The Use of Cloud Technology to Promote E-Waste Awareness for Under-Resourced Villages in South Africa

by

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DECLARATION

I, Odwa Gazana, declare that the contents of this dissertation/thesis represent my own unaided work, and that the dissertation/thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

OGazana 25 June 2024

Signed **Date**

ABSTRACT

The rapid increase in electronic waste (e-waste) around the world has become a great concern. This is because e-waste contains hazardous elements such as mercury, lead, beryllium and many other elements. If these hazardous elements are not properly disposed of or treated, they pose a danger to the environment and human health. The danger associated with e-waste is caused by the hazardous elements leaching into the underground water, into the soil and polluting air when the e-waste is burnt.

It has been observed that communities in the under-resourced villages of South Africa lack knowledge of how e-waste is managed. The observation has prompted the researcher to conduct this study to explore a possible solution that addresses the identified e-waste challenges. The study aimed to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste. Based on the study aim, four research questions were drafted: i) How do people living in under-resourced villages manage e-waste? ii) What are the challenges and impacts posed by the disposal of e-waste on the ecosystem in the under-resourced villages? iii) What strategies of a cloud-based solution could be used to manage e-waste for the under-resourced villages? iv) What strategies could be identified and adopted in developing the cloud e-waste awareness solution?

In answering the above questions and achieving the study's aim, the study adopted a qualitative research strategy embracing a case study design. Two cases of under-resourced villages in the province of Eastern Cape were chosen for the study. The two cases studied are Village A and Village B. Village A and Village B are under Municipality C. Data was collected using semi-structured interviews, co-design methods and document analysis. Semi-structured interviews were used to collect primary data while document analysis and co-design methods were used for collecting secondary data. Two theories underpinned the study, namely Social Capital Theory (SCT) and Activity Theory (AT). SCT was used to understand vital issues of the characteristics, lived experiences and nature of individuals, their contribution and what they want to benefit from. AT was used to identify strategies to adopt in developing the cloud e-waste awareness solution.

Data was analysed separately for each case. The study found that people from the two locations (Village A and Village B) dispose of e-waste in landfills, fountains, nearby dams, and

rivers and another disposal method is the burning of e-waste. The findings for both locations indicated that challenges and impacts posed by e-waste disposal on the environment include (1) lack of awareness regarding e-waste and its dangers to the environment and human health. (2) Contamination of food, water and air. (3) Lack of understanding of the impact e-waste has on farming. Different types of e-waste items identified in the under-resourced villages included refrigerators, electronic irons, electronic kettles, televisions, electronic stoves, washing machines, cell phones, car batteries, cell phone batteries, electronic hairdressers, radios, electronic cables, digital video discs (DVDs), electronic wall plugs and globes. However, it was found that people in this area are willing to learn about e-waste to better manage it. It was recommended that there should be incentives for handling and handing in their e-waste collected and disposed of from their homes. Interviewees further suggested that the e-waste topic can be presented when they have scheduled community gatherings. They further proposed that e-waste should be integrated as a topic for learners in the schools that are situated in both locations. The study noted that the municipality that oversees service delivery to the locations did not have an e-waste policy document. The findings also noted that the municipality lacks e-waste awareness programs.

Based on the findings, a cloud-based solution to help curb and spread e-waste awareness for the two locations was developed. Through the Activity theory, the study findings noted the importance of acquiring the technical and non-technical requirements, governance and stakeholder collaboration to ensure effective execution of the cloud solution for the intended users. A prototype of the proposed solution is documented in the upcoming chapters. The proposed cloud-based solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste.

The contribution to the solution included villagers' perceptions and experiences in designing of the proposed technology-based solution prototype. The adopted theory enabled the researcher to collaborate with communities in terms of their experience towards the development of the cloud-based solution. Practically the proposed cloud solution can be adopted by other provinces in South Africa and other African countries. In addition, the study adds value to the existing body of knowledge in terms of the introduction of a cloud-computing e-waste management system.

Keywords: Activity Theory, Cloud-based solution, E-waste, Social Capital Theory, Under-resourced Villages.

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DEDICATION

I dedicate this research:

Firstly, to my father for his everlasting love and support.

Secondly, to the People of Village A and Village B, we may at the moment feel as if we are neglected in so many ways in terms of service delivery but if we stand together, we can change our villages for the better.

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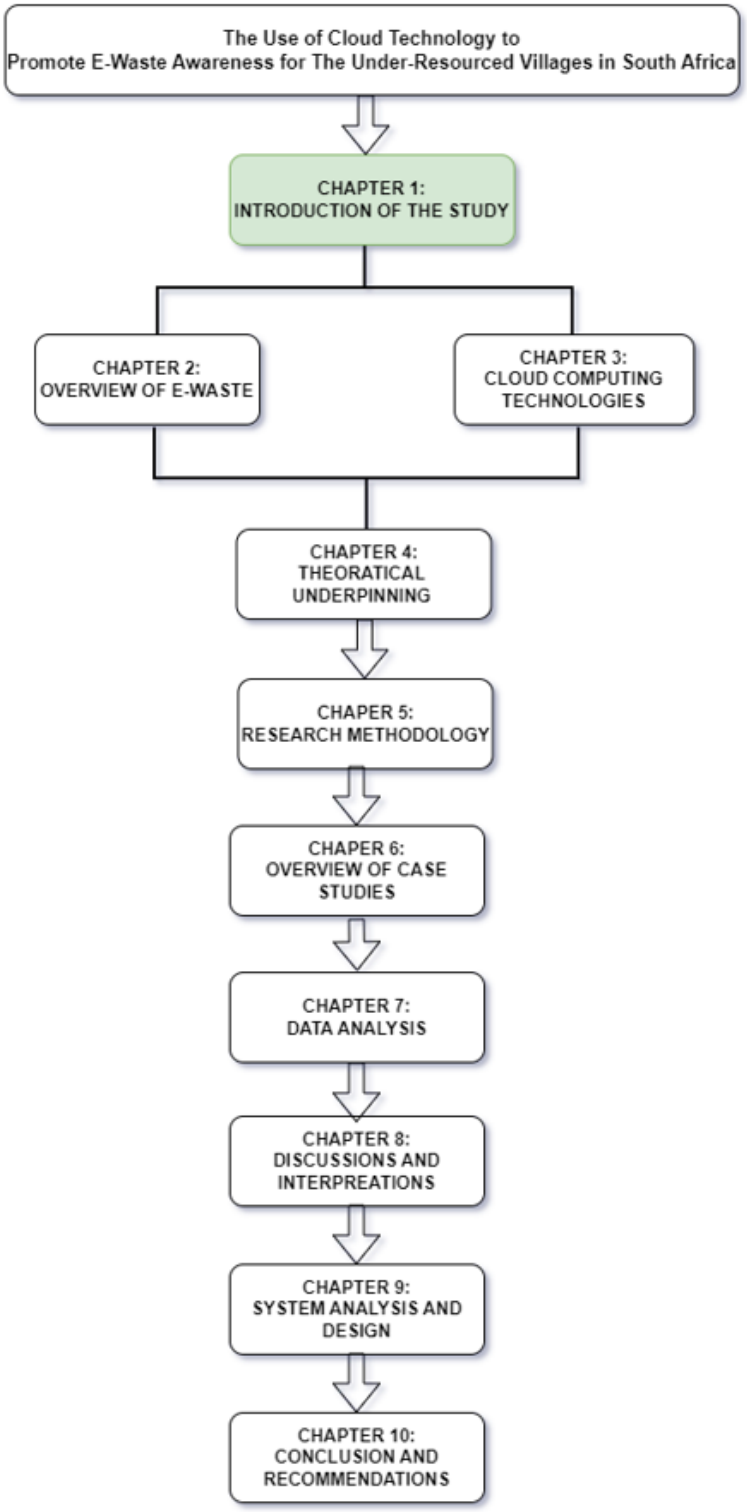
GLOSSARY

