.

4.4.5.1 First Iteration

The initial codebook, designed by the codebook designer (researcher), was presented to the coders, who in turn performed descriptive and process content coding (Miles, Huberman, & Saldana, 2014) to extract ESD areas of concern and ESD-PRT requirements based on the narrative that clarifies the research context. The cloud based CAQDAS (Delve, 2021) allows real time collaboration of multiple participants. Figure 28 is a screenshot of the initial codebook, while Appendix 6 shows the detailed codebook. The codebook designer made conscious efforts to ensure an atmosphere of productive engagement and constructive criticism, declaring that no question is too small (or big) to clarify any aspects of the texts presented to them.

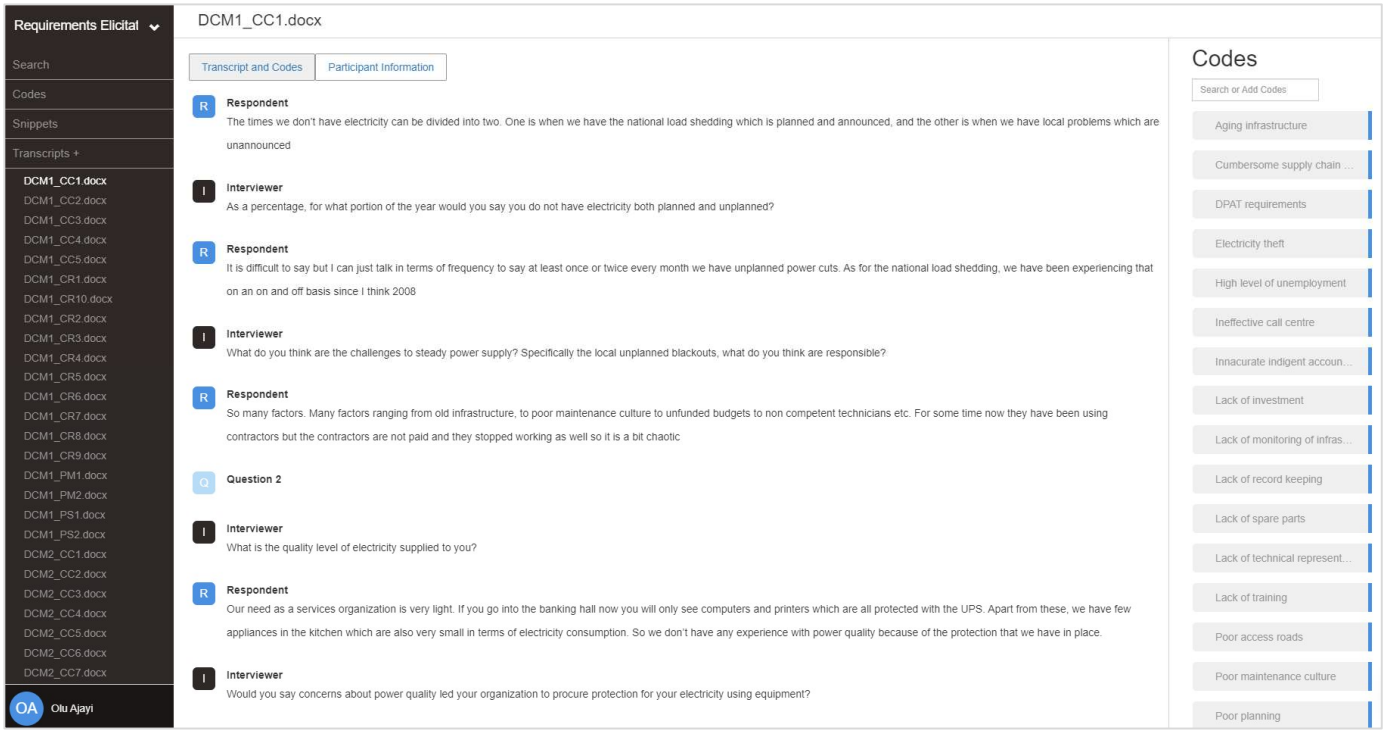
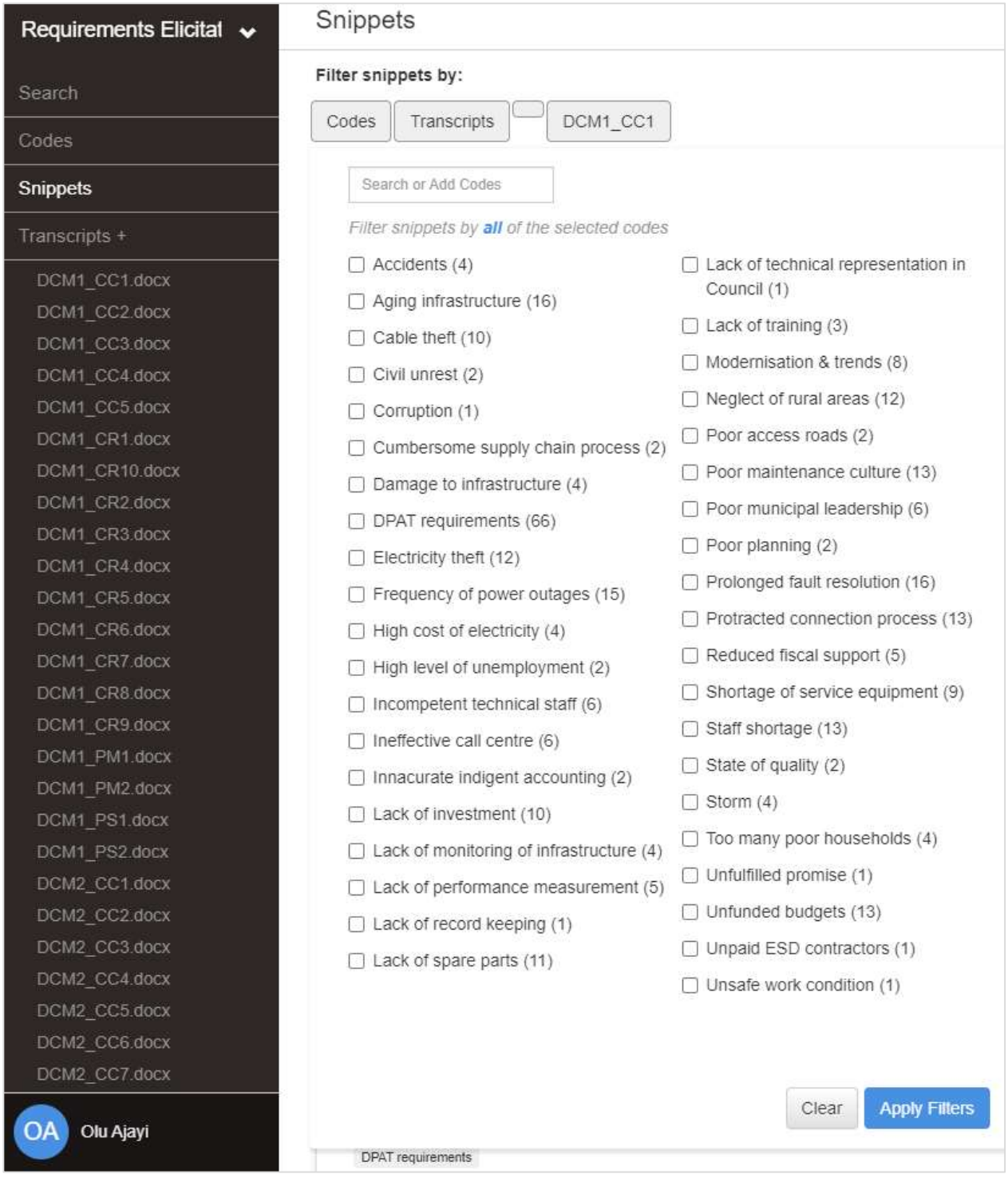


Figure 28: Initial Codebook

During this initial individual coding process, coders' queries were addressed, and changes to the initial codebook as highlighted in section 4.4.5 were communicated to all participants who could view the changes on Delve. After the coding, they committed (submitted) their changes which propagated in real time on Delve for the attention of the codebook designer, who analysed the outcome for disparities and conformity to the narrative. In all, the first iteration consisted of 40 codes (initial areas of concern and ESD-PRT requirements), which included 27 deductive (theory driven) and 13 inductive (data driven) codes. Table 29 shows a consolidated view of these codes (the full code list is attached as Appendix 6), Table 30 shows an excerpt of the codebook based on Boyatzis (1998), while Table 31 outlines clarifications and improvements made to update the codebook before the second iteration.

Table 29: Initial codebook - Codes



For each code label, the CAQDAS coding scheme allows the input of initial thoughts and description, exclusions and examples, as shown in Table 30.

Table 30: Excerpts from the initial codebook

Code label	Definition	Exclusions	Examples
Aging infrastructure	PSR and infrastructure that are old and at the end of their useful lives	Old PSRs that are used as backups (redundancy)	*Some or most of our equipment are very old. If there's a problem on any of them, we may not be able to get the exact parts required since they are no longer manufactured.* DCM1_PS1
Lack of investment	Shortage of funding for PSR and infrastructure	Infrastructure for other areas of service delivery such as water, and sanitation	*The municipality has not been investing in distribution infrastructure for many years ……..thereby putting pressure on the existing infrastructure.* DCM2_PM1
Accidents	Vehicles accidentally colliding with & damaging PSR and damages caused by other natural causes	Damages caused by illegal connections and cable theft	*They are many, ranging from a bird bridging a line to a heavy storm and flooding or a truck hitting an electric pole*…….DCM3_PS2
ESD-PRT requirements	Functional and non-functional requirements for the ESD-PRT development	Integration to municipal systems	*User friendly interface which does not need any major learning to use…..reliability in terms of availability and uptime……..simplicity….the last one will be support*…..DCM1_CC1

Clarifications and improvements made to update the codebook before the second iteration are contained in Table 31.

Table 31: Clarifications and Improvements to Initial Codebook

Issue	Participant	Coder	Adaptation
The word *availability* is interpreted in a vague and general sense to mean availability of electricity in the municipality	DCM1_CR10	2	Codebook description has been updated to indicate that *availability* refers to electricity availability at the household or business level
The phrase *quality of electricity supply* omitted as it is not deemed as an area of concern	DCMs	1,2,3,4	Quality of supply (QoS) created as a code and described as a steady supply of electricity (voltage, amperage, frequency) with no damaging impact on household or business equipment
Coders' classification of *accident* differs	DCM1_CR1, DCM1_CR7, DCM2_PS1	1,3	Include any form of accident negatively impacting the uninterrupted supply of electricity under the code accident
The phrase *civic unrest* was interpreted as all forms of public protest actions	DCM1_CR4	1	Do not code as *unrest*, if the protest action is not ESD related
The phrase *indigent accounting* is classified as accounting for rural households that cannot pay for electricity	DCM1_CC4	3	Definition updated to include both rural and urban households too poor to pay for electricity
ESD-PRT requirement contains 66 snippets	DCMs	1,2,3,4	Create sub-codes under the ESD-PRT requirement to cluster functional and non-functional requirements

Similarly, other minor problematic codes were discussed and redefined, while technical ESD languages were, where necessary substituted to plain language.

4.4.5.2 Second Iteration

As indicated in section 4.4.5 and guided by De Vries (2020), upon the update and adaptations made to the codebook, the codebook designer and the coders now coded as a group, forming a focus group moderated by the codebook designer. The group therefore comprised of 4 participants (coders) and a moderator (codebook designer). This second iteration aims to re-code the text according to the updated codebook until thematic saturation is achieved. According to Hoogervorst (2018), the inquisitive process is deemed complete when, for a given narrative, there is a high level of agreement and clarity. For the second iteration, coding and recoding were done in an interactive and iterative manner until agreement was reached among the focus group participants on the coding results and themes, with no new codes emerging. By consensus, some additional changes to the codebook include:

a. Merging of *cable theft* with *electricity theft*
   Rationale: They are both theft and yield the same outcome
b. Merging of *unfunded budget, reduced fiscal support and lack of investment,* and renamed *financial difficulty*
   Rationale: They all refer to shortage of funds, indicating financial difficulty
c. Merging of the *storm* with *accidents*
   Rationale: They are both unplanned events, leading to the same outcome
d. Merging of *poor municipal leadership* with *corruption*
   Rationale: The excerpts linked municipal leadership (only) to corruption
e. Dropping of *lack of records*
   Rationale: Lack of representation
f. Dropping of *lack of technical representatives*
   Rationale: Lack of representation
g. Dropping of *unsafe work condition*
   Rationale: Lack of representation
h. Dropping of *unpaid ESD contractors*
   Rationale: Lack of representation

Emerging themes and areas of concern are outlined in Table 32.

Table 32: Emerging Themes and Areas of Concern

Performance Areas as Codes	Areas of Concern as Sub-codes	Frequency
Financial difficulty	• Unfunded budgets • Reduced fiscal transfers • Lack of investment	28
Availability of power	• Theft • Accidents • Ageing infrastructure • Damage to infrastructure • Civic unrest • Poor access to roads • Poor planning • Poor municipal leadership • High level of unemployment • High cost of electricity • Inaccurate indigent accounting • Lack of spare parts • Neglect of rural areas	67
New connections	• Staff shortage • Protracted municipal process • Cumbersome supply chain process • Poor households (rural & urban) • Poor municipal leadership • Unemployment rate • Lack of spare parts • Shortage of service equipment • Modernisation & trends • Ineffective call centre	39
Fault resolution	• Staff shortage • Prolonged municipal operations • Lack of performance measurement • Incompetent technical staff • Lack of spare parts • Shortage of service equipment • Damage to infrastructure • Lack of training • Modernisation & trends • Poor access to roads • Poor maintenance culture • Ineffective call centre	44
Quality of supply	• Frequency of power outages	17
Quality of maintenance	• Poor maintenance culture • Ageing infrastructure • Lack of spare parts • Lack of infrastructure monitoring • Lack of performance measurement • Poor municipal leadership • Shortage of service equipment	12

An example of how this information was extracted from the CAQDAS (Delve) is presented in Figure 29, while Table 33 shows an excerpt of classification into design domains from where they may be addressed.

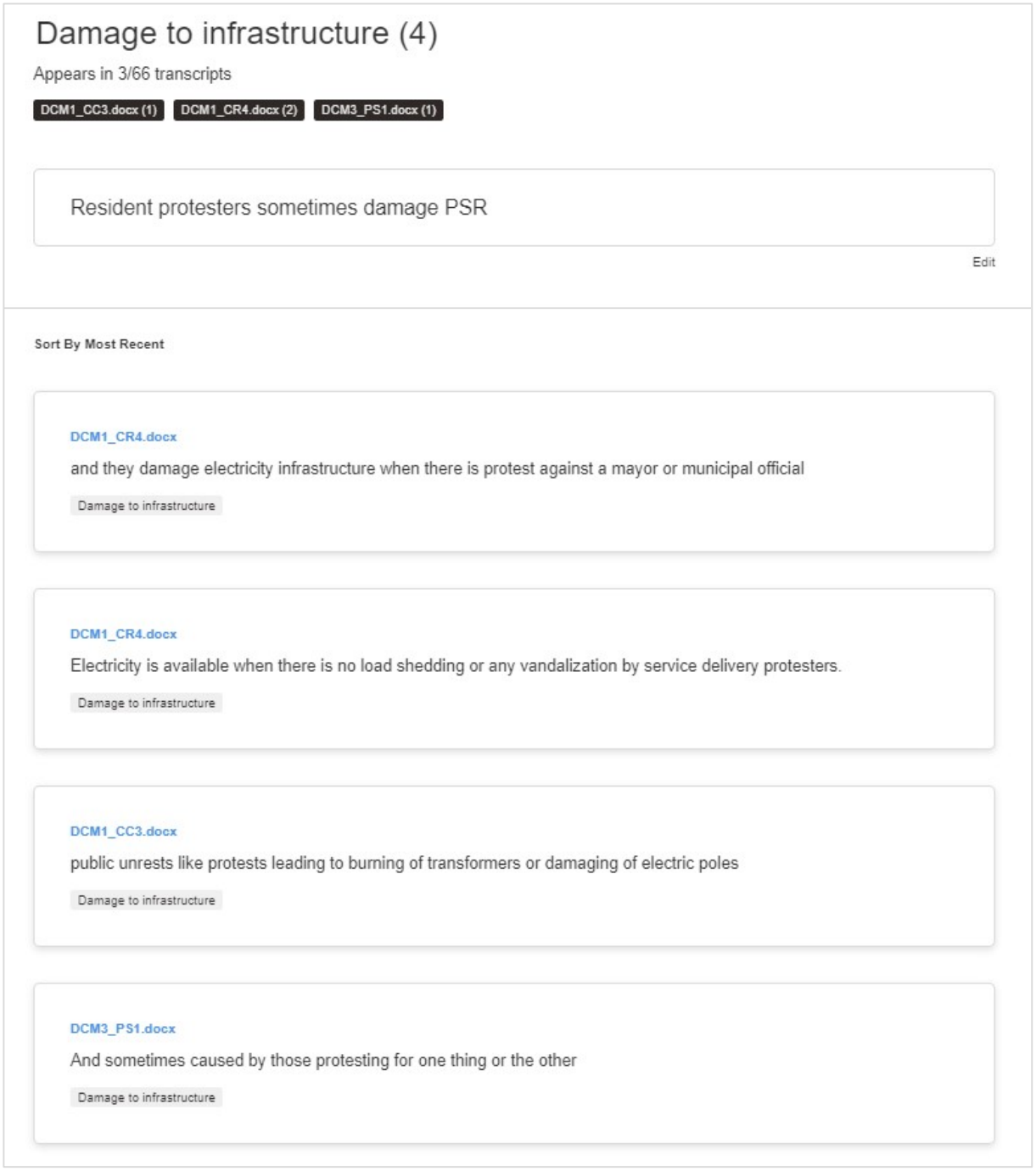


Figure 29: Extraction of Themes as Performance Areas & Areas of Concern

4.4.5.3 Enterprise Design Domain Classification

Since the extracted areas of concern are *desirables* that must be realised through design within specific design domains, they are further classified according to design domains to aid the establishment of requirements and definition of design principles. However, the levels and demarcation of design domains are not universally defined (Bernard, 2005; De Vries et al., 2017; Hoogervorst, 2018), meaning there is yet to be a consensus on their classification. Four

domains that can be identified in Hoogervorst's (2018) approach are business, organisation, information and information technology. Given the supposition that consensus in this context would be beneficial (Hoogervorst, 2017; Lapalme, 2017), De Vries (2017), citing a previous study that suggested certain difficulty with Hoogervorst's classification, proposed four alternative enterprise design domains, namely Organisation, ICT, Infrastructure, Human skills and know-how domains. Table 33 shows the classification based on De Vries (2017).

Table 33: Design Domain Classification of *Areas of Concern*

Based on De Vries (2017)

ICT Domain (Software/Hardware) • Infrastructure monitoring • Electricity & cable theft tracking • Call centre services • Indigent accounting • Planning tool • Municipal connection process automation • Supply chain process automation • Inventory management system • Performance measurement system	**Organisation Domain** • Infrastructure monitoring • Infrastructure upgrade • Electricity & cable theft tracking • Call centre operations • Accident mitigation • Leadership development • PSR monitoring • Accounting operations • Planning • Inventories • Supply chain process optimisation • Maintenance approach • Training needs • Staff complement • Quality of service
Infrastructure Domain • Maintenance planning tools • Infrastructure health • Access to roads • Service vehicles & equipment	**Human skills and know-how Domain** • Personnel qualifications • Training needs
Other Enterprise Constructional Facets • Maintenance culture	

According to Hoogervorst (2018), appropriate design of design domains and mature operation and management within design domains should address key performance areas/areas of concern. Table 33 shows design related factors (deficient design) as well as operating-and-management related factors that need to operationalise certain performance areas. Interrelationships and multi-level interconnectedness across domains exist, but they are not shown in Table 33.

4.4.5.4 ESD-PRT Requirements

Further to the identification and extraction of performance areas in section 4.4.5.2, requirements for the ESD-PRT were interpreted, defined, and grouped into the external interface, functional and non-functional requirements by the focus group as shown in Table 35 (Table 34 is the generic information systems requirements indicated by performance areas). Based on the identified areas of concern, requirements from an Information Systems (IS) perspective represent what the system users *want* and *need,* meaning, *what* the ESD-PRT must manifest.

Repetitions, where multiple participants required the same or extremely close requirements, are avoided, and unique participants are identified for traceability to the codebook. Due to strict government regulations and requirements concerning application developments (solution design, solution development, and solution deployment), information management, and personal computing devices, additional mandatory technical requirements have to be followed without compromising users' requirements. The additional (government) requirements, as they affect this study, are contained in the SRS located in Appendix 5. The guidelines (De Villiers, 2020a, 2020b; SITA, 2020) are published by State Information Technology Agency (SITA), the South African government business entrusted with consolidating and coordinating State's information technology resources for improved interoperability and capability. Other documented requirements are derivatives (construction) of user requirements which are in the SRS. For example, where a user desires (*wants* or *needs*) a secure login (functional desirability, i.e. the *what*) but does not specify its operationalisation (constructional realisation, i.e. the *how*), such is derived as part of the design process.

Other constructional aspects are outlined in Chapter 5 (Constructional Components for the ESD-PRT) and the SRS, guided by the Institute of Electrical and Electronics Engineers' (IEEE) guideline (1984) to Software Requirements Specifications (IEEE Std 729-1983, ANSI/IEEE Std 730-1981).

From an information systems perspective, the generic requirements, driven by the performance areas, are outlined in Table 34, while Table 35 focuses on detailed information systems requirements.

Table 34: Generic Information Systems Requirements Indicated by Performance Areas for ESD-PRT

Main Design Domain	Performance Area	IS Requirement Indicated per Performance Areas
Organisation	Financial difficulty	Excluded (Confidential government information)
	Availability of power	Monitor, assess & report on organisational competencies
		Monitor, assess & report on the health of PSR
	Quality of supply	Monitor, assess & report on the health of PSR
		Monitor citizens' (consumer) perception of quality
ICT	Fault resolution	Link call centres to technical services department
	Quality of maintenance	Spare part inventory management system
		Monitor & report MTTR and MTBF
Organisation of Infrastructure	New connections	The municipality must track the evolution & development of new households & businesses vs available power/infrastructure
		Monitor the health of service equipment
Organisation of Human Skills & Know-how	Quality of maintenance	Develop training needs analysis (TNA) & monitor implementation
	Fault resolution	

The ESD-PRT is new; hence requirements elicitation is absolute, not relative to an existing system or similar solution. The requirements, as shown in Table 35, are drawn from the codebook, which was derived from direct interviews with the DCM participants. As outlined in section 4.4.4, the codebook is useful in requirements elicitation as it enabled the extraction of both implicit and explicit design intentions from the transcripts.

Table 35: Detailed ESD-PRT Information Systems Requirements

Quote	Interpretation	Requirement		
		External Interface	Functional	Non-Functional
I mean an interface that is not busy with too many colours and information. DCM1_CR4.	Simple, Clear, Concise	**X**		
As long as it is user-friendly, it should be fine. DCM1_PS1	Intuitive, Efficient, Familiar	**X**		
Clear and clean interface. DCM1_PM2	Clear, concise	**X**		
User friendly interface which does not need any major learning to use. DCM1_PM1	Intuitive, Efficient, Familiar, Consistent	**X**		
Just attractive so that people will be motivated to use it. DCM2_CR8	Intuitive, Attractive	**X**		
Standard stuff, something that can be easily understood since it is for everybody, I assume. DCM3_CR6	Intuitive, Efficient, Familiar, Consistent	**X**		

Quote	Interpretation	Requirement		
		External Interface	Functional	Non-Functional
It must be simple and not confusing. DCM2_CR4	Simple, Clear	**X**		
….and it is very easy to use for people who are not very educated. DCM3_CR1	Intuitive, Efficient, Familiar, Consistent	**X**		
It must clearly show their theme, corporate identity, and logos basically. DCM1_CC1	Visual hierarchy, Familiar, Consistent	**X**		
Reports on the equipment. It is the equipment that is used to distribute power. DCM2_CR4	Condition assessment and reporting of PSR		**X**	
If it can show maintenance culture…..if you remove poor maintenance, most of our problems will be gone. DCM1_CR8	Trend analysis of maintenance records		**X**	
It must be secure without leaking out municipality data. DCM3_PS1	Cyber & digital information security			**X**
……if it shows the condition of our infrastructure and the amount needed to maintain or refurbish…… DCM3_PS1	Condition assessment and reporting of PSR with costing		**X**	
*The first report must show the condition of our electrical assets for everyone to see….management does not know…..*DCM2_PS2	Condition assessment and reporting of PSR		**X**	
…..it must be hosted in the cloud to see it whether we are at work or home. DCM3_PM1	Hosting			**X**
*Just performance of the technical section….it will be great to incorporate their maintenance plan on the system so that…….*DCM1_PM1	Organisational competency assessment and reporting. Maintenance plan broadcast.		**X**	
A functionality showing the challenges that the municipality is facing. DCM2_PM1	Organisational competency assessment and reporting. Condition assessment and reporting of PSR		**X**	

Quote	Interpretation	Requirement		
		External Interface	Functional	Non-Functional
The platform must always be up and running.....DCM1_CR8	Reliability and Availability			**X**
....and must not leak out people's identity. DCM1_CR8	Security, anonymity, confidentiality			**X**
I would personally like to see how they are performing with services. DCM3_CR3	Organisational competency assessment and reporting.		**X**	
....doing this research in 3 municipalities, we would like to compare our municipality to other municipalities maybe...DCM2_CR2	Benchmark study		**X**	
.....then it must show us how the municipality is performing. In future, we also want you to do the same thing for water, not just for electricity. DCM1_CR7	Organisational competency assessment and reporting. Portability		**X**	**X**
……not too complicated and user friendly like the banking App. DCM2_CC5	Ease of use. Usefulness			**X**
.....interactive.....can add other municipalities in the entire country. DCM2_PM1	Scalability			**X**

4.5 Chapter Conclusion

The need for an ESD-PRT for electricity service delivery is further illustrated from local and international perspectives in Chapter 4. This is heavily underpinned by South African government records showing poor performance of electricity service delivery due to several reasons, including lack of performance assessment and monitoring.

A global search for diagnostic service performance assessment tools revealed a battery of tools. Still, these must satisfy specific local criteria and context to be deemed useful for the South African environment. These criteria were validated and tested against the tools to select, through a scientific method (the AHP), the most appropriate for the South African state. Yet, the selected tool, the PJM, falls short of some critical considerations, leading to a design process to design one for the local context. Also, Phase 2 (implemented in this chapter 4) sets out to understand the objectives and requirements of the artefact. Both functional and constructional requirements were therefore extracted from 66 participants from the DCMs and are outlined in

Tables 34 (per performance area) and 35 (for external interface, functional and non-functional requirements). Given the iterative coding process and cycles, which ensure that each performance area was explored until no new information is generated, it can be assumed that the goal of phase 2 is achieved. Through independent demonstration and evaluation of the artefact, how well it meets the requirement and the outcome of meeting the requirements are documented in Chapters 6 and 7.

Next, Chapter 5 deals with the objective systems properties and ontological aspects of the ESD-PRT, that is, its constructional parts.

Chapter 5 Constructional components of ESD-PRT

This chapter details design aspects for the physical manifestation of the ESD-PRT. As demonstrated in Chapter 4, migration from the functional desirability (*what*) to constructional manifestation (*how*) presented in this chapter emerged through cycles of social engagements and interaction (the inquisitive process) with multiple stakeholders across a wide geographical horizon (citizens in three DCMs) but within the same context. The chapter, therefore, answers RQ5, which is repeated here:

RQ5: What are the constructional components of the new performance assessment/reporting tool?

As indicated in Figure 30, this chapter focuses on *phase 3* of the DSRM process.

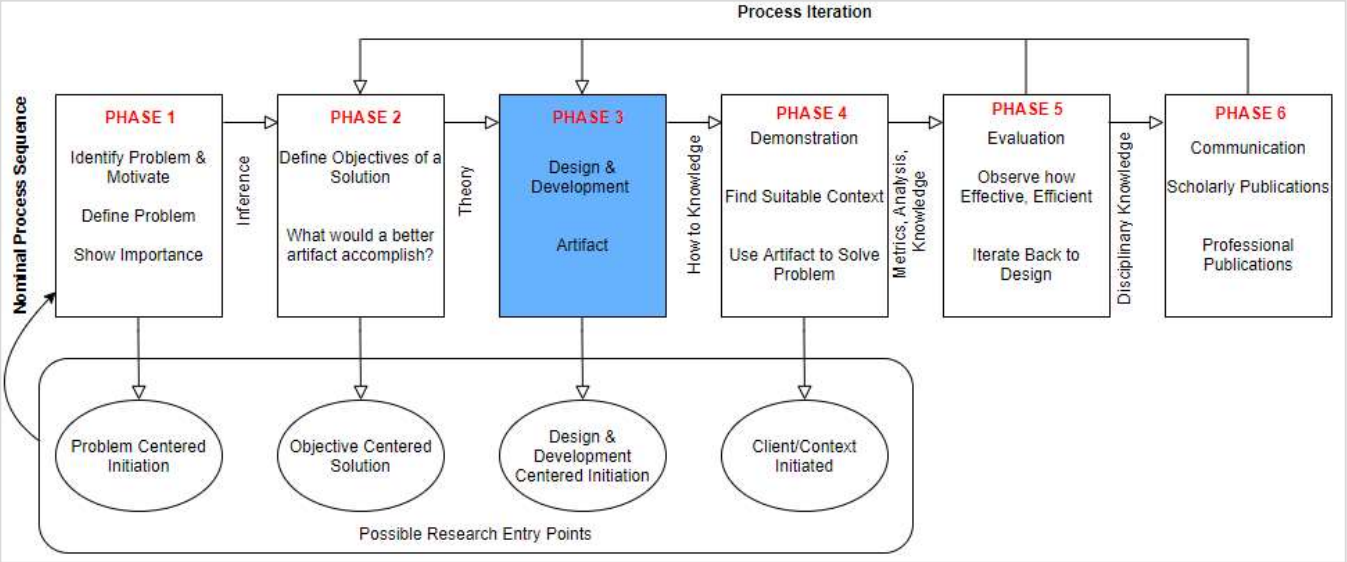


Figure 30: DSRM Process for the ESD-PRT, focusing on Phase 3

(Peffers et al., 2008)

5.1 Constructional Decomposition of the ESD-PRT

This section provides a structural decomposition of the ESD-PRT and its relationship with its users. To operationalise the functional requirements in Chapter 4, some of the constructional parts required include application programs, web and application servers, databases, technology clients and network. Details of the operationalisation of each construct are contained in the SRS (Appendix 5) and represented by an essential model in section 5.2. The constructs are embedded in the web interface model shown in Figure 31.

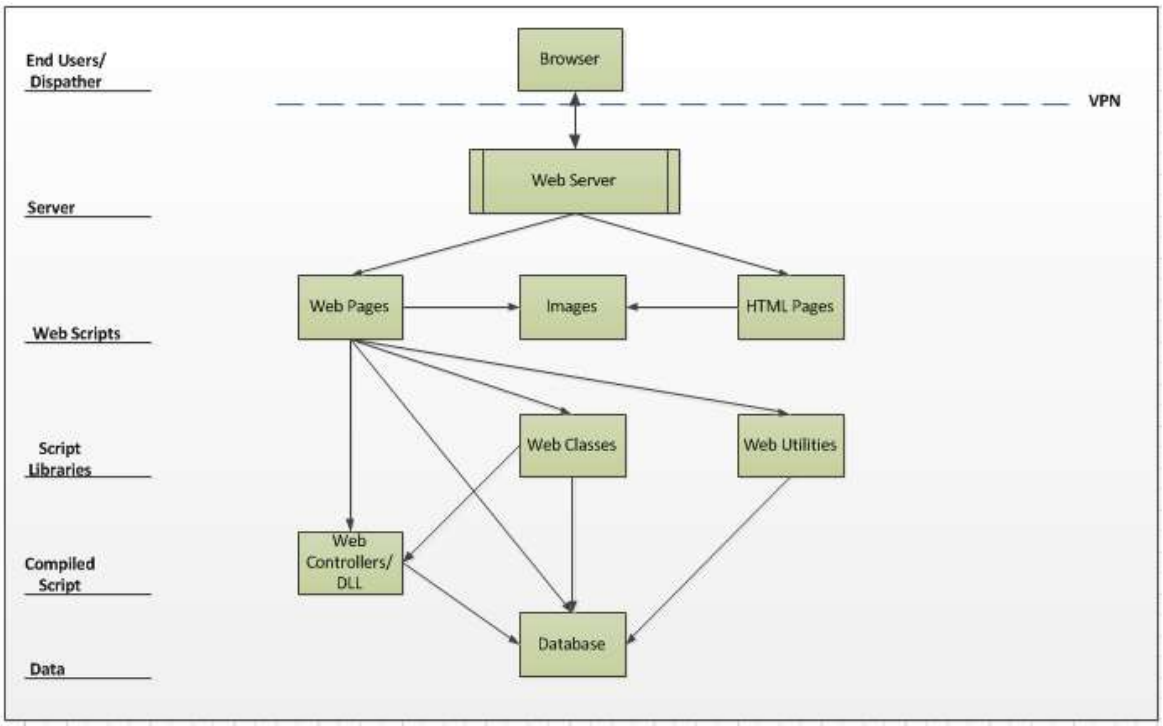


Figure 31: ESD-PRT Web Interface Construction Diagram

Data acquisition constructs follow the ETL (Extract, Transform, Load) method aligned with users' functional requirements and government guidelines for application development, information management, and personal computing devices. Figure 32 is a process flow diagram of the ETL method, while Figure 33 shows its application in 3 logical ESD-PRT layers, i.e. Extract (data mapping), Transform (Business logic), and Load (presentation).

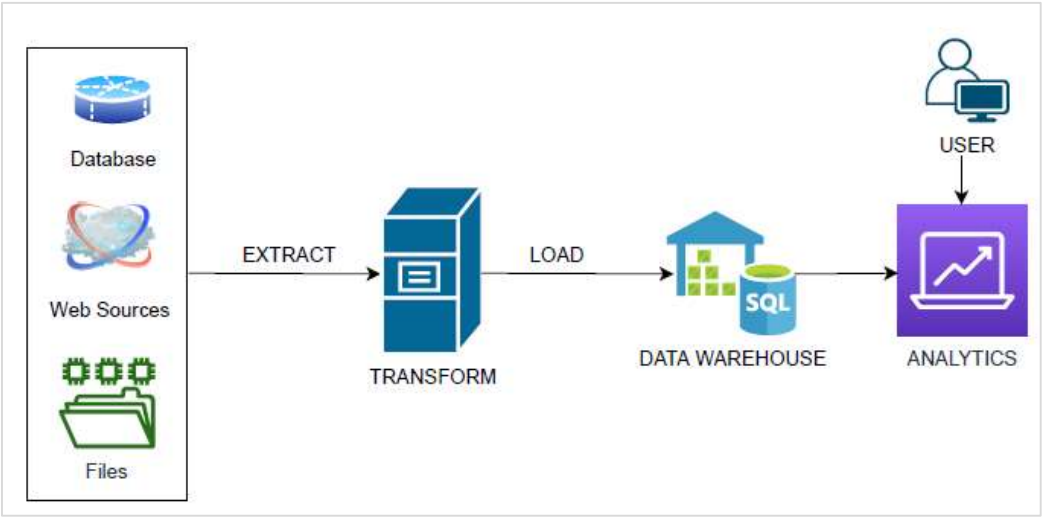


Figure 32: ESD-PRT ETL Construction Method

In general, the *extract*, *transform*, *load* construction ensures data:

a. Auditability
b. Integrity
c. Recoverability
d. Predictability
e. Flexibility

Figure 33 is a block diagram of the three core aspects of the ESD-PRT, covering users' (citizens) perspective, infrastructure health, and organisational competencies. Detailed methods for each layer are contained in the SRS but are briefly explained in this section.