Acronyms	Definitions
AES	Advanced Encryption Standard
AI	Artificial Intelligence
API	Application Programming Interface
AT	Activity Theory
CC	Cloud Computing
CPU	Central Processing Unit
CRUD	Create, Read, Update, Delete
CSCW	Computer Supported Collaborative Work
DEA	Department of Environmental Affairs
DPPs	Digital Product Passports
DSS	Digital Signature Standard
DT	Design Thinking
DVD	Digital Video Disc
EEE	Electrical And Electronics Equipment
EPR	Extended Producer Responsibility Regulations
E-Waste	Non-Functioning Electronic Equipment
FIPS	Federal Information Processing Standards
GDP	Gross Domestic Product
HCI	Human Computer Interaction
HMAC	The Keyed-Hash Message Authentication Code
HTTPS	Hypertext Transfer Protocol Secure
IaaS	Infrastructure As A Service
ICT	Information And Communication Technology
IOT	Internet Of Things
IP	Internet Protocol

Acronyms	Definitions
IQ	Intelligence Quotient
IS	Information Systems
ISO	International Organisation for Standardisation
IT	Information Technology
JSON	Javascript Object Notation
JWT	JSON Web Token
Kg	Kilograms
KMIP	Key Management Interoperability Protocol
LAN	Local Area Network
Location	Collective Noun For The Two Villages Studied.
Mt	Million Tons
NEMA	National Environment Management
NN	Neural Networks
OSI	Open System Interconnection
PaaS	Platform As A Service
PC	Personal Computer
PKI	Public Key Infrastructure
REST	Representational State Transfer
POP	Persistent Organic Pollutants
RFC	Request For Comments
RFID	Radio Frequency Identification
SA	South Africa
SaaS	Software As A Service
SCT	Social Capital Theory
SHS	Secure Hash Standard
SMS	Short Message Service
SPML	Service Provisioning Markup Language

Acronyms	Definitions
SSL	Secure Socket Layer
TA	Thematic Analysis
TLS	Transport Layer Security
UK	United Kingdom
UML	Unified Modelling Language
UNESCO	United Nations Educational, Scientific and Cultural Organization
USA	United States of America
VM	Virtual Machine
WEF	World Economic Forum
XML	Extensible Markup Language

CHAPTER 1: INTRODUCTION OF THE STUDY



1.1 Introduction and Background

Electronic waste (e-waste) contains toxic elements that pose a danger to the environment hence it is important to avoid discarding it in the spaces that are not suitable for littering or recycling. DeVroom (2019) supports the above statement that electronic devices contain hazardous chemicals and if these elements are not discarded safely, they can pose health problems to the ecosystem. This is further supported by Elytus (2019) that when electronic devices are improperly disposed of toxic chemicals are released into the air, soil, and water and thus create an unfriendly environment. The environment then becomes not conducive to live in.

The villages are catching up with urban areas in terms of e-waste generation and have no proper mechanisms for of disposing it (Bhat & Savale, 2019). This has been observed in the villages used as cases for this study whereby out-of-life electronic devices are thrown into open pits and open landfills as means of disposal, contributing to the challenge that e-waste brings about climate change.

People from villages may not know the impact that e-waste brings on the environment and their lives. People from villages may make use of electronic devices and may not be aware of the dangers that e-waste poses to the environment. Furthermore, most users in these areas may not know what to do with e-waste when these devices have run out of life and are thus wrongly discarded.

Residents from villages can be considered as small-holding farmers, as they grow their food by planting vegetables and maize and breeding their livestock. They use water from the nearby rivers and dams for drinking and irrigation, hence e-waste poses a pollution challenge and health hazard to their products, livestock, and communities. Li and Achal (2020) state that under-resourced villages might no longer be suitable for food growing, and use of water for drinking due to the toxic elements leached into the land and the under-ground water.

A need to educate and bring awareness to the communities in the villages on the dangers posed by e-waste is vital. The researcher suggested community involvement in the process of developing the proposed awareness mechanisms to inspire ownership and improve understanding of e-waste knowledge. The research theory adopted suggested involving communities in the process of creating cloud-based technology solutions for e-waste management to mitigate e-waste impact on the ecosystem.

E-waste is described by CalRecycle (2020) as electronic devices whose lifespan has ended and cannot be used in any way. Examples of such devices include computers, televisions, stereos,

copiers, cell phones, fax machines, etc. Whilst there is no traditional definition of e-waste, the European Union describes e-waste "as waste, including all components, sub-assemblies, and consumables, which are part of the product at the time of discarding" (Kapoor *et al.*, 2021:1). These devices can be found in business offices and households.

The high demand for the use of these devices for various activities has posed a challenge in the increase of carbon emissions once discarded into the environment. Kristanto and Koven (2019) agree with the previous statement by stating that carbon emissions from discarded electronic devices are dangerous to the environment and human lives.