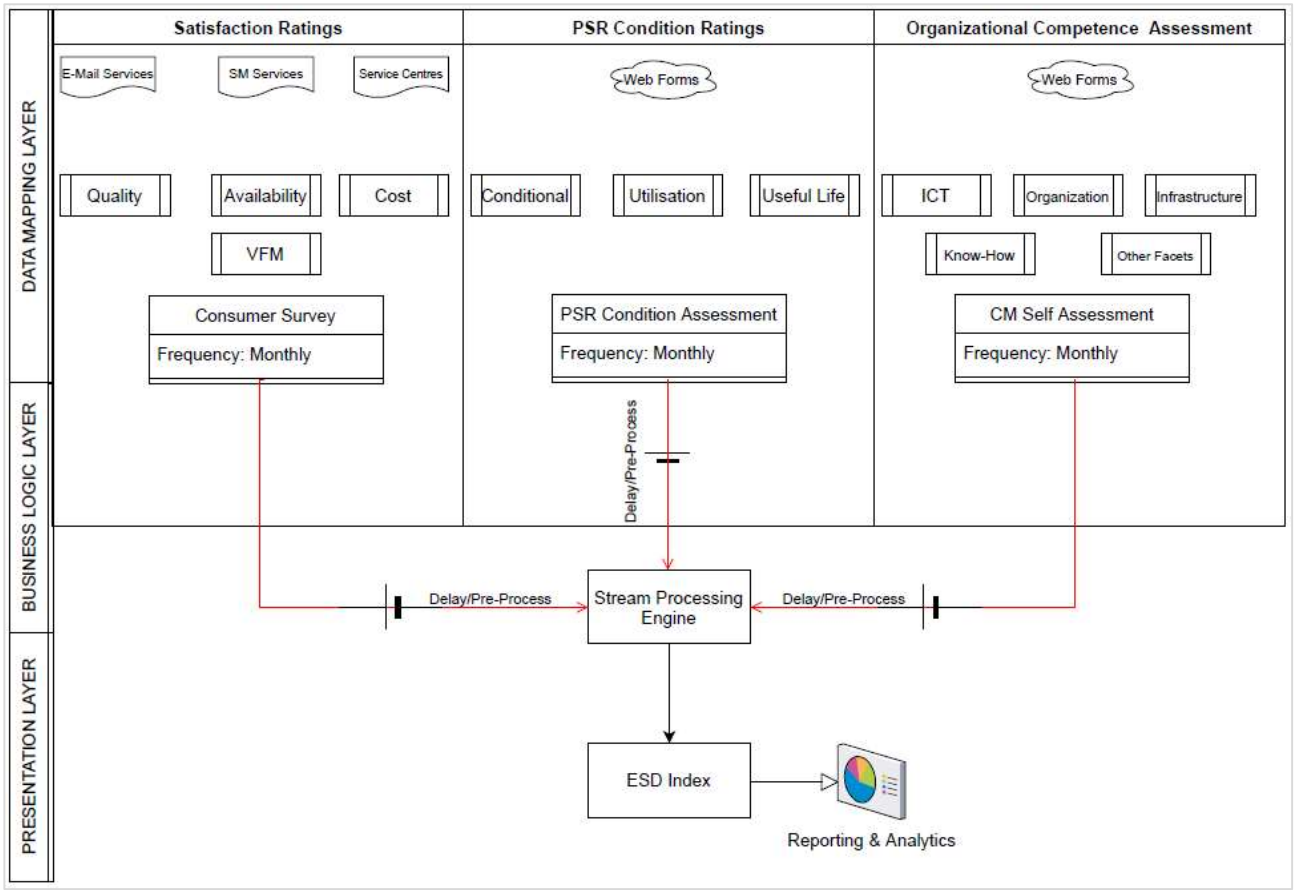


Figure 33: ESD-PRT Logical Aspects Block Diagram

5.1.1 Satisfaction Ratings

Citizens (consumers) require their voices to be heard. Electricity service delivery is for and about them. It is, therefore, necessary to consider them in assessing and reporting electricity service delivery performance. Government reports (Maluleke, 2019) and evidence from this research (Chapter 4) have shown that mere access to electricity does not guarantee citizens happiness and satisfaction. Citizens have indicated that, beyond having access to electricity,

they would like to have less frequent power cuts, reduced duration of each power cut, affordable electricity, value for money, faster turn-around times for new household/business connections, speedy fault resolution, an effective municipality call centre, competent municipal technical personnel, focus on rural electrification, and modernisation of municipality services and processes. Therefore, the ESD-PRT takes citizens' input in monthly diagnostic assessment and reporting of electricity service delivery for DCMs 1 to 3.

Registered citizens log in to the ESD-PRT after paying for electricity every month to conduct the short survey, which may be accessed via any web browser as required by the citizens. Citizens' experience r*ed flag* areas, i.e. areas of concern showing the most neglect, are highlighted and flagged on the ESD-PRT. There are rules and business logic within the ESD-PRT construction to ensure a citizen cannot submit more than one survey per month.

Examples of how some of the scores are computed are shown below per month:

$$Availability\ Score\ (AS) = \sum_{fi=1}^{n} a_{fi}/n$$

$$Quality\ Score\ (QS) = \sum_{fi=1}^{n} q_{fi}/n$$

$$Cost\ Score\ (CS) = \sum_{fi=1}^{n} c_{fi}/n$$

The *f* represents the web form (survey), and *n* is the last form for the month.

Satisfaction rating (SR) aggregates averages of the parameters = (AS + QS + CS)/n_p, where n_p is the number of parameters surveyed.

Although large sample sizes are desirable, it can be problematic to achieve in this environment on a permanently ongoing basis given that respondents (citizens/consumers, municipality technical employees and municipality management) complete the survey as volunteers. Although DCM2 has indicated its intention to make the ESD-PRT a permanent feature on its website, it may only make the survey mandatory for its staff, while citizens participation will continue to be voluntary. Given that better statistical results are achieved with larger sample sizes, a minimum sample size rule was created to analyse the survey data, giving the user the opportunity to use their data range. For normally distributed data, many authors (Aron, Coups, & Aron, 2013; Bujang & Adnan, 2016; Crawley, 2014; Hertzog, 2008; Jenkins & Quintana-Ascencio, 2020; Perezgonzalez, 2015) agree that a general rule for a minimum of 30 as sample

size is reasonable to make any meaningful statistical conclusion. Otherwise, estimations for power could be more precise but with the risk to overestimate or underestimate the required sample size. In this instance where consumers are not obliged to complete the survey, estimating effect sizes and sensitiveness would be problematic; hence the minimum sample size rule is adhered to, even then, this is still a high target given that local municipalities have fewer human resources to complete the organisational surveys, and minimum financial resources to incentivise their citizens to complete the survey.

5.1.2 PSR Condition Ratings

As derived from the requirement elicitation process, both the municipal personnel (provider) and the general citizens (consumer) are interested to know the health of PSR. This is also surveyed once a month by municipality technical services via online forms, which are equally available on their mobile devices for field assessments. Performing this condition survey would assist the municipality to:

a. Discover defective electrical assets
b. Ascertain impairment of assets
c. Determine remaining useful life (RUL) of assets
d. Discover reasons behind the poor performance of underperforming assets
e. Plan for the appropriate maintenance or refurbishment requirements
f. Consolidate assets' failure statistics.

While PSR condition assessment is not a panacea to ESD performance, not knowing the condition of an asset will lead to a very costly premature failure. The following PSR under the DCMs jurisdiction for distribution are therefore condition assessed once a month:

a. Medium Voltage Substation:
    i. Mini substations
    ii. Transformer substations
    iii. Switching substations
b. Medium Voltage Network:
    i. MV lines
    ii. MV switching equipment
c. Low Voltage Network
    i. LV lines
    ii. LV switching equipment

d. Service Connections:
    i. Overhead
    ii. Underground
e. Energy Meters:
    i. Conventional
    ii. Prepaid

The scoring scale, which is aligned to The World Bank indicators for monitoring the performance of electric utilities (Tallapragada et al., 2009), is shown in Table 36.

Table 36: Scoring Scale – PSR

Scale	Description	Detailed Description
5	Excellent	New, sound structure or appearance that is well maintained. Continue with normal scheduled maintenance.
4	Good	Performance is acceptable with minor deterioration visible. Normal scheduled maintenance continues.
3	Fair	Some evidence of deterioration. Minor maintenance may be required.
2	Poor	Significant deterioration in structure or appearance. Major repairs or upgrade is required.
1	Very poor, scrap or retire	Not functional, unusable, fully deteriorated. Needs reconstruction, replacement, or disposal.

Figure 34 is a screenshot of the same functionality on the tool.

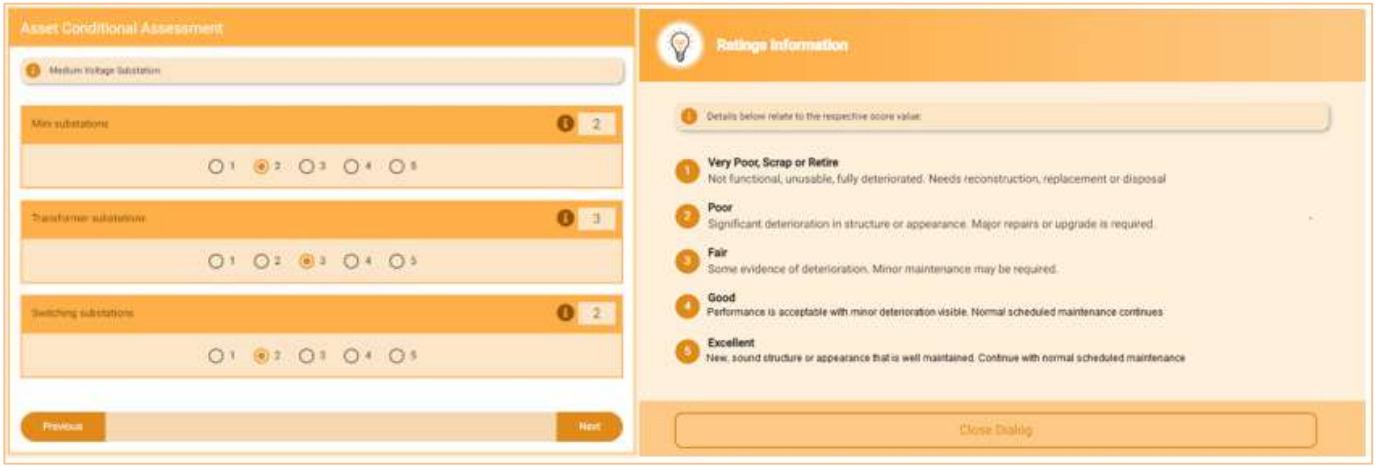


Figure 34: Scoring Scale on the ESD-PRT - PSR

5.1.3 Organisational Competency Assessment

The organisational performance areas are equally assessed by municipal management once a month. Few of the areas as extracted in Chapter 4 are:

a. Infrastructure monitoring
b. Electricity theft tracking

c. Personnel qualifications and training
d. Call centre operations

Again, the scoring is guided by the World Bank electric utility indicators (Tallapragada et al., 2009) but organized into design domains according to functions that the municipality participants can relate with, as extracted during the RE process. An example of the financial operations (functional area) is shown in Table 37 while the full scope of assessment is outlined in Appendix 2.

Table 37: Scoring Scale for Organisational Competency

Function	Design Domain	Rating	Performance Area that will be affected
Financial operations	Organization	0 (None): No funding/fiscal transfer/investment policies/processes at all 1 (Basic): Poor funding/fiscal transfer/investment policies/processes 2 (Intermediate): Good funding/fiscal transfer/investment policies/processes but require improvement 3 (Advanced): Adequate funding/fiscal transfer/investment policy/processes 4 (Highly Advanced): Superior funding/fiscal transfer/investment policy/processes	Budgets (Actual – Funded budget) Fiscal transfers (Expected – Actual transfer) Investments (Expected – Actual investment) Unit: ZAR (South African Rand)
	ICT	0 (None): No ICT in use for funding/fiscal transfer/investment processes at all 1 (Basic): Poor ICT in use for funding/fiscal transfer/investment processes 2 (Intermediate): Good ICT in use for funding/fiscal transfer/investment processes but requires improvement 3 (Advanced): Adequate ICT in use for funding/fiscal transfer/investment processes 4 (Highly Advanced): Superior ICT in use for funding/fiscal transfer/investment processes	
	Infrastructure	0 (None): No facilities to perform funding/fiscal transfer/investment processes 1 (Basic): Poor facilities to perform funding/fiscal transfer/investment processes 2 (Intermediate): Good facilities to perform funding/fiscal transfer/investment processes but require improvement. 3 (Advanced): Adequate facilities to perform funding/fiscal transfer/investment processes 4 (Highly Advanced): Superior facilities to perform funding/fiscal transfer/investment processes	
	Human Skills & Know-how	0 (None): No human actors to perform funding/fiscal transfer/investment processes 1 (Basic): Incompetent humans perform funding/fiscal transfer/investment processes	

Function	Design Domain	Rating	Performance Area that will be affected
		2 (Intermediate): Competent humans perform funding/fiscal transfer/investment processes but require improvement 3 (Advanced): Adequate human competencies available to perform funding/fiscal transfer/investment processes 4 (Highly Advanced): Superior human competencies available to perform funding/fiscal transfer/investment processes	

In terms of the organisational competency, the PSI theory has been followed to clarify and interpret the construction and operation of the DCMs, that is, how human actors (such as employees and suppliers) follow a transaction pattern when they coordinate their actions on performing production acts. A basic ESD transaction pattern can be typified by a citizen (initiator) applying for electricity connection or reconnection, while the municipality technician (executor) will make certain that the property or household is connected or reconnected, declaring categorically that the production act (or service) is done, after which the citizen accepts the result. This ontological foundation and perspective informed the structure of the RE process whereby both the citizens/consumers and DCM employees/providers were interviewed to decompose the interaction patterns as condensed in the codebook.

Figures 35 and 36 are examples of scoring scales on the ESD-PRT per design domain.

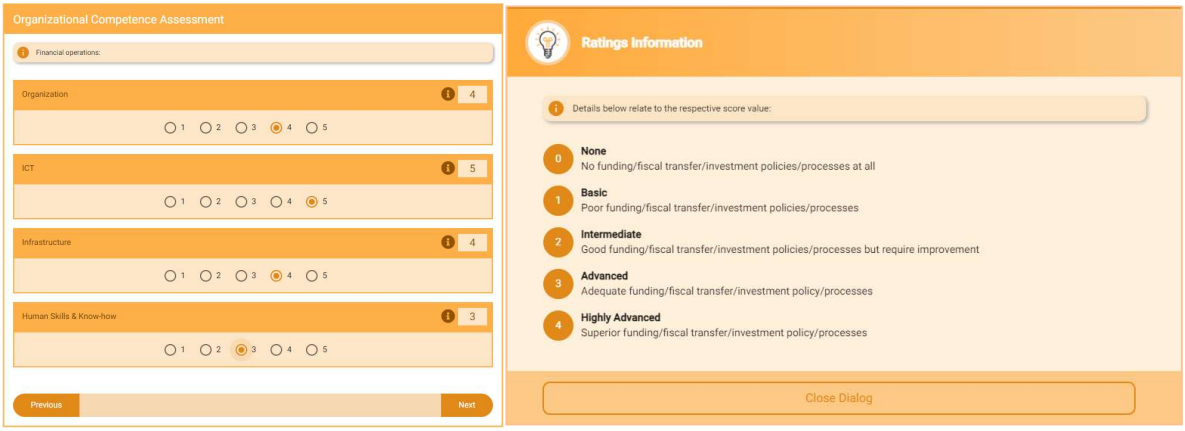


Figure 35: Scoring financial operations by design domains

Users are urged to *click* the information (i) button to get scoring information per function and design domain.

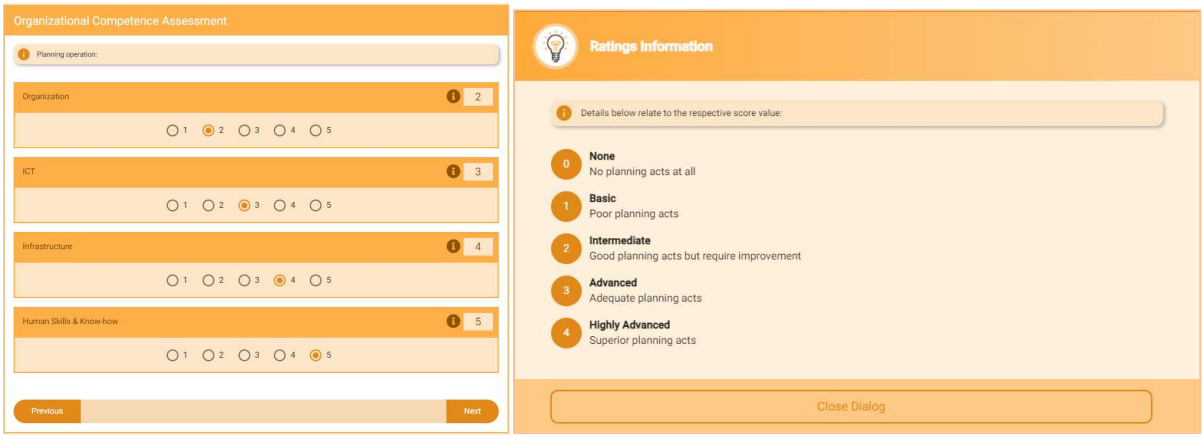


Figure 36: Scoring the planning function by design domains

Although there has been debates on the types of questions to be asked, the granularity of scoring and reliability of the scale when using Likert like scales (Pearse, 2011), this study depended on three key elements to decide on the final scales used, which are (1) dependence on an existing body of knowledge for electric utility, (2) rounds of pilot tests with the survey questions and scales, and (3) feedback from the demonstration exercise.