In addressing environmental challenges posed by toxic elements such as e-waste, the United Nations Environment Programme (UNEP, 2024) established the Sustainable Development Goal 12 (SGD 12), which was established to ensure sustainable consumption and production patterns. SGD 12 provides 11 targets that the world needs to observe and ensure the provision of a green environment. The 11 targets of SGD 12 promote measures for waste reduction and require that communities be involved in the process. In realisation of the SDG 12 targets the study adopted the Social Capital Theory (SCT) by collaborating with communities to develop the solution.

Table 1.1 gives examples of toxic elements found in electronic devices, which are mostly found in households and business offices.

Table 1.1 Components and constituents of E-waste (Ilankoon et al., 2018)

Components	Key Constituents
Data tapes and floppy disks	Chromium (Cr)
Television sets, PC monitors, batteries, light bulbs, lamps	Lead (PB)
Fluorescent lamps, lightening devices for flat screen displays, CRTs, PCBs, thermostats	Mercury (Hg)
Computer batteries, ink or toner photocopying machines	Cadmium (Cd)
Capacitors and transformers	Poly chlorinated Bb-phenyls
Lubricants and coolants in generators, fluorescent lighting, ceiling fans, dishwashers, electronic motors	POPs including brominated flame retardants
Radio, amplifier, and stereo	Lead and chromium, brominated flame retardants
CRTs, metal coatings, batteries	Zinc (Zn)

It has been observed that communities have a limited knowledge of these devices as a threat to the environment. To empower communities on this subject matter, Saldana Duran *et al.* (2020) are emphasising that e-waste is an environmental problem that needs communities' participation in producing a solution. The existing solutions for e-waste management, such as the 3Rs (recycle, reduce and reuse), the Basel Convention, the Bamako Convention, and informal collection are according to Owusu-Ansah (2020), Abalansa *et al.* (2021) and Lundgren (2012) not technologically based. The above authors' claim concurs with the researcher's observation that there is a lack of technologically based solutions to support the management of e-waste with a specific reference to under-resourced villages (these are defined as rural remote areas and villages in this study). This is further supported by (Berg *et al.*, 2020; Shevchenko *et al.*, 2021) suggesting that cloud-based technology solutions are still not yet fully implemented for e-waste management.

The adoption of cloud-based technology solutions has the potential to support the management of e-waste, prevention, collection, and treatment (Sipka, 2021). Sipka further indicates that the possible solution can be driven by adopting Artificial Intelligence (AI) and online applications to develop such solutions. The technological solutions suggested by Sipka (2021) can be used as a base for the development of the proposed solution in this study.

1.2 Research context

The section below details the contextual setting of the research. It provides background on e-waste globally and in South Africa. Herein the researcher focuses on the following sub-headings, which are e-waste definition, e-waste in developed countries, e-waste in developing countries, e-waste in South Africa (SA) and the negative impacts of e-waste on the ecosystem and lastly technology as a solution to e-waste. The research context aims to showcase the importance of the study.

1.2.1 Definition of e-waste

E-waste has a variety of definitions across the globe. According to Owusu-Ansah (2020), the Basel Convention 1989 described e-waste as waste that contains electronic gadgets, including household items, such as computers, cell phones, fridges, and air conditioners. The primary definition is from The European Union Waste Electronic and Electric Equipment (EU WEEE) directive which states that e-waste is "all waste including all components, sub-assemblies and consumables, which are part of the product at the time of discarding" (Kapoor, *et al.*, 2021:1).

The Electronic Waste Association of South Africa (EWASA) states that e-waste is electronic and electrical waste including Information and Communication Technology (ICT) equipment, consumer electronics, small household appliances and large household appliances (EWASA, 2020). Atria Innovation (2020) supports EWASA by stating that the term e-waste covers a wide range of electronic equipment that can be grouped into household appliances, ICT equipment, medical devices, tools, and toys.

Owusu-Ansah (2020) categorises e-waste as uncontrolled disposal of e-waste that could be harmful to the environment and the well-being of humans because of the toxic substances and heavy metals in it. According to Lenkiewicz (2021), e-waste is categorised into six (6) groups namely cooling and freezing equipment, screens and monitors, lamps, large equipment such as printers, small items (household items such as cell phones and laptops), and ICT equipment. Different authors define e-waste in a similar manner hence this study has adopted its definition as such.

1.2.2 E-waste in developed countries

The World Bank describes developed countries as countries whose economies are mature and sophisticated based on the gross domestic product (GDP) measurement. Developed countries produce a high number of electronic devices for business purposes. Latchem (2021) suggests that the highest number of electronic devices produced could be linked to high GDP generation. The

level of production of e-waste based on the GDP poses the same level of e-waste management. Despite the level of e-waste production, the developed countries have mechanisms in place for the management of e-waste. Wideman **(**2019**)** agrees that developed countries like Canada and the USA have proper ways in place for e-waste management. This includes exporting substantial portions to developing countries such as India, Nigeria, Egypt and South Africa (Wideman, 2019**)**. In support of this, Abalansa *et al.* (2021) state that e-waste is problematic for the environment for most developed countries, so to get rid of it, they export it to developing countries as donations, as it is a cheaper method to recycle it. The above suggests that developed countries use developing countries as their dumping sites for e-waste. Owusu-Ansah (2020) agrees that developed countries have the technology to manage e-waste but choose to dump it as a cost-saving method in the lower developed countries.

Even with the awareness of the disadvantages of e-waste, many of the developed countries continue to pile up e-waste and transfer it to the developing. Malloy (2021) states that the United Kingdom (UK) is en route to becoming the biggest e-waste contributor in Europe rivalling Norway. Latchem (2021) supports this by stating that the UK and Norway lead the European countries in producing the most e-waste per household.

E-waste requires investment for it to be managed effectively. The Australian government initiated and funded a national television recycle scheme that enabled households and small business to have their e-waste collected for free especially televisions and computers (Herat & Panikkar, 2019). This model can be the best alternative way of managing e-waste by the municipalities.

1.2.3 E-waste in developing countries

Developing countries can be described as countries whose GDPs are not matured and sophisticated and which have less developed industrial base (O'Sullivan & Steven, 2003). Developing countries face socio-economic challenges, such as political instability, poor infrastructure and limited healthcare facilities (OECD, 2020). It is for this reason that developed countries make donations as a form of assistance. According to the United Nations (2021), developing countries require finacial assistace and technologial support from developed countries.