Scoring for all aspects of the ESD-PRT is aggregated to give the ESDI per municipality per month, trended, and benchmarked for inter-municipality comparative analysis (Figure 33). Therefore, ESDI signifies the health of electricity service delivery for a municipality as it contains performance data on the citizens (customer survey & perspective), electricity infrastructure and the municipality as an enterprise.

5.2 ESD-PRT Constructional Model

Models are generally valuable for conveying design information, product definition or process. Computational or descriptive models are also used sometimes to simulate real world scenarios. In information systems, models are used for requirements elicitation and description of systems property (Molnár, Benczúr, & Béleczki, 2017). To show the essence of the ESD-PRT, an essential model abstracted from its actual development is shown in this section. Since the audience and users of the ESD-PRT are varied both in background and vocation, a simple way to visualise the abstractions is preferred. The C4 model (Brown, 2020) fits this requirement by postulating four distinct but manageable levels of abstraction: Context, Containers, Components and Code. The four views are briefly defined in Table 38 and graphically illustrated in Figure 37.

Table 38: C4 Model - Levels and Views

Level	The 4Cs	Description
1	Context	The tone and context for the project are set here, with relationships to key role players (e.g users, and actors). What is the project about, who are the role players, what is the big picture within the larger environment?
2	Container	This decomposes the artefact into containers showing relationships and responsibilities of technology choices across the entire solution.
3	Component	Each container is made up of components. This level shows the components, their technology and deployment information
4	Code	This view is typically presented on demand due to its extreme details, it shows how each component is executed as code.

The first two levels basically give an overview of the entire system, while *level 3* zooms down to component level, showing component interaction and dependencies within a container. How the components are executed programmatically are detailed in *level 4*.

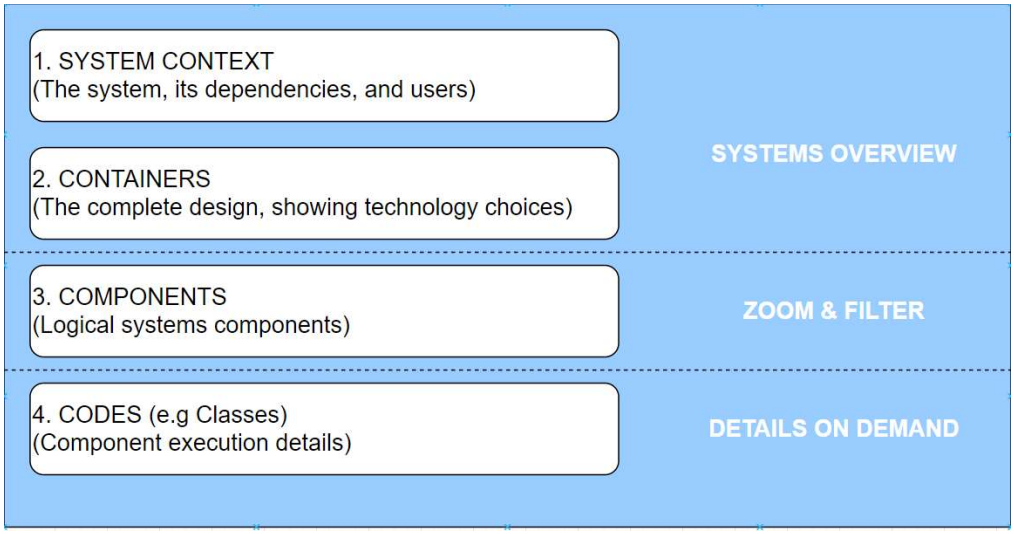


Figure 37: Graphical Illustration of 4C

The system context and container views are shown in Figures 38 and 39, while component and code level details are included in Appendix 7.

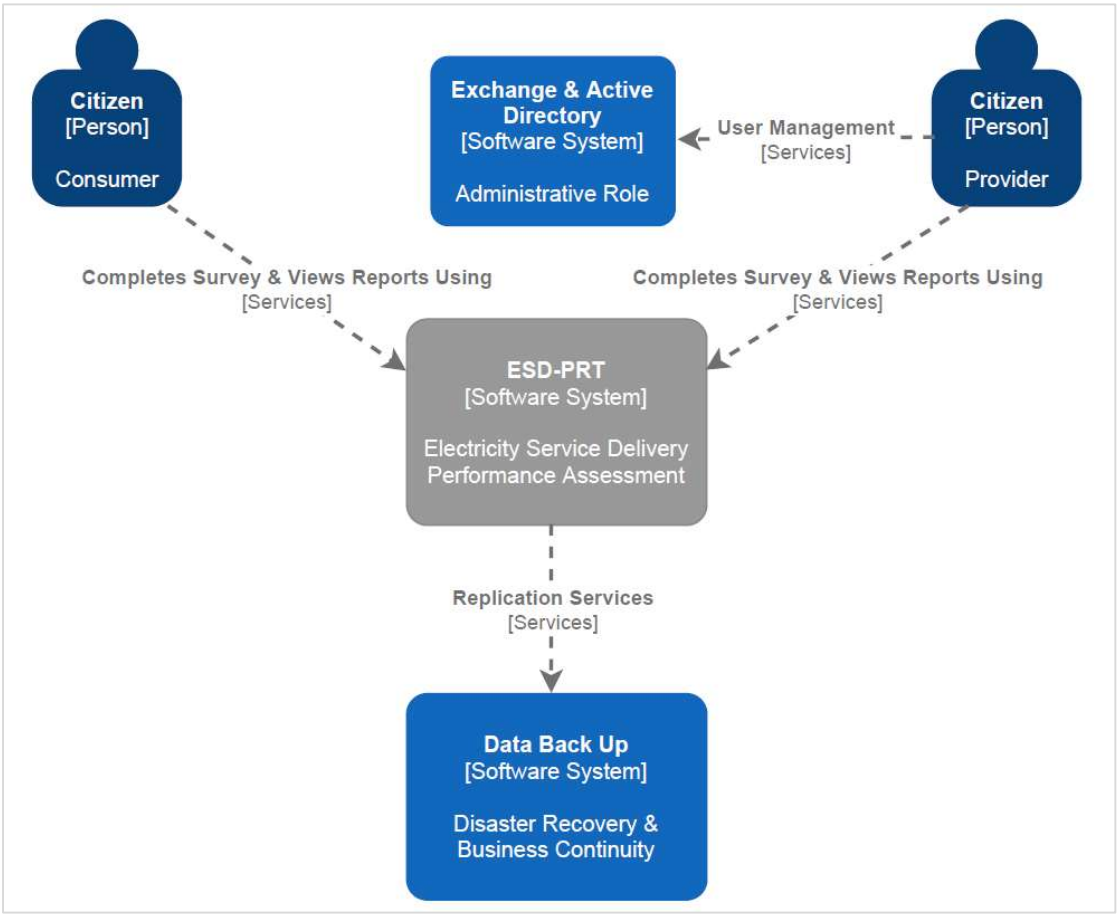


Figure 38: ESD-PRT Model, i.e. Context View

The providers (DCMs) have dual privilege, first to complete surveys and view reports, but also as the administrator to register citizens to participate.

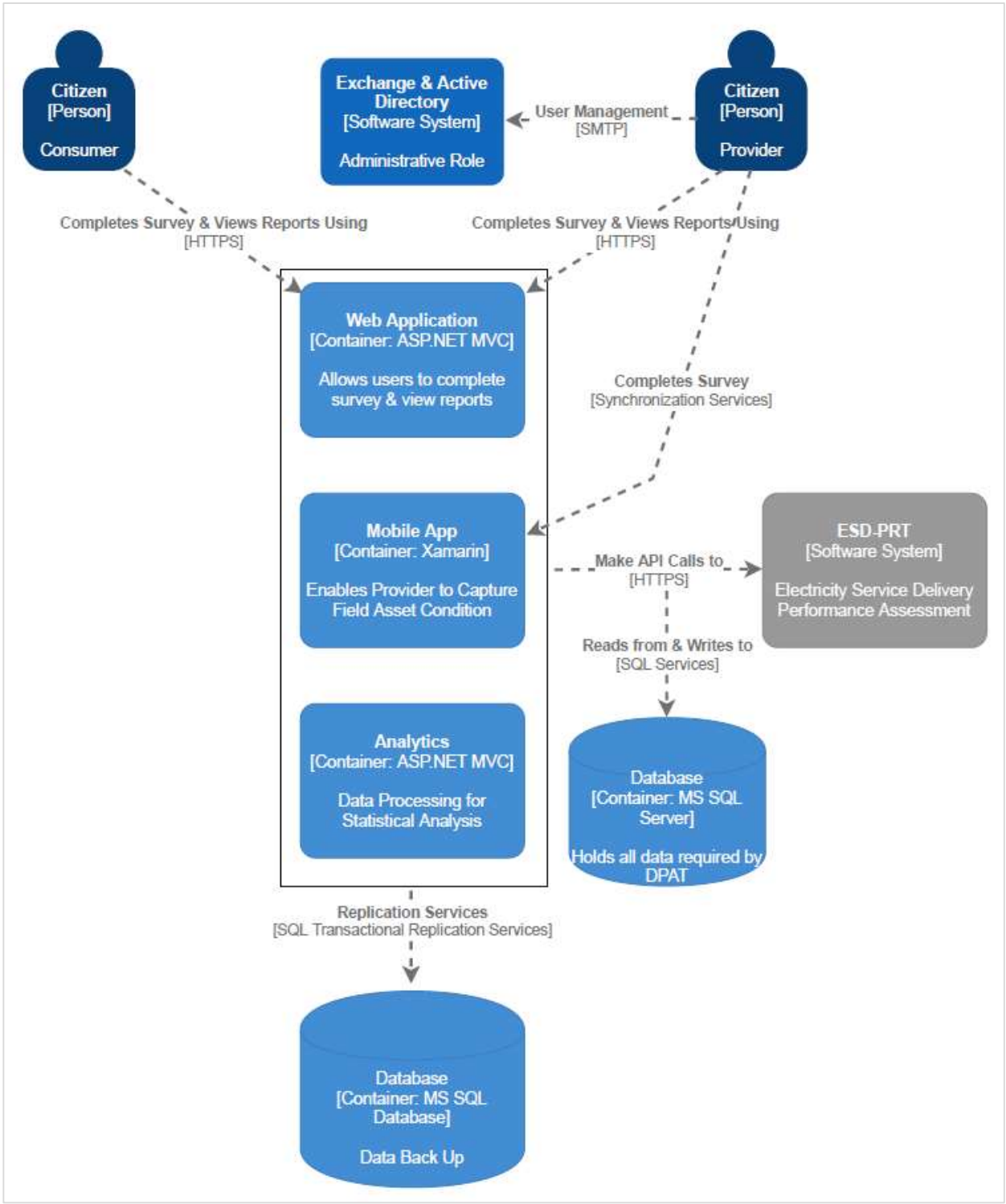


Figure 39: ESD-PRT Model, i.e. Container View

5.3 Chapter Conclusion

Chapter 5 details the constructional aspect of the ESD-PRT, arising from rounds of socially constructed engagements with strata and classes of stakeholders. Conceptually, the components

are modelled using the C4 model, which defines software systems in four hierarchical views for ease of understanding and clarity to a wide range of stakeholders. Although the model is abstracted from actual implementation, the SRS draws from it to give details of the actual constructional components of the ESD-PRT. In addition to this, Chapter 5 fulfils *phase 3* of the DSRM process, namely design and development. Next, Chapters 6 provides a demonstration of the ESD-PRT.

Chapter 6. Demonstration of ESD-PRT

A demonstration exercise is inevitable, to show the use of the ESD-PRT in solving one or more instances of the problem domain. The demonstration, aimed at testing real life cases as a *proof of concept,* is a key part of this study before progressing to evaluation. The chapter, therefore, answers RQ6, which is repeated here:

RQ6: To what extent does a demonstration of the performance assessment/reporting tool partially demonstrate the usefulness and user-friendliness of the tool?

Furthermore, it addresses *phase 4* of the DSRM process as postulated by Peffers et al. (2008). The phased process is repeated as Figure 40 for convenience.

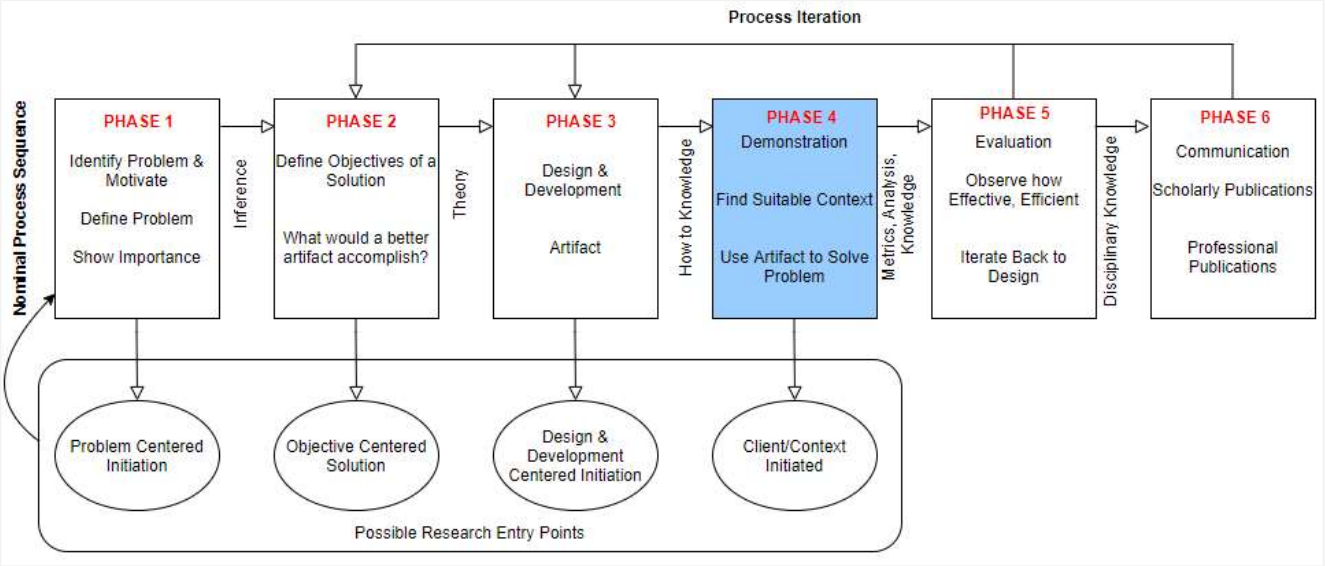


Figure 40: DSRM Process for the ESD-PRT, focusing on Phase 4

(Peffers et al., 2008)

Demonstration is considered as a pre-evaluation exercise. It shows how the use of the artefact address one or more instances of the functional requirement, whether it works as intended, and to what extent. Since the exercise allows an initial feel of the artefact as a precursor to the full-blown evaluation and deployment, it is best conducted in a real-life environment, simulating its final destination.

The intent of this demonstration, therefore, is to:

Use the beta version (prototype) of the ESD-PRT as a proof of concept to demonstrate an ability to diagnose electricity service delivery health and meet information systems functional requirements of users (user-friendliness) and the problem domain.

According to Peffers et al. (2008) and Johannesson and Perjons (2014), the artefact should be tested in the form of proof, use case, case study, experiment or simulation to address one or more instances of the problem during the demonstration. The demonstration was thus used as an initial evaluation of the artefact.

6.1 Planning

Ahead of the demonstration kick off, the ESD-PRT was subjected to a few tests, which includes unit, regression, and interface tests, within the development environment, using test cases. A date and time was therefore agreed with demonstration participants, and provision was made for the researcher to present the objective to the participants. Each participant had a laptop (specified in line with SITA guideline) and a notebook with a pen to record any deviations, issues, or concerns. COVID-19 regulations allowed the gathering of up to 50 people in a location but with all health guidelines observed and this requirement was met.

6.2 Participants

Demonstration of the ESD-PRT involved 6 participants, 3 of which were involved in the design process (with expert knowledge), two who are familiar with the ESD value chain and would use the application after the final deployment, and one person who is unfamiliar with the entire project but was introduced at the beginning of the demonstration exercise. The majority of the participants were thus familiar with the problem domain since knowledge of the specific context is essential for effectively demonstrating the artefact. The guest (unfamiliar participant) was invited to bring an independent perspective to the exercise, since the DCMs register new users who are neither part of the requirements elicitation nor design processes.

6.3 Method

Participants were introduced to the purpose of the demonstration and urged to identify errors and any aspects that attract their attention freely. The ESD-PRT itself does not require training as it is designed to be self-explanatory. Although participants were allowed to freely navigate the application, a minimum set of checklists was given to them, which was agreed by the focus group participants as sufficiently representative of most modules of the ESD-PRT and heavily weighted during the requirements elicitation process. The checklist is shown in Table 39, while Table 40 outlines the demonstration feedback from participants.

Participants were given the following instructions and demonstrated on the screen through a projector:

a. Type the web address on any web browser to get to the landing page (Figure 41).

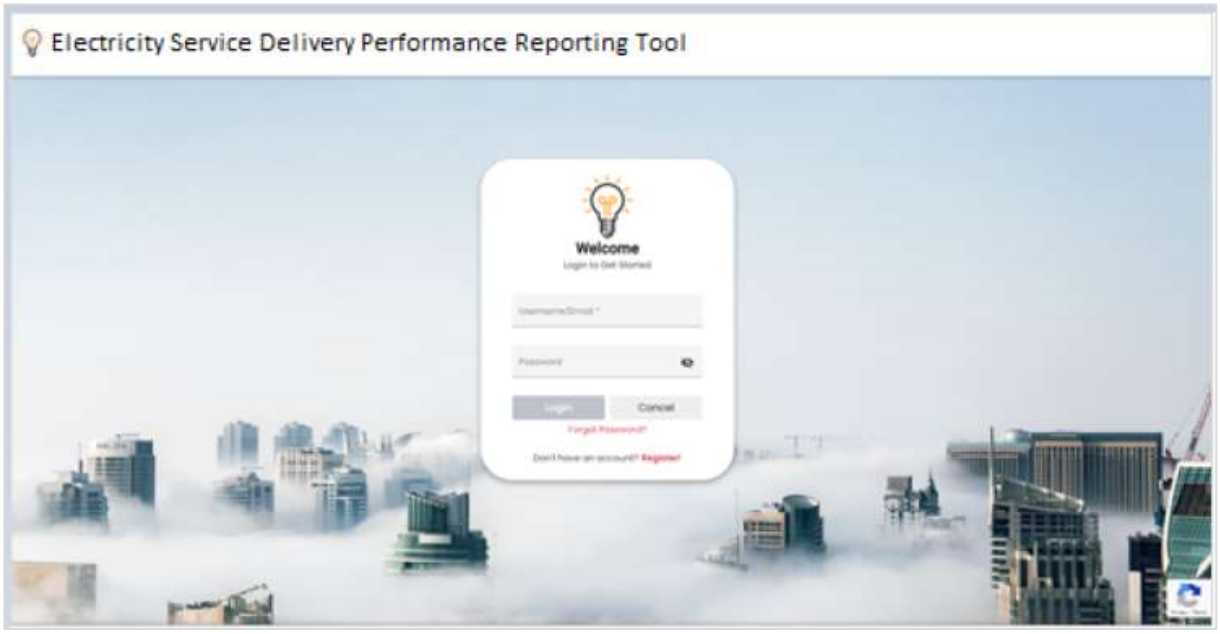


Figure 41: ESD-PRT's Landing Page

b. Register yourself as a user by creating a username and password (Figure 42).

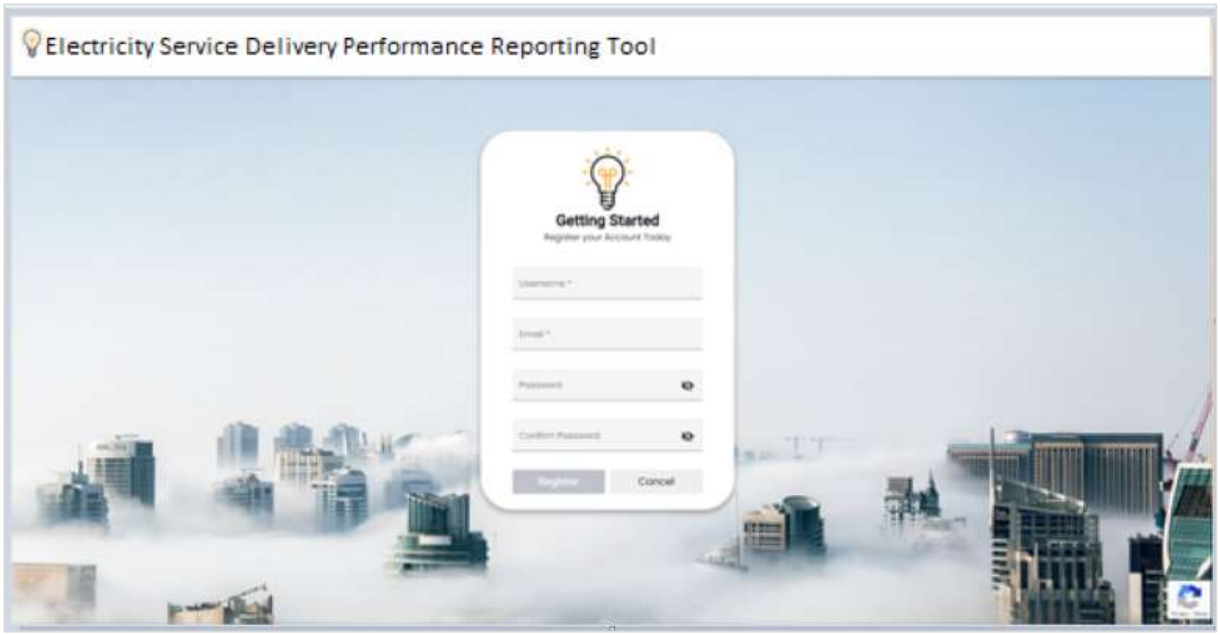


Figure 42: ESD-PRT's Registration Page

c. Enter an email for password recovery should you forget your password.
d. On successful login, please navigate freely through the ESD-PRT (Figure 43). However, ensure to test the functionalities provided in the checklist (see Table 39).

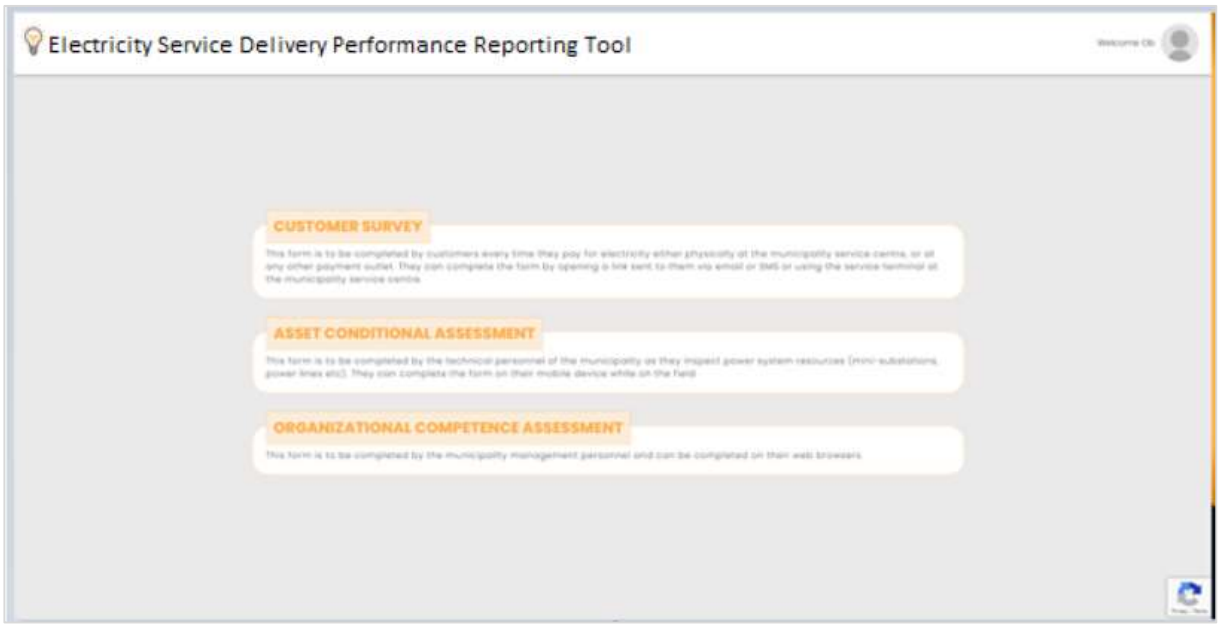


Figure 43: ESD-PRT's Home Page

The functionalities in Table 39 were considered as adequate instances to demonstrate the feasibility of the ESD-PRT for final deployment.

Table 39: Mandatory Functionality Tasks

Task No	Description
1	Get to the landing page of ESD-PRT through the given web address
2	Register as a user
3	Complete surveys
4	View reports
5	Log out

e. On completion, please log out of the ESD-PRT

Each user's input data is automatically saved in the ESD-PRT and aggregated for the overall report. All users logged out successfully after the exercise.

6.4 Outcome

At the end of the exercise, a review of all the activities by the participants was conducted to see how they were administered within the ESD-PRT and whether they achieved the desired objective. Figure 44 is a screenshot of one of the analytics based on participants' data input.

Figure 44a: ESD-PRT Sample Analytics

Figure 44b: ESD-PRT Sample Analytics

Figure 44c: ESD-PRT Sample Analytics

The sample analytics (Figure 44) is evidence that the artefact addressed some of the requirements that were defined in addressing the problem/phenomenon that was identified for this study (see section 4.4.5.4, and Table 35). In addition to this group review, individual assessment of the mandatory functionality task was sought via a simple questionnaire, and Table 40 outlines the outcome of this assessment.

The question related to the prototype is:

Please rate the ease and success of performing each task in the mandatory functionality task checklist.

The legend, rating mandatory functionality tasks are presented in Table 40.

Table 40: Mandatory Functionality Tasks for Ease of Task Execution

Very Bad	Bad	Average	Good	Very Good
				

Task No	Description	P1	P2	P3	P4	P5	P6
1	Get to the landing page of DPAT through the given web address						
2	Register as a user						
3	Complete surveys						
4	View reports						
5	Log out						

Although all participants agreed it was easy to implement all the mandatory problem areas given to them, it was necessary to further test the outcome of the task execution. That is, answering the question: *How well does the artefact address the requirements?* Table 41 is the outcome of the latter.

Table 41: Mandatory Functionality Tasks for Success of Task Execution

Unsuccessful	Successful
○	●

Task No	Description	P1	P2	P3	P4	P5	P6
1	Get to the landing page of DPAT through the given web address	●	●	●	●	●	●
2	Register as a user	●	●	●	●	●	●
3	Complete surveys	●	●	●	●	●	●
4	View reports	●	●	●	●	●	●
5	Log out	●	●	●	●	●	●

Two additional suggestions were about aesthetics and a request by one municipality participant to extend the use of the artefact to other service delivery areas such as water, sanitation, and permitting. The request for aesthetic amendment has been implemented as an improvement, while the latter is beyond the scope of this study.

6.5 Additional Suggestions Post Demonstration

Some suggestions to improve the ESD-PRT were considered given the iterative nature of the DSRM, providing for a feedback loop to improve the artefact. The suggestions include:

a. The ability for technicians to upload images of defective PSR since visualisation of the problem may aid or accelerate resolution.
b. The ability for respondents to give feedback. This is to take care of emerging areas of concern or performance areas.
c. Re-arrange the landing page so that respondents first choose the municipality that they represent.
d. Restrict access to reports and analytics to municipality respondents only, as citizens may use consolidated reports and analytics against the municipality.

6.6 Limitation of Demonstration

Based on the problem instances demonstrated, it is evident that the ESD-PRT passed the test for functionality and practicality (user friendliness), as respondents reported no functional issues while completing their surveys and navigating through the ESD-PRT. The time to

complete the survey was also recorded in the system logged, and no complaints were recorded for the time taken either. Through the generated report, the ability to diagnose the health of electricity service delivery, which is a primary goal of the ESD-PRT, was demonstrated. However, only a few cycles were tested with only six respondents. Another limitation is the fact that the functionality tests are pre-determined, limiting the scope of review. However, it is typical for demonstrations to be focused on specific instances while the evaluation is more comprehensive.

6.7 Chapter Conclusion

Research question 6 of the study, and *phase 4* of the DSRM, i.e. a demonstration of the prototype, are addressed in Chapter 6. A pre-evaluation phase to demonstrate the artefact for the first time in a real-life scenario, addressing some of the requirements for the ESD-PRT, involved 6 participants, of which 5 knew the problem domain. The outcome of the demonstration confirmed the fit, ease, and success of the ESD-PRT prototype in addressing the functional requirements of the artefact. Few aesthetic comments from the participants have been used to improve the look and feel of the ESD-PRT. Next, Chapter 7 presents evaluation results, based on the improved ESD-PRT.

Chapter 7. Evaluation Results

Given the outcome of the demonstration exercise (Chapter 6), the researcher proceeded to the evaluation phase, repeated as Figure 45, to observe how effective and efficient the artefact is in addressing requirements in the problem domain. According to Peffers et al. (2008), during the evaluation phase, the objectives of the artefact is tested against its primary objectives, thus answering the question of usefulness, i.e. How useful is the solution? This chapter and phase, therefore, answer one of the research questions, repeated here:

RQ 7: How useful and user-friendly is the new performance assessment/reporting tool?

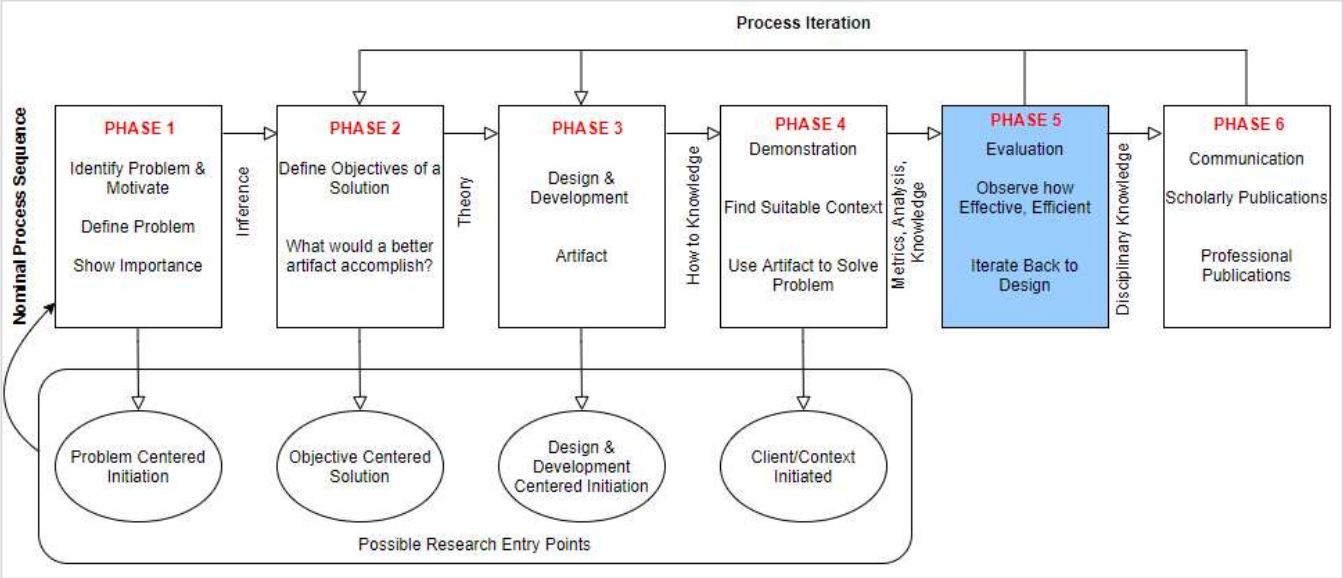


Figure 45: DSRM Process for the ESD-PRT, focusing on Phase 5

(Peffers et al., 2008)

Early in the research phase, a focus group (section 4.2), which included representatives of the South African national government, state department, local government, non-governmental organisations and independent participants, had concluded that a diagnostic assessment tool to monitor and report on the health of service delivery was necessary for the South African state. Their position is heavily corroborated by the World Bank Group's research outcome (2011) on accountability in South Africa's Public Services, which indicates that one of the major reasons for service delivery issues is inadequate assessment, including monitoring and feedback, of the health of service delivery. Because of the import and gravity of this challenge, local authors and researchers (Makanyeza, 2013; Sibanda, 2012) added their voice to take the same position as the focus group and the World Bank group. Specifically, to the electricity service delivery, the South Africa COGTA (2019) echoed the same sentiment, concluding that the over 26 billion

Rands debt owed to Eskom (the national power producer) is largely due to the inability of municipalities to effectively assess, track and manage the performance of the distribution network, i.e. PSR. This is apart from citizens' discontent about electricity service delivery (Maluleke, 2019). While a tool to monitor and report on this PSR will likely not solve the droves of electricity service delivery dilemma, the researcher posits that it is an entry point to the solution based on the aforementioned evidence. Problem solving without evidence gained through monitoring and reporting on the current operation, solutions are not sustainable (Vernon, Hocking, & Tyler, 2016).

The design and development of the ESD-PRT following a DSRM, is a direct response to this challenge. To evaluate the artefact, we draw from requirements extracted from stakeholders during the requirement elicitation process, and it is based on the artefact's functional and non-functional design aspects. In addition to providing knowledge on the effectiveness and efficiency metrics of the artefact, i.e. *phase 5* of the DSRM, the evaluation process renders useful information on the quality of the construction phase (*phase 3*) of the DSRM.

7.1 Evaluation Approach

Design science focuses on investigating the practicality or relevance of solutions to address the theory-practice gap, thereby necessitating pragmatic approaches to the design and development of constructs, models or systems (Van Aken, Chandrasekaran, & Halman, 2016). Designed based on this paradigmatic standpoint, relevant evaluation approaches were investigated before selecting the one deemed most appropriate. According to Hevner et al. (2004), the choice of an evaluation method goes a long way in determining the performance of an artefact. Yet, the choice must be context specific, and reflect the *style* of the design. Accordingly, many approaches/strategies have been proposed for evaluation in DSR. While Hevner et al. (2004) suggested evaluation methods outlined in Table 42 with general steps for each method, Venable et al. (2016) proposed a framework (FEDS – Framework for Evaluation in Design Science Research) shown in Figure 46.