The technology support aspect to developing countries has been argued by many reseachers as a means for developed countries to rid of their e-waste (Wideman, 2019; Awunsu-Ansah, 2020; Bazilian, 2020; Abalansa et al, 2021). E-waste equipment from developed countries could clutter towns and villages, bringing sickenesses and harming the enviromment (Bazilian, 2020). Developed

countries donate e-waste to developing countries as they see it as a cheaper option of discarding e-waste (George, 2021). This is concerning, as there is lack of e-waste management systems in place for developed countries. Bazilian (2020) agrees that this becomes a burden on villagers and the environment, as it gets pollulated. Developing countries suffer the consequances of e-waste due to the high rate of e-waste generation (George, 2021).

Due to the high rate of e-waste genaration in Malaysia, drastic measures were taken to contain e-waste; governement introduced environmental quality regulation for households and business community (Shad *et al.* 2020) . It was also found that e-waste had increased by 14% by the end of 2020 in the country, this was attribited to household e-waste generation and donations from developed countries (Perunding Good Earth, 2021). According to Nyamrunda (2020), Tanzania has been genarating e-waste in large quantities. The US and other developed countries have put regulations to prevent illegal dumping. However not all developing countries have these laws and regulations in place, leading to illegal dumping of e-waste (Bazilian, 2020).

Informal recycling sites are then born out of not having laws, policies and regulations. Orisakwe *et al.* (2019) states that due to the lack of such regulations, the rise of informal sites brings risks. Bernhardt (2021) supports the above statement by indicating that, India, Pakistan and Nigeria are some of the developing countries that lack regulations, laws and policies for proper management of e-waste.

1.2.4 E-waste in South Africa

South Africa is a developing country with a population estimated to be just over 59 million (World Bank, 2022). Each citizen's rights are protected by the country's constitution. According to the President's Office (South Africa, 1996), each citizen has a right to a healthy environment, basic services such as sanitation, electricity, quality of healthcare and proper infrastructure.

The country's constitution underpins the importance of providing a clean environment and healthy lives for all South Africans. However, with the fast-growing of e-waste and high level of illegal dumping in the country, the right to a healthy environment is compromised and poses serious risks to the environment and human life (Ichikowitz & Hattingh, 2020). This could be attributed to the fact that many South Africans do not recycle their e-waste and lack an awareness of e-waste management (Gcwabe, 2021) .

A study by Ichikowitz and Hattingh (2020) supports this by stating that a lack of consumer awareness about e-waste recycling is the main cause of illegal open fields of e-waste dumping. Not knowing the

dangers of e-waste and how e-waste can be got rid of has led to people disposing of e-waste carelessly, especially in rural areas. Gcwabe further indicated that these areas do not just dispose of e-waste in the open fields but also in the pits, nearby rivers and dams which also expose e-waste to the heat. According to The Green Lakes Electronic Corporation (2022) exposing e-waste to heat and open lands releases toxic elements that pollute the land, water and air. According to World Health Organisation (WHO) the quality of air in South Africa is moderately unsafe (Gcwabe, 2021).

Just like other countries, the South African market is inundated by different household electronic devices which include mobile devices, computers, radios, televisions, dishwashers, fridges and cameras. These devices end up as e-waste once they no longer operate (Workman, 2020).

South Africa has its citizens living in two settlement types namely the urban and rural areas. Rural areas are being referred in this study as under-resourced villages. Under-resourced villages in this study are defined as small settlements found in rural settings or outside towns. South Africa has many under-resourced villages, particularly in the Eastern Cape. These areas have limited or no resources such as clean running tap water, sanitation and proper infrastructure (Abrams *et al.*, 2021).

For under-resourced villages, e-waste is a huge burden, as there are no mechanisms of managing it. Out-of-life electronic devices are either thrown into open pits or thrown into open landfills as a means of disposal, contributing to the challenge that e-waste brings with regard to climate change (Ferronato & Torretta, 2019). Under-resourced areas are catching up with urban areas in terms of e-waste generation and no proper mechanisms of disposing it (Bhat & Savale, 2019). Under-resourced villages are demarcated under municipalities in the country, this means that municipalities are responsible for service delivery such as e-waste management for these areas. However, most municipalities supporting under-resourced villages lack the resources needed for e-waste management (EWASA, 2023).

1.2.5 E-waste negative impacts on human health and environment

A number of reseachers state that improper disposal of electronic devices is problematic to the ecosystem (Elytus, 2019; Halim & Suharyanti, 2020; Kapoor *et al.*, 2021). Disposal may lead to the following four negative effects:

- Air pollution – informal disposing and burning of electronic devices releases toxins into the air, causing air pollution, which damages respiratory health.

- Soil contamination – improper disposal of electronic devices into landfills causes heavy metals to penetrate deep into the soil. This contaminates the underground water, which leads to contamination of crops and trees.
- Water contamination – metals from e-waste, such as mercury, lithium, lead and barium from underground water leak through the earth into water streams, such as dams and rivers.
- Human and animal lives health impact – the above 3 negatives highly impact the fourth aspect affecting humans and animals who need air to breathe, soil to live and food and water for drinking. Human health problems caused by air and soil pollution and contamination present negative health challenges such as heart problems, liver complications, brain damage, respiratory problems and skeletal system damage.

E-waste challenges and the negative impact identified in the literature have been observed in the under-resourced villages investigated for this study. The increase of such e-waste spread and growth prompts an urgent need for a cloud-based technology solution to mitigate challenges posed to the ecosystem.

1.2.6 Cloud-based technology solution

For this study, a cloud-based technology solution refers to the technological application developed to enable rural communities to effectively manage e-waste. This cloud-based technology solution can improve the ecosystem when it is adopted correctly to manage e-waste. Mukta and Ahmed (2020) state that integrating cloud-based technology solutions in addressing e-waste challenges can provide positive contributions to the environment. The adoption of the technology-driven solutions has means to improve the state of e-waste hence the researcher is developing a technology solution that is customised to address the needs of the under-resourced villages that can be adapted for different settlements. Mmeah *et al.*(2018) support the above statement by stating that cloud-based technology services must be able to deliver a green ecosystem to ensure that the current and future generations are not compromised by e-waste mismanagement. Sipka (2021) argues that using cloud-based technology solutions, such as Artificial intelligence (AI), Digital product passports (DPPs), Apps and online platforms can assist in the proper handling of e-waste recycling. It is important for the study to co-design the cloud-based technology solution that addresses under-resourced villages' needs.

1.3 Problem Statement

Outdated and non-functioning electronic equipment poses environmental challenges for both developed and developing countries. (Orhorhoro & Oghoghorie, 2019). Under-served communities in developing countries suffer the most in this regard as dumping of e-waste in open fields is a common thing that leads to ill health and environmental issues (Mukta & Ahmed, 2020).

According to Abalansa *et al.* (2021), toxins such as cadmium, lead, copper, and mercury are mostly found in the air, soil and water in places where there is no formal e-waste management system. The environment, animals, and people living close to dumping areas are affected by such toxic emissions. Literature suggests that in India where there was no e-waste management system in place, there was a rise in health issues such as breathing difficulties and skin irritation (Cruvinel *et al.*, 2019). In Chile, sores in the body were found on people also living where there was no e-waste management system in place (Yohannessen *et al.*, 2019).

The above historical studies demonstrate how mishandling of e-waste can impact the environment and human health. Hence this study proposes an under-resourced community-driven technology-based solution to protecting the environment and health from e-waste mismanagement. This is because under-resourced villages have no proper means of handling e-waste. Weerasundara *et al.* (2020) state that improper handling of e-waste is dangerous to human health and the ecosystem. The study focuses on the two chosen cases due to the researcher's observations that e-waste was carelessly disposed into landfills.

The littering and mismanagement of e-waste by communities in the villages' open fields and illegal dumping sites threaten the ecosystem because of the toxic components found in the electronic devices.

This is further supported by Sadan (2019) and Elytus (2021) indicating that the disposal of electronic devices in landfills and dumping sites is problematic and dangerous to humans and the environment. Furthermore, Sadan (2019) states that a lack of awareness and a lack of a formal take-back scheme contributes to the problem. However, Masoabi (2020) and Mouton (2020) state that where there are formal take-back schemes, people require some form of compensation for handing in their e-waste items.

The use of technology-based solutions to promote e-waste awareness in under-resourced villages can improve the ecosystem and limit hazardous challenges posed by e-waste littering and mismanagement (Sipka, 2021). In the United States of America, online (website) applications have

been developed by companies for users to recycle their e-waste. The online apps require that users state their goods to be recycled and users pay a fee for the collection of the goods (ewasteonline, 2020). The researcher observed that this would not work for under-resourced villages in South Africa as most of the villagers' financial support is limited to the social grants and that cannot afford to pay for such services, hence a cloud-based technology- solution is proposed in this study. The proposed solution is found to be more convenient because most of the village communities have access to smart mobile phones (Dutt *et al.,* 2019).

The study addresses the problem of South African villages' lack of e-waste awareness by proposing a cloud technology that can be used as a solution.

1.4 Aim of the Research

The study aims to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste.

1.5 Research Questions and Objectives

Based on the study's research problem presented above, the following research questions and objectives are presented in Table 1.2:

Table 1.2: Research questions, objectives, and research methods

Main research question	**MQ:** How can a cloud-based technology solution promote e-waste awareness in under-resourced villages of South Africa?	
Research sub-questions	**Objectives**	**Data Collection Method(s)**
SQ1: How do people living in under-resourced villages currently manage e-waste?	**O1:** To determine how people living in under-resourced villages manage e-waste currently.	Literature review Interviews
SQ2: What are the challenges and impacts posed by the disposal of e-waste on the ecosystem in the under-resourced villages?	**O2:** To determine different types of e-waste, challenges, and impacts on the ecosystem in the under-resourced villages.	Literature review Interviews Observations
SQ3: What strategies could be used to manage e-waste for the under-resourced villages?	**O3:** To identify strategies that could be used to manage e-waste for the under-resourced villages.	Literature review Interviews
SQ4: What strategies could be identified and adopted in developing the cloud e-waste awareness solution?	**O4:** To identify strategies to adopt in developing the cloud e-waste awareness solution.	Literature review Interviews Co-design Design thinking

The study explored the main research question (MQ) by addressing the four sub-questions (SQ1 to SQ4), associated respectively with research objectives O1 to O4.

1.6 Design Frameworks

The study embraced two design frameworks; co-design and design thinking to underpin the design phase of the study.

1.6.1 Co-design framework

Co-design is a framework that is about design with and not for. Co-design is a process whereby all stakeholders are involved in the design process. Singh *et al.* (2023), Mager (2008) and Slattery *et al.* (2020), state that co-design allows a system to be built on the users' lived experiences. Including stakeholders in system design is important to instil a sense of ownership, user satisfaction with the system, and user awareness (Dwivedi & Dwivedi, 2021; Alam, 2002 & Kujala, 2003). This theory is designed to engage people in the process of development, improvement and innovation by using collective experiences to build new services. Burkett (2021) states that to change complex social problems, there is a need to incorporate the skills, experiences and knowledge of all people involved or impacted by the problem. It is observed that Co-design provides a means of engaging end users with a range of stakeholders to assist in the process of understating the social issues in designing and implementing programs.

Co-design consists of different traditions that are presented in Table 1.3.

Table 1.3: Key traditions of co-design (Zamenopoulos & Alexiou, 2018)

	Community design	**Socio-technical design**	**Co-creative design**	**Social design**
(Historical) context	Democratic design in architecture and planning	Democratic design of socio-technical systems	Innovation in service and product design	Social change, and social innovation
Key interests	Community building Consensus building	Cooperative action between adversaries Polyphony	Learning from the collective creativity of potential (users) Co-created value	Making use of the power of connecting people Social good
Key concepts	Participation, communicative action	Participation, infrastructuring, agonism	Generative research, tools for engagement	Creative citizenship, design activism, DIY and self-help practices
Key motivations	Democracy and sustainability	Democracy	Innovation	Social innovation and sustainability

Co-design was chosen as a framework because the solution is to be designed with villagers, evidence based on Table 1.3. Stickers, pencils, colouring pencils, boards and videos were used to explain the concept and its design process. During the co-design sessions, the isiXhosa language was used to engage with the participants, this was to ensure that they understood what the study is about and to also use a medium that participants are comfortable with. Xhosa is the most common communication language used in the studied area.

1.6.2 Design Thinking Framework.

Design thinking (DT) is a process used to solve complex problems in a user-centric way (Stevens, 2020). Users are the centre of the design process, as they are the ones who understand the problem and provide lived experiences by producing workable solutions. DT is used to understand human challenges and develop solutions based on the understanding (Brunetto, 2018). According to Stevens (2020), problems solved by using DT are not only common problems that have tried

and tested solutions. DT is for complex problems that cannot be solved using standard approaches (Stevens, 2020). DT is a user-centric hands-on approach with five phases.