Table 42: Evaluation Methods

(Hevner et al., 2004)

Method	Description
Observational	Case Study: Study artefact in depth in the business environment
	Field Study: Monitor use of artefact in multiple projects
Analytical	Static Analysis: Examine the structure of artefact for static qualities
	Architecture Analysis: Study fit of artefact into technical IS architecture
	Optimisation: Demonstrate inherent optimal properties of an artifact or provide optimality bounds on artefact behavior
	Dynamic Analysis: Study artefact in use for dynamic qualities
Experimental	Controlled Experiment: Study artefact in a controlled environment for qualities
	Simulation: Execute artefact with artificial data
Testing	Functional (Black Box) Testing: Execute artefact interfaces to discover failures and identify defects
	Structural (White Box) Testing: Perform coverage testing of some metric (e.g. execution paths) in the artefact implementation
Descriptive	Informed Argument: Use information from the knowledge base (e.g. relevant research) to build a convincing argument for the artefact's utility
	Scenarios: Construct detailed scenarios around the artefact to demonstrate its utility

The FEDS is an evaluation strategy that includes a two-dimensional evaluation trajectory, namely the functional purpose of the evaluation on the x-axis, which depicts the idea of formative and summative evaluation, and the evaluation paradigm on the y-axis, incorporating the idea of naturalistic and artificial evaluation. In general, the pathway followed is a function of the problem type and the resources at the researcher's disposal. For this study, a possible trajectory would be the *human risk and effectiveness* pathway since there are indications that the project may be deployed to a real-life environment. However, due to resource constraints and minimal risk of implementation and use, the *quick and simple* trajectory was followed. A first stage evaluation (demonstration) represented by the first star in Figure 46 was conducted as reported in Chapter 6, followed by a more naturalistic summative evaluation reported in Chapter 7.

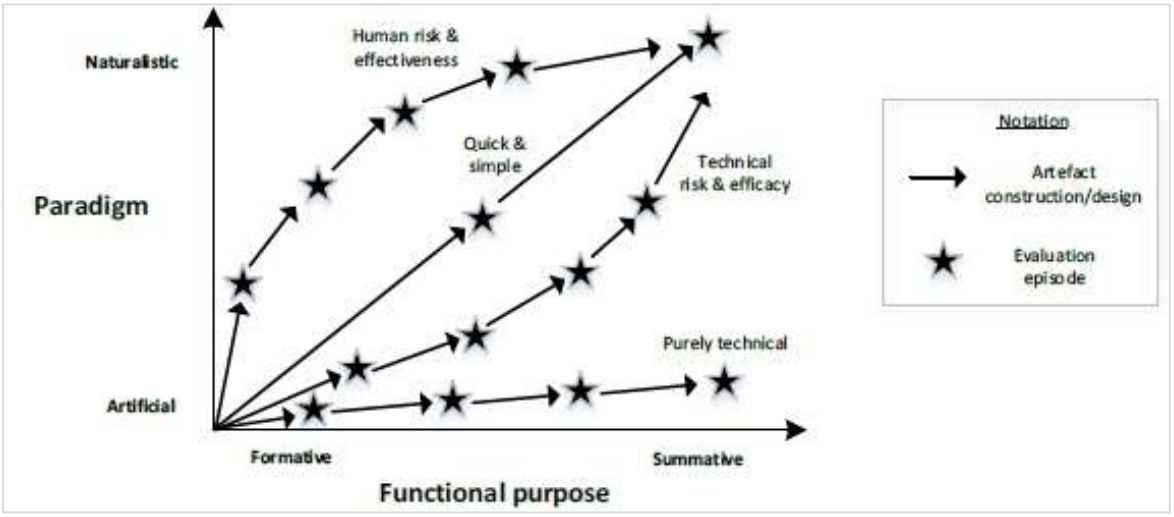


Figure 46: FEDS with Evaluation Strategies

(J. Venable, Pries-Heje, J., & Baskerville, R. , 2016)

Additionally, given the nature of the artefact and the problem domain, a multi-method evaluation approach based on Hevner's (2004) was followed for evaluating the ESD-PRT. Next, the multiple methods that were used during summative evaluation were highlighted.

a. DCM2 has already signified its intention to use the ESD-PRT as a permanent tool on the municipality website and apply it to service delivery areas other than electricity, *observing* the tool in a real-life environment.
b. Early discovery of defects through *functional and structural (stress) testing* was necessary since the number of respondents using the ESD-PRT in future may be significantly high, especially if DCM2 goes ahead with a planned incentive scheme for the survey.
c. *Survey feedback* was obtained from the end users when they evaluated the usefulness and user-friendliness of the ESD-PRT using the SUMI (1990) survey.

Rigour is thus required in evaluating the ESD-PRT. For the multi-method observational and functional/structural testing, three key techniques and criteria set, including functional evaluation & testing against pre-validated criteria, were covered through surveys outlined in Appendix 4. An additional survey, SUMI (1990), is used to focus on user-related criteria. The evaluation strategy is in accordance with Hevner et al.'s (2004) guidelines indicate that requirements from the operating environment must drive the evaluation of an artefact. This study applied the guidelines as follows:

a. Validated Criteria: Evaluation participants evaluated the ESD-PRT against criteria that were pre-validated by a focus group (Please see section 4.2), which determined what

criteria such an assessment tool must satisfy to be considered useful in the South African context. The focus group had firstly debated and concluded that a performance assessment tool was necessary but went ahead to review evaluation criteria from the literature from which it selected, (re)defined and validated those it deemed mandatory for a tool for the South African state to satisfy.

b. Requirements Elicitation: One of the key performance areas extracted during the requirement elicitation process, with reference to see section 4.4, is requirements for the ESD-PRT from an Information Science perspective. It is therefore evaluated against the requirements and functionalities as indicated by the human actors.
c. Demonstration Results: A pre-evaluation exercise, with reference to section 6.5 a to d, was conducted to demonstrate that the ESD-PRT could perform well for a few instances of the problem domain. Additional feedback was received, with which the ESD-PRT was updated. How effective the ESD-PRT addressed the additional feedback was also tested during evaluation.
d. User Experience: In addition to the perspectives above, additional rigour was applied by extracting test and evaluation parameters from an existing body of knowledge. The SUMI (1990) is a method for measuring software quality from the end user's point of view, as explained in section 3.4.2, and it has a very extensive reference database. The test method has taken information from the industry and academia to improve its scientific basis for testing in over 25 years.

7.2 Participants

Thirty-five respondents (Please see Table 43), most of whom have been involved in the study from the beginning, participated in the extensive evaluation through the multi-objective survey shown in Appendix 4.

Table 43: Evaluation Participants

	DCM 1	**DCM 2**	**DCM 3**
Municipality employees	4	4	3
Municipality residents	6	7	11
Total Participants	10	11	14
Grand Total	**35**		

Table 44 further outlines the profile of the participants

Table 44: Profile of the 35 Respondents

Category	Description	Number
Gender	Male	16
	Female	19
Municipality employees	Management	3
	Others	8
Municipality residents	Commercial account	13
	Residential account	11
Age (Years)	20-30	6
	31-40	15
	41-50	11
	Over 50	3

The four coding assistants were excluded from the open evaluation for two major reasons: (1) they were involved with regression testing in the staging environment hence having a very good understanding of the tool, and (2) they (including the researcher) were on standby to assist participants who may require help or clarification while evaluating the artefact. Apart from a few occasions of latency in connection, especially from DCM2, where connectivity is a problem, there were no major issues reported by the participants.

7.3 Outcome

This section outlines the outcome of the pre-validated tool criteria, functionality, and user experience evaluation. For the tool's pre-validated criteria and functionality, a Likert scale ranging from 1 (very low) to 5 (very high) was used to evaluate the degree and extent to which the tool satisfies the evaluation indicators. In contrast, the user experience evaluation was based on metrics extracted from SUMI (1990) with three scoring options, i.e. agree, undecided or disagree.

7.3.1 Evaluation of Pre-validated Tools Criteria

This segment evaluated necessary criteria that the tool must satisfy locally as presented in Table 45. The study used the same criteria that were identified at the start of this study, confirmed via a focus-group discussion (please see section 4.2). Major findings include:

a. Two of the pre-validated criteria cannot be evaluated without prolonged use of the tool, i.e. *reliability* and *predictive ability* (the tool must be able to estimate or project what public service delivery performance would look like in the near future, based on historical and current data), and *reliability* (the tool must be consistent when used to measure public service delivery performance repeatedly, with results that are reasonably comparable with similar tools). Hence most of the evaluators believed that these criteria were *not* met. Refer to

the metric mean, and the columns labelled *reliability* and *predictive ability* in Table 45.

b. All evaluators believed that the tool met the other criteria (independence, relevance, comprehensibility, measurement expressiveness, diagnostic ability, robustness, engagement, customisable, ease of use, comprehensiveness, accuracy) either to a high or very high degree (Please see Table 46). Satisfying these criteria indicate that the tool can assist stakeholders with a multi-perspective diagnosis of electricity service delivery in the local municipalities (DCMs). Table 45 presents summary/descriptive statistics of all the criteria.

Table 45: Descriptive Statistics of Validated Criteria

Metrics	Independence	Relevance	Reliability	Comprehensibility	Measurement Expressiveness	Predictive ability	Diagnostic ability	Robustness	Engagement	Customizable	Ease of use	Comprehensiveness	Accuracy
Mean	4.029	4.800	2.800	4.600	4.800	2.514	4.914	4.400	4.971	4.971	4.514	4.800	4.114
Standard Error	0.112	0.069	0.128	0.084	0.069	0.103	0.048	0.084	0.029	0.029	0.095	0.069	0.128
Median	4.000	5.000	3.000	5.000	5.000	2.000	5.000	4.000	5.000	5.000	5.000	5.000	4.000
Mode	4.000	5.000	3.000	5.000	5.000	2.000	5.000	4.000	5.000	5.000	5.000	5.000	4.000
Standard Deviation	0.664	0.406	0.759	0.497	0.406	0.612	0.284	0.497	0.169	0.169	0.562	0.406	0.758
Sample Variance	0.440	0.165	0.576	0.247	0.165	0.375	0.081	0.247	0.029	0.029	0.316	0.165	0.575
Kurtosis	-0.577	0.483	-1.143	-1.932	0.483	-0.323	8.029	-1.932	35.000	35.000	-0.695	0.483	-1.189
Skewness	-0.030	-1.568	0.359	-0.427	-1.568	0.758	-3.094	0.427	-5.916	-5.916	-0.586	-1.568	-0.197
Range	2.000	1.000	2.000	1.000	1.000	2.000	1.000	1.000	1.000	1.000	2.000	1.000	2.000
Minimum	3.000	4.000	2.000	4.000	4.000	2.000	4.000	4.000	4.000	4.000	3.000	4.000	3.000
Maximum	5.000	5.000	4.000	5.000	5.000	4.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
Sum	141.000	168.000	98.000	161.000	168.000	88.000	172.000	154.000	174.000	174.000	158.000	168.000	144.000
Count	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000

Mean scores of 3 and above implies that the tool meets the specific criteria, while mean scores below 3 indicate the tool does not satisfy the specific tool criteria.

Table 46: Evaluation of Pre-Validated Criteria (N = 35)

		Scoring Guide: (1) Very low (2) Low (3) Somewhat (4) High (5) Very High	
Evaluation Criteria	**ID**	**Description**	**Average**
Independence	PC1	To what extent can the participants be free of financial inducement?	4
Relevance	PC2	To what extent does the tool reflect important public issue?	4.8
Reliability	PC3	To what extent is the tool consistent when used repeatedly?	2.8
Comprehensibility	PC4	To what extent is the tools report easily digested and understood?	4.6
Measurement Expressiveness	PC5	To what extent can the tool output trigger action/correction by the municipality?	4.8
Predictive ability	PC6	To what extent can the tool estimate what electricity service delivery would look like in future?	2.5
Diagnostic ability	PC7	To what extent does the tool identify specific issues with electricity service delivery?	4.9
Robustness	PC8	To what extent are the metrics used clear?	4.4
Engagement	PC9	To what extent are the stakeholders involved in the tool development?	5
Customisable	PC10	To what extent can the tool be adapted to other service delivery areas such as water, sanitation, waste removal and housing?	5
Ease of use	PC11	To what extent is it easy to use the tool	4.5

		Scoring Guide: (1) Very low (2) Low (3) Somewhat (4) High (5) Very High	
Evaluation Criteria	**ID**	**Description**	**Average**
Comprehensiveness	PC12	To what extent does the tool cover all relevant areas of electricity service delivery?	4.8
Accuracy	PC13	To what extent are the reports precise?	4.1

The results of Table 25 are also indicated graphically in Figure 47.

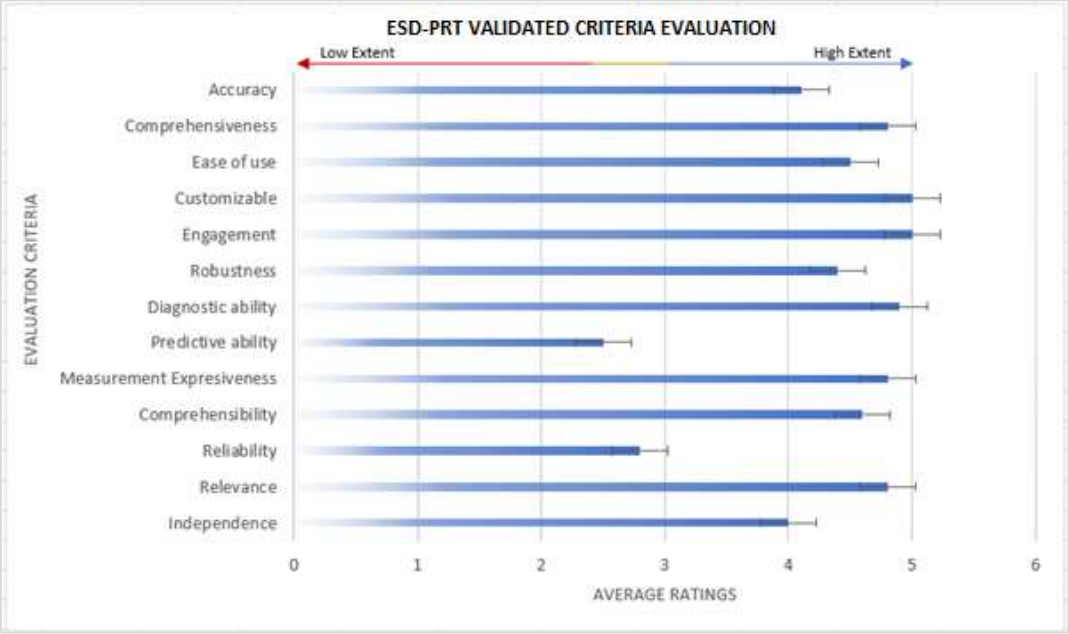


Figure 47: Evaluation of Pre-Validated Criteria

7.3.2 Users' Functional Requirements

Users' functional requirements (during requirement elicitation and demonstration) for the ESD-PRT was also evaluated, and this section presents the outcome. The intention was to understand the ease and degree to which evaluators could perform (achieve) the required software functions and features. Table 47 and Figure 48 show the outcome of this evaluation.