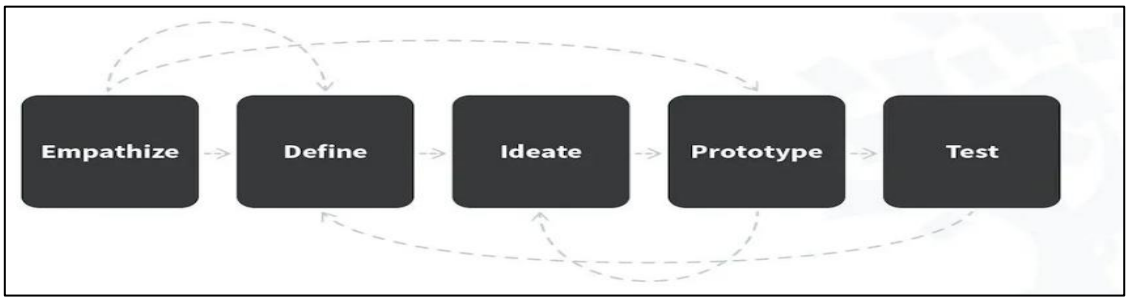


Figure 1.1: Five stages of design thinking (Dam, 2021)

Figure 1.1 sets out the five (5) stages that are important for the DT process in solving complex issues that are facing companies, countries and even communities (Dam, 2021). For this study, DT was adopted to solve the complex issue of e-waste mismanagement in under-resourced villages by using people from the villagers as end users.

- Empathise – identifies the problem by observing what the community does, and what it is that they do that results in a problem.
- Define – define the problem based on the literature review and observation.
- Ideate - sets down and brainstorms ideas by both the researcher and the participants on how a solution can be developed to help curb the situation of e-waste littering in the villages.
- Prototype – develops a prototype after brainstorming and data analysis to curb e-waste littering in the villages.
- Test – evaluates the prototype developed to check if it meets the requirements needed to curb e-waste littering in the villages.

1.7 Underpinning Theories

The two theories are selected to underpin this study to accomplish its aim. These two theories are Social Capital Theory and Activity Theory.

The study adopted the two theories because of their suitability to accommodate qualitative research (Victoria *et al.*, 2019). Both Social Capital Theory and Activity Theory deal with how research that involves communities as participants should be undertaken. Social Capital Theory deals with how

people from the communities should be catered for when sharing their lived experiences and Activity Theory provides guidance to gain a deeper understanding of human activity within systems.

1.7.1 Social Capital Theory

Social Capital Theory (SCT) is defined by Garip (2008) as a means of producing services using community networks to benefit individuals or parties. Literature has proven that social capital motivates individuals from communities to share their lived experiences (Wasko & Faraj, 2005; Nahapiet & Ghoshal, 1998). Social Capital seems to go hand in hand with co-design, hence the researcher adopted this theory and co-design for this study. In support of this, (Fari & Yar'adua, 2015:19) states that "the core components of any organisation are the individuals who contribute towards the overall success of the system from its inception to the sharing of knowledge with each other and outside parties". As stated, co-design requires that participants get involved with the project from the inception phase to the last phase until it is done and tested. Figure 1.2 depicts components of the social capital.

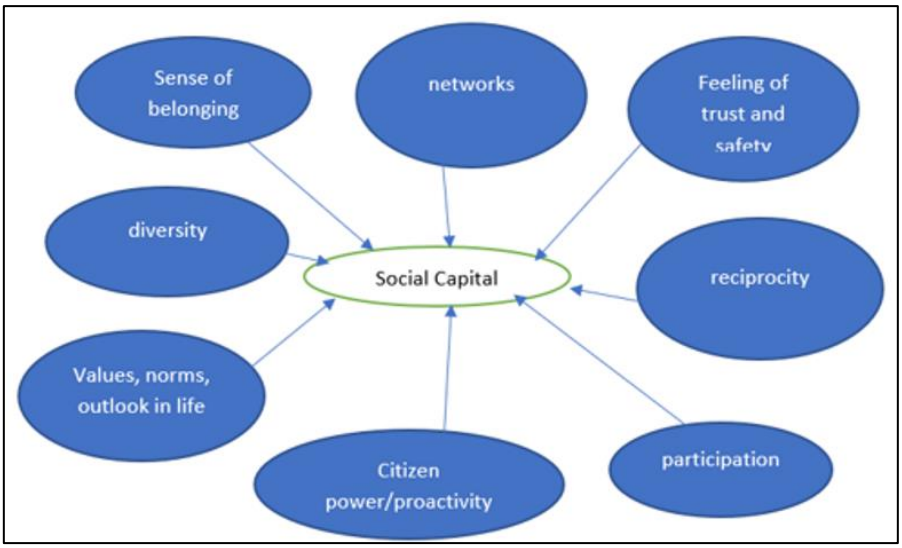


Figure 1.2: Social Capital Theory components (Halpern 2005)

The components of the SCT, adopted for this study include:

- Sense of belonging – Individuals have a sense of security when surrounded by others with a common goal, this boosts one's confidence (Chow & Chan, 2008). For this study, this allows participants to speak openly knowing they have the support from other community members.
- Network – It provides a platform for the participants to communicate and share information and innovate the solution needed to manage e-waste.
- Feelings of trust and safety – this element creates a safe space for participants in terms of sharing ideas and having a common goal which is assuring them that their discussions have limited risk of any kind. To get full participation, this study adopts this approach.
- Diversity – diversity is the practice of having different people from different backgrounds such as age, education, gender, and engaging in activity. This element allows diverse contributions from participants with different age groups and levels of education. This presents an understanding of the different needs of the communities.
- Reciprocity – reciprocity is the mutual benefit from exchanging of ideas by people. Participants may be rewarded by having the cloud-based technology solution they designed implemented in real life to assist them with e-waste management.
- Values, norms and outlook – values, norms, and outlook refer to trust and equality among community members. Participants from the community must have respect for each other when deliberating on the issue at hand. No one is bigger than the other and all responses are heard and considered.
- Power – Power is the ability to enforce change. A united community with a common goal in mind has the power to improve their lived experiences. This assists the study by having the community working towards the goal as united.
- Pro-activity and participation – pro-activity and patriation refer to individuals having a positive mind when working within a team to achieve a goal that is common to everybody within the team. This assures the overall success in achieving that goal.