Table 47: Evaluation of Functionalities (N = 35)

		Scoring Guide: (1) Very low (2) Low (3) Somewhat (4) High (5) Very High	
Evaluation Criteria	**ID**	**Description**	**Average**
Web Access	FC1	To what degree and level of ease are you able to load the ESD-PRT via the weblink?	5
User Registration	FC2	To what degree and level of ease are you able to register as a user?	5
Secure Login	FC3	To what degree and level of ease are you able to log in with your registered credentials?	5
Workflow	FC4	To what degree and level of ease are you able to select your municipality and complete the survey?	5
Report Rendering	FC5	To what degree and level of ease are you able to generate and view reports?	4.6

		Scoring Guide: (1) Very low (2) Low (3) Somewhat (4) High (5) Very High	
Evaluation Criteria	**ID**	**Description**	**Average**
Report & Analytics	FC6	To what degree and level of ease do you understand the report and analysis?	4.5
Report & Interpretation	FC7	To what degree are you able to interpret and make decision based on the reports?	4
Report & Options	FC8	To what degree and level of ease are you able to choose date filters and generate a report based on your filter?	5
Report Exports	FC9	To what degree and level of ease are you able to generate and print PDF reports?	5
Feedback	FC10	To what degree and level of ease are you able to provide feedback on the tool?	5
Power Condition Visualisation	FC11	To what degree and level of ease are you able to upload images of defective PSR (if applicable)?	4.8
Organisational Competence	FC12	To what degree and level of ease are you able to update the status of customers and technicians' feedback (if applicable)?	4.9

Figure 48 is a graphical illustration of the functionality evaluation outcome

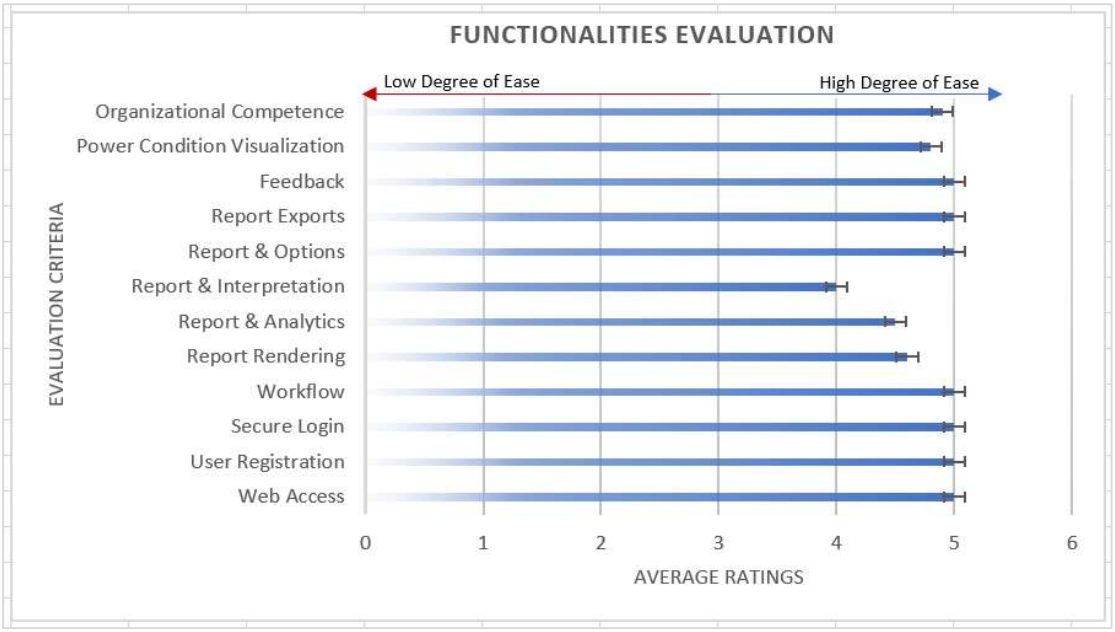


Figure 48: Evaluation of Functionalities

7.3.3 User Experience

Although all the functional and non-functional parameters have been tested directly from all stakeholders, an external perspective, i.e. the SUMI survey (SUMI, 1990) driven by other test parameters, was used to determine users' experience. The test parameters were extracted from SUMI and included in the overall evaluation pack for ease of completion for respondents. While some of the questions require a response from 3 options (agree, undecided or disagree), others are free texts prompting other rounds of thematic analyses through coding to determine the

dominant themes and important patterns for this evaluation category. The three free text responses are presented below, while Figure 49 shows excerpts from the codebook:

a. What, in general, do you use this software for?
b. What do you think is the best aspect of this software, and why?
c. What do you think needs most improvement, and why?

The cloud based CAQDAS (Delve, 2021) has been described in section 4.4.5.1, but it is used again to extract important patterns from the users' experience.

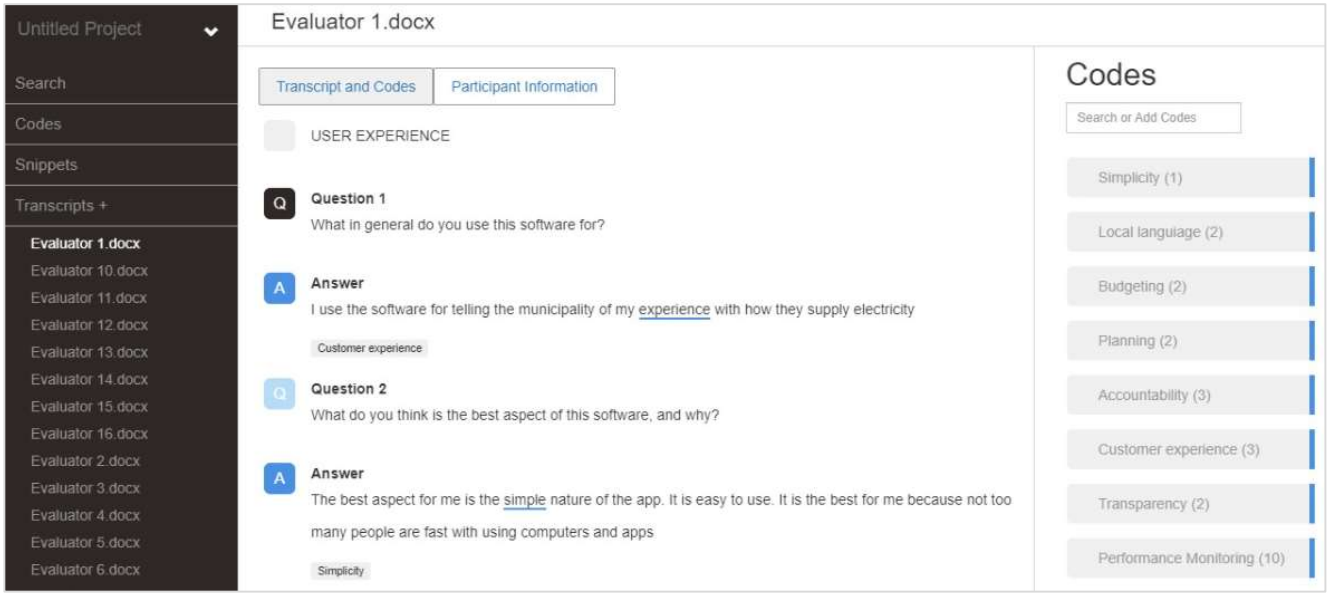


Figure 49: User Experience Themes

The outcome of the full analysis is presented below:

a. Users believed the tool is used for monitoring the performance of municipality distribution of electricity.
b. Users believed the best aspect of the tool is that it helps stakeholders to know the current state of electricity service delivery.
c. The most frequent request for improvement is to extend the tool to other municipality service areas.
d. A total of 88% of the evaluators believed the tool is extremely important.
e. A total of 12% of the evaluators believed the tool is important.

Participants evaluated other areas of users' experience, and results are synthesised in Tables 48 to 52. Table 48, on *efficiency* (SUMI, 1990), captures users' perceptions on the ease or difficulty of getting the job done through the tool. The results indicate there is a strong agreement among evaluators that the tool is efficient and easy to use.

Table 48:Tool User Experience Evaluation of Efficiency

Description	Agree %	Undecided %	Disagree %	Total
This software responds too slowly to inputs	3	0	97	100
I would recommend this software to my colleagues	100	0	0	100
The instructions and prompts are helpful.	94	6	0	100
This software has at some time stopped unexpectedly.	0	0	100	100
Learning to operate this software initially is full of problems.	0	3	97	100
I sometimes don't know what to do next with this software.	11	3	86	100
I enjoy the time I spend using this software.	97	0	3	100
I find that the help information given by this software is not very useful.	3	3	94	100
If this software stops it is not easy to restart it.	0	0	100	100
It takes too long to learn the software functions.	3	3	94	100

Table 49, indicating the *affect* (SUMI, 1990) of the ESD-PRT, i.e. highlights users' sentiment and fondness towards the tool, meaning their mental state of happiness or exasperation while using the tool. The results indicate that there is minor disagreement on whether working with the tool offers a mentally stimulating experience, and whether users would rather stick to the functions that they know best. Apart from these, evaluators generally agree that they understand the tool and enjoy control while using it.

Table 49: Tool User Experience Evaluation for Affect

Description	Agree %	Undecided %	Disagree %	Total
I sometimes wonder if I am using the right function.	5	0	95	100
Working with this software is satisfying.	100	0	0	100
The way that system information is presented is clear and understandable.	95	0	5	100
I feel safer if I use only a few familiar functions.	70	5	25	100
The software documentation is very informative.	95	5	0	100
This software seems to disrupt the way I normally like to arrange my work.	5	5	90	100
Working with this software is mentally stimulating.	50	20	30	100
There is never enough information on the screen when it's needed.	0	5	95	100
I feel in command of this software when I am using it.	90	5	5	100
I prefer to stick to the functions that I know best.	45	10	45	100

The outcome of *helpfulness* rating, which according to SUMI (1990), examines the communication fluency of the tool in assisting users to solve intended problems, is presented in Table 50. The results indicate that evaluators believe they are able to use the tool to achieve the desired purpose. There is minor disagreement on how much one needs to read to navigate through the entire tool as about 30% of evaluators think there is too much to read while using the tool.

Table 50: Tool User Experience Evaluation on Helpfulness

Description	Agree %	Undecided %	Disagree %	Total
I think this software is inconsistent.	5	5	90	100
I would not like to use this software every day.	5	5	90	100
I can understand and act on the information provided by this software.	90	0	10	100
This software is awkward when I want to do something which is not standard.	0	10	90	100
There is too much to read before you can use the software.	30	5	65	100
Tasks can be performed in a straightforward manner using this software.	85	5	10	100
Using this software is frustrating.	0	15	85	100
The software has helped me overcome any problems I have had in using it.	90	5	5	100
The speed of this software is fast enough.	95	5	0	100
I keep having to go back to look at the guides.	5	5	90	100

Users love to be in control when they use software and applications to solve problems or enhance their operational activities. They expect consistency when they give instructions or commands to the tool. A low control score is an indication that the tool requires additional mental efforts to get things done. Table 51 thus evaluates this important factor, *control* (SUMI, 1990). The results indicate major agreement on control with the exception of optimization of the keystrokes, where evaluators are divided on the economy of the keystrokes while giving inputs to the tool.

Table 51: Tool User Experience Evaluation on Control

Description	Agree %	Undecided %	Disagree %	Total
It is obvious that user needs have been fully taken into consideration.	95	5	0	100
There have been times in using this software when I have felt quite tense.	5	0	95	100
The organisation of the menus seems quite logical.	95	5	0	100
The software allows the user to be economical with keystrokes.	40	20	40	100
Learning how to use new functions is difficult.	5	5	90	100
There are too many steps required to get something to work.	0	5	95	100
I think this software has sometimes given me a headache.	0	0	100	100
Error messages are not adequate.	10	10	80	100
It is easy to make the software do exactly what you want.	0	5	95	100
I will never learn to use all that is offered in this software.	5	10	85	100

The ease of learning, unlearning, and relearning of the tool is evaluated in Table 52. This measure, *learnability* (SUMI, 1990), refers to the users' assessment that it is relatively

uncomplicated to use the tool. The global verdict on learnability is that the tool is easy to learn and uncomplicated. No major disagreement is indicated in learnability of the tool.

Table 52: Tool User Experience Evaluation on Learnability

Description	Agree %	Undecided %	Disagree %	Total
The software hasn't always done what I was expecting.	5	5	90	100
The software presents itself in a very attractive way.	100	0	0	100
Either the amount or quality of the help information varies across the system.	5	5	90	100
It is relatively easy to move from one part of a task to another.	10	10	80	100
It is easy to forget how to do things with this software.	5	0	95	100
This software occasionally behaves in a way which can't be understood.	10	5	85	100
This software is very awkward.	0	5	95	100
It is easy to see at a glance what the options are at each stage.	90	5	5	100
Getting data files in and out of the system is not easy.	5	5	90	100
I have to look for assistance most times when I use this software.	5	5	90	100

Comparing to the closest solution, the ESD-PRT already addressed the shortfalls of PJM in 4.3.6

7.4 General Research findings

In addition to the evaluation results, additional findings identified during the course of the project are outlined below:

Literature Review:

a. While there are many criteria believed to be necessary for a diagnostic assessment tool to be considered effective, the most subscribed criterion is *comprehensibility*, i.e. the outcome or results of DSPA tools must be easily understood, simple, and uncomplicated, followed by *improvement*, i.e. must not only assess but lead to service delivery improvement.
b. Theoretical investigation of Multi-criteria decision-making models revealed the AHP to be the most frequently applied MCDM technique. However, its inclusion in the study is based on further exploration as presented in sections 2.3.1 to 2.3.3.

Practical Tool Criteria Validation:

a. To gain understanding for the South African context, two new (currently non-existent in the literature) tool evaluation criteria were defined and added by South African focus group members. The criteria are *comprehensiveness* and *accuracy*

b. Although represented in the literature, focus group participants failed to reach a consensus on the usefulness (and definition) of *comparability* as an evaluation criterion. Hence it was excluded.
c. Based on a set of validated (effectiveness, project and technical) criteria, key decision makers from the municipalities, through a pairwise comparison process selected (with an 88.6% consensus index) the PJM as the most appropriate DSPA tool for South Africa

Requirements Elicitation:

The study employed a hybrid of both deductive and inductive coding processes in line with its philosophical standpoint. Through the inductive coding process, participants realities were extracted, leading to new knowledge about the research grand challenge. Some of the findings include functional and constructional ESD areas of concern/requirements. Below are highlights of the inquisitive and coding process:

a. The most frequently occurring theme (area of concern is) *availability of power*.
b. The least frequently occurring theme (area of concern is) *quality of maintenance*.

ESD-PRT Evaluation:

The tool was evaluated based on the DSRM framework chosen for the study:

a. Tools evaluation parameters that evaluators are not particularly happy with are tool's:
    i. Reliability and
    ii. Predictive ability
b. Problematic user experience areas include:
    i. Mental stimulation: Evaluators are generally undecided (50% agreed:20% undecided: 30% disagreed) whether they feel mentally stimulated when using the tool.
    ii. Keystroke economy: Evaluators are generally undecided (40% agreed:20% undecided: 40% disagreed) whether the software workflows provide for economical keystroke application
    iii. Navigation: Many users find navigating through the software to be relatively difficult

7.5 Chapter Conclusion

An evaluation of the ESD-PRT was conducted, among other factors, to determine the utility and how useful and user-friendly the tool is. Three key areas were evaluated, namely pre-validated criteria, which a focus group deemed non-negotiable for a tool such as the ESD-PRT to satisfy, functional requirements expected by stakeholders during the *requirements elicitation* exercise, and *user experience*. Additional areas evaluated included post demonstration improvements occasioned by feedback from demonstration participants. The evaluation achieved four key milestones for the artefact:

a. It successfully tested the theoretical basis of the DSRM framework upon which the tool was designed and developed.
b. It demonstrated that the theories of Enterprise Engineering (TAO, PSI, BETA, SIGMA) applied during the design phase can be incorporated within the framework of the DSRM research paradigm.
c. It showed that the tool satisfies various multi-stakeholders' criteria and functional requirements for the South African context.
d. The evaluation demonstrated that the tool could provide diagnostic information about electricity service delivery, which may be used to re-design the value chain for improved performance.
e. It provided information for improvement of the tool for a future iteration.

Next, Chapter 8 outlines the contributions emanating from this study.

Chapter 8. Contributions

This chapter provides a brief description of the developed artefact as the study's main contribution in section 8.1. In addition, the researcher discusses secondary contributions and the impact of the study in section 8.2, concluding in section 8.3.

Following the motivated DSR philosophy with embedded design principles and specific enterprise engineering theories, it is believed that this study made some useful knowledge contributions in the form of an operational artefact and instantiations with preliminary records of acceptance by the DCMs, the real-world environment from where the research *grand challenge* emanated.

The study initiated with identifying a major challenge at the DCMs, then progressed to systematically explore the literature to understand the current state of solution ideas. This was followed by the design and development of a prototype to respond to the research questions and concluded by cycles of testing, demonstration, and evaluation. In South Africa, electricity service delivery is a major challenge that has been well published both locally and globally. This study argues that treatment without diagnosis is unscientific and short sighted. Therefore, a diagnostic assessment tool for the electricity service delivery problem domain was inductively developed first to show the health of the problem domain, and later to guide the (re)design of same domain for optimised performance. This multi-perspective on citizens' experience, power system infrastructure health, organisational competence of various strata of municipalities structure, operational gaps in design domains and sub-domains, i.e. an ESD diagnostic capability, is currently non-existent in the country.

8.1 The ESD-PRT Artefact as Main Contribution

The ESD-PRT tool assists with providing information and insights into poor electricity service delivery at local municipalities, the arm of government constitutionally designated to render public service delivery, one of which is electricity distribution. The lack of information about the health of this target problem area has been identified as a major problem both locally, as cited by many South African authors, and internationally, voiced by political bodies, including the world bank. Therefore, the tool provides a new solution to this known problem area, using three local municipalities from 2 provinces of South Africa as DCMs. It represents a platform that can save South Africa billions of Rands currently lost to energy losses, downtime in economic activities and social discontent occasioned by power outages and rolling blackouts. The evolution of the tool followed design principles postulated by the enterprise engineering

body of knowledge. Some of the main features of post demonstration ESD-PRT are briefly discussed to highlight the contribution of ESD-PRT as an artefact.

As shown in Figure 50, the tool acquires information from *various stakeholders*, with drill-downs to classified *design domains* and *subdomains*. Figure 50 shows the number of submissions for that period, since a minimum of 30 responses are used for statistical analysis. Other parameters are also shown, including *average time to complete a survey*, *satisfaction rating* and the *red flag area*, which in this specific case, is the customer. Every month (or time window selected by the user), the ESD-PRT shows the red flag area which indicates the worst performing area for the period. In this particular instance, customer satisfaction is worse than the PSR condition and organisational functions, as shown in Figure 50.