Halpern's (2005) Social Capital Theory is chosen for this study because it provides a means to understand important characteristics, lived experiences and nature of different people, their contribution to the study and their benefits. It also informed the process that was used by the group of participants for information gathering. The researcher's experience and observation taught him that women's and young men's views in the rural community meetings are not equally viewed and welcomed like those of elderly men. The attributes of the SCT design present a neutral and fair

process of involving different stakeholders for data collection. The theory enables research to engage with diverse participants in terms of gender and age.

1.7.2 Activity Theory

Activity theory (AT) is derived from Vygotsky and Leont'ev (Hasan & Kazlauskas, 2014). It is used as a guide to gain a deeper understanding of human activity within systems, using its properties namely subject, tool, object, rules, community, and division of labour (Engeström, 2001). The theory can be used to support qualitative research and interpretative research paradigm (Hashim & Jones, 2007). AT's relevance lies in the historical and cultural contexts whereby participants' purposes and tools are in for a rapid change (Hashim & Jones, 2007). Figure 1.3 depicts the components of the activity theory.

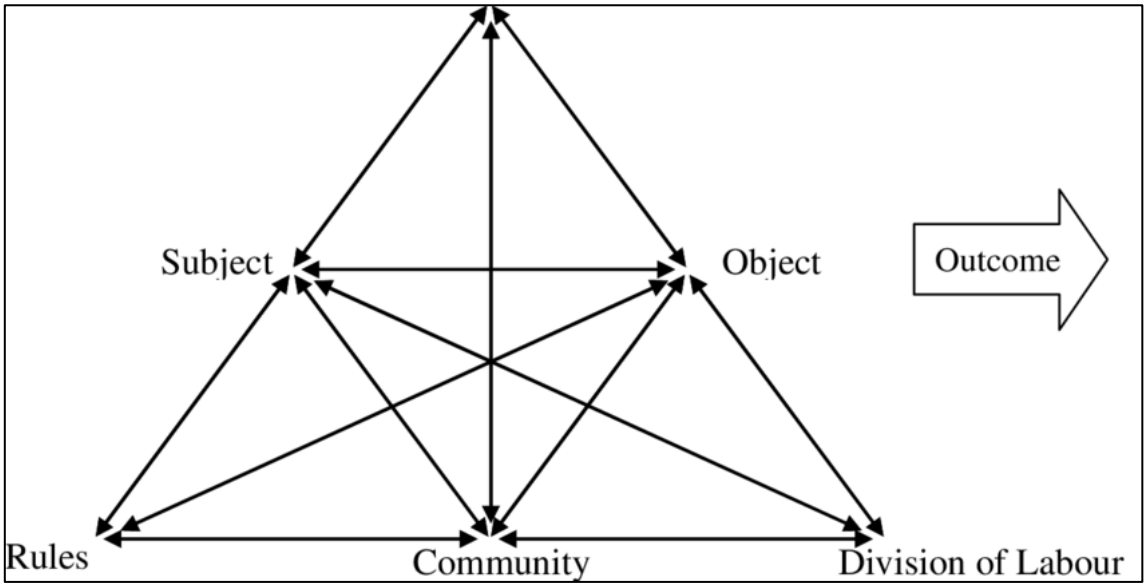


Figure 1.3: Activity Theory Model (Engeström, 2001).

AT helps to inspect the interlinkage between people, and how technologies shape or are shaped by human activities (Mkhomazi & Iyamu, 2013). The study adopted AT to identify strategies to be adopted in developing the cloud e-waste awareness solution. According to Iyamu and Shaanika (2018), AT underpins the development and execution of Information Systems/Information Technology (IS/IT) tools by focusing on areas such as roles of actors involved in the system, rules to be implemented to govern the system and requirements needed to build the system. AT has been applied to many IS/IT research studies in the last 30 years (Karanasios & Allen, 2018). Iyamu and

Shaanika (2018) contend that this is because AT's can be used to focus on IS development of artifacts within social contexts.

1.8 Conceptual Framework

The conceptual framework design for this study is informed by the design thinking and co-design frameworks. The conceptual framework is presented in Figure 1.4 which is intended to direct the process of achieving the results of the study. The community's role in the study is informed by the principles of the co-design framework. The community is placed at the centre of the conceptual framework since the community is the targeted group for this study. To engage with communities, five stages of the DT were embraced. These stages are presented as a second layer of the conceptual framework. The start of the interaction starts with the empathise since it is the first phase of the DT. The researcher used different tools to explain the concept to participants such as stickers, pencils, colouring pencils, boards and videos were used as design probes.

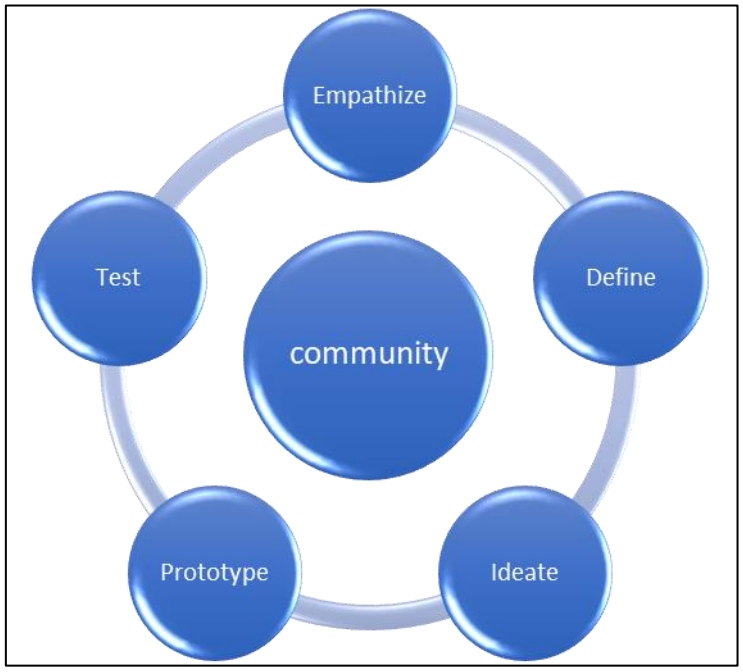


Figure 1.4: Conceptual framework for the study.