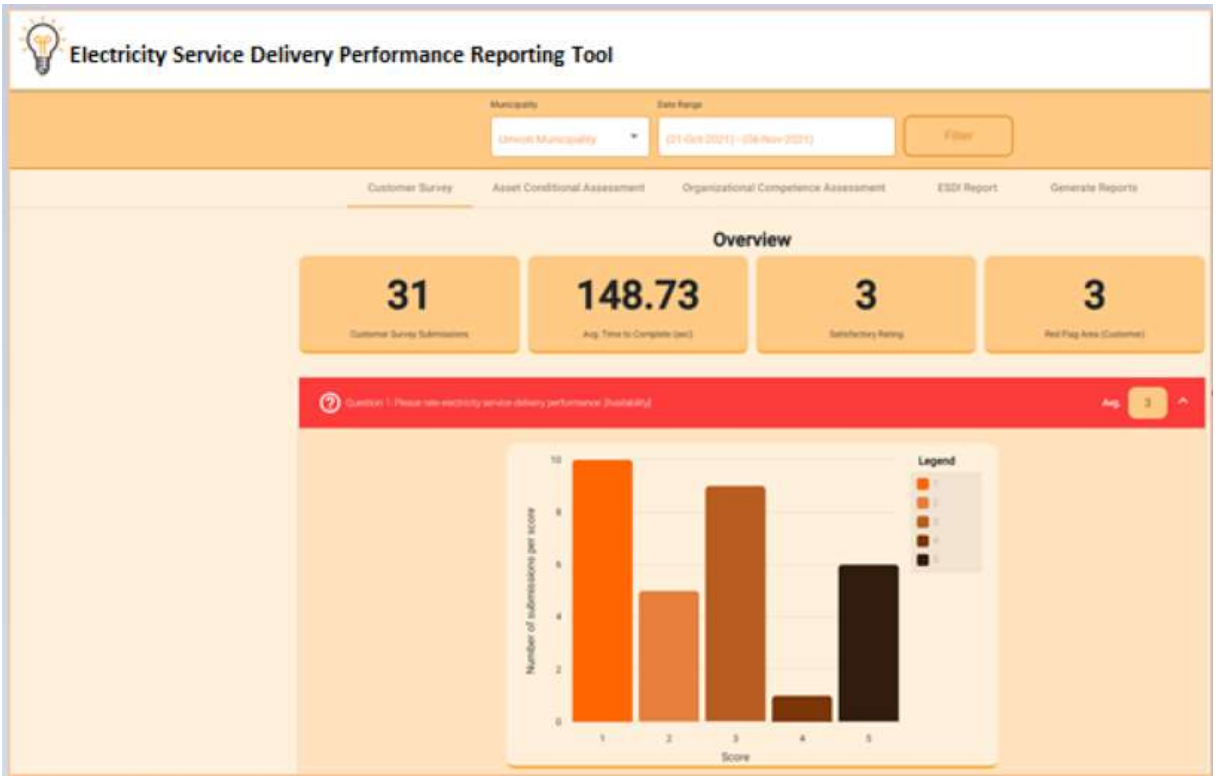


Figure 50: Screenshot Sample Page of ESD-PRT

An aggregation of all the data input produces an ESDI (Electricity Service Delivery Index) that suggests the health of the electricity service delivery per municipality, per time. For the date range and municipality chosen, the specific ESDI is shown in Figure 51.

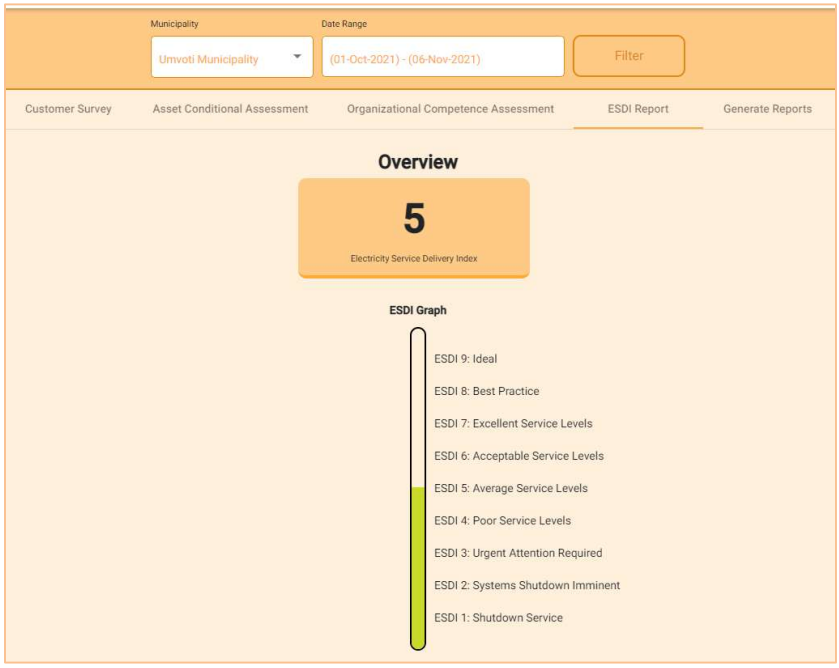


Figure 51: Electricity Service Delivery Index

To cater for emerging areas of concern and performance areas, or any request for improvements, respondents are allowed to submit feedback which is later reviewed by authorised management staff of the municipality. This authority is expected to act and then officially resolve (change the status of) the specific case. The status can either be pending, in-progress, resolved or closed, as shown in Figure 52. Also, the number of cases is rendered per category that is, number of open cases, pending cases, and closed cases.

Figure 52: Feedback for Improvement or Emerging Performance Areas

Where a municipality technician gives feedback, s/he is allowed to upload images or videos of his/her conditional assessment of any PSR, such as substations or components within, energy meters and power lines. An example is shown in Figure 53. The visualisation helps non-technical management principals of the municipality to conceptualise the problem, which, according to the municipality technical participants, is crucial in enabling management to release funds for maintenance and include their request in planning and budgeting, a capability that all three DCMs currently lack.

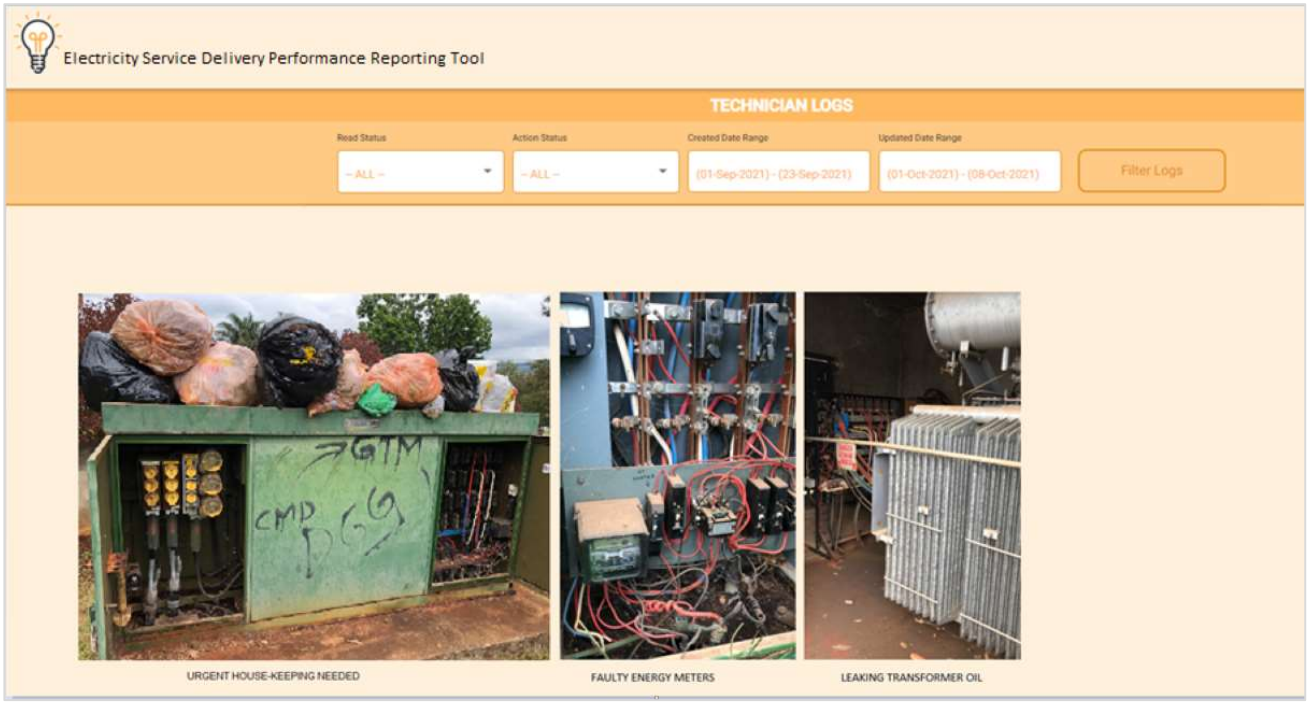


Figure 53: Technicians Log: PSR image upload

Users are generally given enough information and description for each segment of the tool as shown in Figure 54.

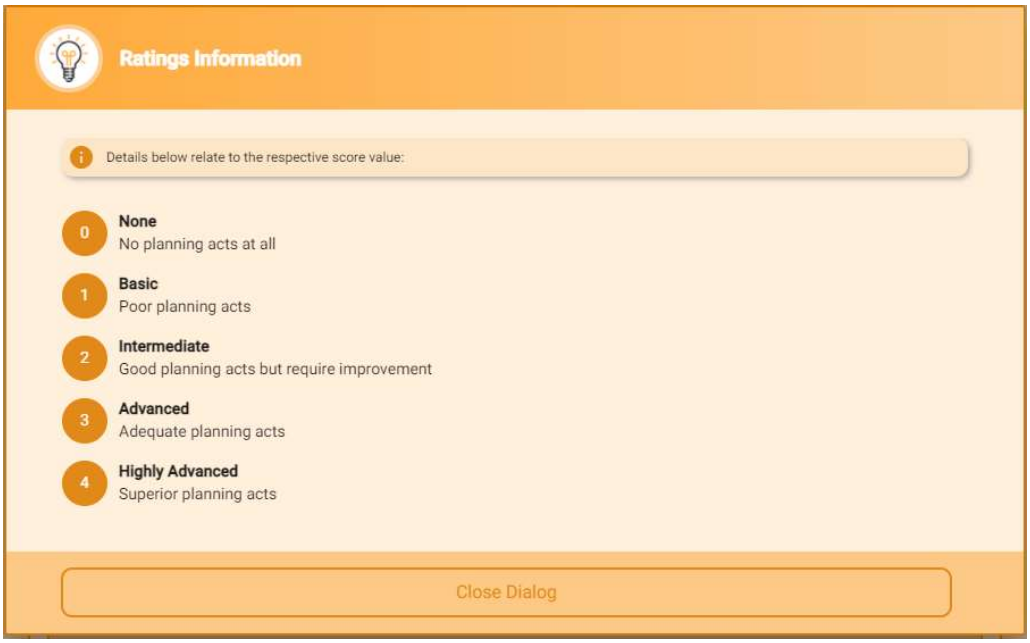


Figure 54: Assisted Survey Entry

Additionally, for research purposes, the tool allows a researcher to generate survey data based on user defined entry parameters. Based on information from the codebook, all these features are currently lacking at the three local municipalities, yet they are considered critical. The majority of participants, indicated in sections 4.4.5.1 and 4.4.5.2, indicate that the absence of these capabilities is, among other things, responsible for poor service levels and a deficit in electricity service delivery.

Finally, the leadership of DCM2 has made an informal request, and its intention concerning the tool is known as follows:

a. To host the tool on their official website.
b. To decide on ways to incentivise their residents to use the tool.
c. To explore the possibility of extending the tool to cover other service delivery areas, such as water, sanitation, waste removal and permitting.

A theoretical contribution is made, exploring existing bodies of knowledge via a SLR, which provided synthesised results that are also useful to other researchers within the field of diagnostic performance assessment, as follows:

a. Extracting existing diagnostic performance assessment tools from literature.
b. An evaluation of these diagnostic tools that are used in the service delivery domain.
c. General evaluation criteria for these diagnostic tools for ESD.
d. Additional design practices to identify and validate which of the criteria are useful in the local context.

The study also demonstrated empirical evidence for *aspects of four of the enterprise engineering theories*, thus extending the EE practice by providing practical methods for diagnosis, which in turn inform design principles within design domains.

Finally, a practical contribution was made by the approach and process followed in extracting areas of concern and performance areas using a codebook. The coding strategy, which provides a framework for requirements elicitation for electricity service delivery, can be applied to other service delivery areas such as water, sanitation and waste removal. It is also a useful framework for practitioners within the Enterprise Engineering disciplines to minimise vagueness and ambiguity when dealing with intention related concepts within design domains.

8.2 Chapter Conclusion

Chapter 8 described the ESD-PRT and outlined the main contributions made by the study. The entire study is concluded in Chapter 9.

Chapter 9. Conclusion and Recommendations

Chapter 9 provides an overview of the research objectives, the research questions, implementation and operationalisation plans of the prototype, limitations of the study, and further research.

9.1 Summary of the Research Objectives

The research aimed to develop capabilities for local municipalities to be able to know, on an on-going, holistic basis, the health of electricity service delivery within their official geographical boundary. This is a matter of national significance as deficits in ESD is already taking a great toll on the economy while drastically denting investors' confidence in making the country their destination of choice. Therefore, the study aimed to provide information and evidence that may guide redesign efforts in addressing performance deficit in electricity service delivery within South African local municipalities. Meaning, an exploration to determine the design domains (or sub-domains) of municipality electricity service delivery which, when observed to be functioning abnormally or below expectation, will help to explain the gaps between the observed and expected electricity service delivery performance. While the developed ESD-PRT provides information and insight into poor ESD, it is hoped that a future version would provide a full-blown diagnostic capabilities to guide ESD redesign. Without this first order, evidence-based reporting, and diagnosis, a solution pathway cannot be successfully designed and operationalised.

9.2 Concluding on the Research Questions

The research objective led to some pertinent research questions, which were answered, using fitting research paradigms and methods. The questions are repeated here for convenience:

a. *RQ1: What diagnostic service performance assessment tools are available in general?*
b. *RQ2: Which of these DSPA tools are used within the service delivery domain?*
c. *RQ3: What criteria must these DSPA tools satisfy to be selected and considered effective in addressing service delivery performance gaps?*
d. *RQ4: What software tool functions are needed (i.e. software tool requirements) to support the identification of areas of concern & critical failure factors of electricity service delivery?*
e. *RQ5: What are the constructional components of the new performance assessment/reporting tool?*

f. *RQ6: To what extent does a demonstration of the performance assessment/reporting tool partially demonstrate the usefulness and user-friendliness of the tool?*
g. *RQ7: How useful and user-friendly is the new performance assessment/reporting tool?*

RQs 1 to 3 were addressed through a SLR where over 2400 publications were sourced from more than ten major related databases. Over 21 tools, developed and applied across four continents within various sectors were extracted. Furthermore, 18 evaluation criteria for the tools were extracted from the literature, which were later reduced to 13 based on additional filters.

To achieve *RQ4*, a focus group session was held to:

a. Validate the need for a service delivery diagnostic tool for assessing public service delivery performance.
b. Validate criteria extracted from literature and identify additional criteria to evaluate the performance of existing public service delivery assessment tools.
c. Use the validated criteria to propose a hierarchy of criteria that decision-makers could use to prioritise the criteria.

The focus group participants were purposively selected to cover all areas of relevance in the problem domain. The group re-defined and validated requirements for a South African solution. Furthermore, the AHP was used to select, among existing "Off-the-shelf" tools, the closest one to the pre-selected criteria. The AHP is a MCDM method used to determine the performance of decision alternatives across several contradicting qualitative and/or quantitative criteria, resulting in a compromise solution. The PJM, which came out with the highest ranking was found to have shortcomings for the local context, a situation which triggered a design journey to design and create a tool for South African local government. Furthermore, to avoid ambiguity and vagueness in extracting the requirements, a codebook was developed clarifying the necessary areas of concern and performance for 3 municipalities.

Addressing *RQ5* began with a structural decomposition of the ESD-PRT to help operationalise the outcome of *RQ4*. The tool was modelled using the C4 constructional model, which defines software systems in four hierarchical views for ease of understanding and clarity to a wide range of stakeholders.

RQ6 and RQ7 were addressed through planned demonstration and evaluation of the artefact, respectively. For *RQ6*, a demonstration of the ESD-PRT deemed as a mini evaluation, included 6 participants and tested specific instances of the problem domain to prove the utility of the

solution. With 35 participants, answers to *RQ7* were provided, evaluating the user-friendliness and usability of the tool.

9.3 Implementation Plan

The evaluated artefact is a prototype that would be subject to improvement as new knowledge is gained and additional performance areas are discovered. The University of Pretoria and the researcher retains ownership of the intellectual property while the tool is made available to the local municipalities to improve the electricity service delivery and potentially other services delivery. For each municipality, the following steps are deemed necessary for the use of the tool: (1) Stakeholders' engagement which includes representatives of the municipality top management, workers union and residents to get their *buy-ins* for the application of the tool; (2) Training of a site champion who will be the administrator of the tool; (3) Training of other users; (4) Deployment of the tool; and (5) Monitoring of whether the tool is used as intended. All participating citizens and municipality officials currently have access to the ESD-PRT. An anonymous user with administrative privileges is also created here: http://129.232.253.250:60000/, (username: anonymous, password: P@ssw0rd2021).

9.4 Limitations of Study and Areas of Further Research

There are some notable limitations to the study. The study focused only on South African local municipalities and the same study assumptions may not hold for larger, more affluent municipalities. Likewise, as indicated in Figures 2 and 3, the research focused on the distribution of electricity mostly performed by the municipalities. This study may be extended by testing the ESD-PRT in metropolitan municipalities and testing the tool for a broader set of enterprise functions, namely electricity generation and transmission, and quantitative objective measures. Additional testing will increase the generalisability of the tool to diagnose problems within a broader ESD context.

The evaluation of the ESD-PRT also indicated a low score on the predictability and reliability of the tool. The study recommends that the ESD-PRT be used for six months, re-evaluating the low-scoring criteria.

Finally, the study did not create, based on aforementioned EE theories, the essential models of ESD. It is recommended that future work should consider developing the models based on Hoogervorst (2018).

9.5 Concluding Statement

This study presented the following thesis statement as a synthesis of the research intent:

A ***user-friendly*** performance reporting tool (PRT) for obtaining inputs from various stakeholders *is* ***useful*** to initiate diagnosis of electricity service delivery at some local South African municipalities.

The study provided sufficient evidence to confirm the thesis statement.

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