Figure 1.4 outlines the five aspects of the conceptual framework of the study:

- Empathise – the first step was to identify the problem by observing what the community does, and what it is that they do that results in a problem. The aim here was to understand the problem through the community's actions/perspective.
- Define – the second step was used to define the problem based on the literature review and observation. The purpose of this phase was to use different contexts to collect data, hence there is no direct interaction between the community and this phase.
- Ideate – the researcher embraced the discussion groups with communities in this phase, where the researcher and communities brainstormed, discussed and established the best approach and ideas that led to the development of the proposed solution to their challenges. Data collected through this phase led to the potential solution to solve the problem which is detailed in Chapter Four.
- Prototype – based on the data collected and the brainstorming, the researcher analysed the data and built a prototype of the solution with the community's assistance. In this phase, co-design tools were used to design the prototype, the detailed process of the prototype is captured in Chapter 5.
- Test – after the prototype phase, an application was developed and tested with communities to check if it is capturing the communities' contributions and meets their expectations and whether it is working. The testing of the solution was presented in different forms and the results are detailed in Chapter 6.

1.9 Research Design and Methodology

This study adopted the research design guidelines offered by the Research Onion (Saunders *et al.*, 2012) which informed the considerations needed to answer the research questions. Saunders *et al.* propose the Research Onion as a layered model. Six sequential layers support the research design of the study. The layers follow a certain set of decision processes. The processes start with the outer layer, the research philosophy. The core is the data collection methods layer - it is reached sequentially. The Research Onion is presented in Figure 1.5.

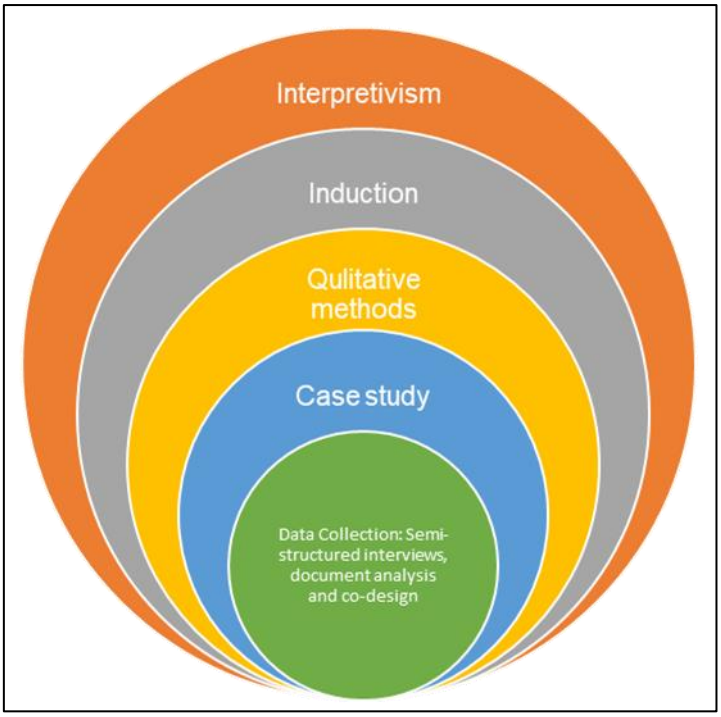


Figure 1.5: Research Onion adapted from Saunders et al. (2012)

This study embraced interpretivism, induction, qualitative methods, case study and data collection methods. The benefit of the Research Onion is that it illustrates the research stages which enables the researchers to understand all the important layers of the research process (UKEssays, 2019).

1.9.1 Research Philosophy

The first layer of the Research Onion is the foundation of the research study as it states the set of beliefs on which the research study is based (Saunders *et al.* 2012). Research philosophy comprises both the ontological and epistemological.

Ontology is the “what” and “how” of what is known (Saunders *et al.* 2012). This aspect helps researchers know the truth regarding the nature and existence of things they are studying (Moon & Blackman, 2017). An ontological standpoint indicates the researcher’s view regarding what is known and what is the truth that exists in a given research (Al-Saadi, 2014). In this study, the ontological perspective addresses what is known about the mismanagement of e-waste in under-resourced villages and the lack of protection of the ecosystem from carelessly discarded e-waste in villages. There is also no cloud-based technology solution to address e-waste management for under-resourced villages.

Saunders *et al.* (2012) state that epistemology refers to “how” knowledge is obtained and understood. This aspect importantly influences how a researcher scopes his/her research in an attempt to discover knowledge (Moon & Blackman, 2017). They further state that epistemology deals with the validity, scope and ways adopted to acquire knowledge. According to Ormston *et al.* (2014), acceptable knowledge can be regarded as part of epistemology. For this study, epistemology encompasses: (1) how e-waste is currently managed in under-resourced villages, (2) what the impact of e-waste mismanagement is in under-resourced villages, and (3) how the use of a cloud-based technology solution can address e-waste management for under-resourced villages.

The following are three research philosophical stances that can be associated with the ontological and epistemological assumptions:

- Positivism – what is studied can only be objective, which means opinions and personal views cannot be included in the study, the researcher can only observe and not interpret (Saunders *et al.* 2012; Myers, 1997).
- Interpretivism – people’s views and options are catered for in research, this method is used to comprehend and clarify people’s experiences through qualitative research methods (Saunders *et al.* 2012; Deetz, 1996).
- Pragmatism – considers a phenomenon to be true without proving that it is true (Saunders *et al.* 2012).

This study therefore adopted the interpretivism philosophy, as it looks to develop with the communities’ assistance a cloud-based technology solution to protect the ecosystem of the under-resourced villages from dangers posed by e-waste mismanagement and promote awareness of e-waste. With interpretative research, people attach their meaning to their practices. This study attempts to understand and develop a cloud-based technology solution by accessing the meaning of participants.

1.9.2 Research Strategy

The study adopted the case study research strategy. A case study is defined as “an empirical enquiry that investigates a contemporary phenomenon within its real-life context especially when the boundaries between phenomenon and context are not clearly evident” (Yin, 2018:15). Another, reason for using the case study is that the researcher intends to answer the why and how questions and to cover contextual conditions, and it is the most commonly used qualitative method in Information System (IS) research (Rashid *et al.*, 2019).

The use of a case study is applicable when the researcher is seeking to understand the phenomenon being studied within its real-life context. A case study can be a single or multiple case study. Yin (1994) states that case studies can be embedded or holistic. Yin (1994) further states that the embedded case study has more than one sub-unit whereas the holistic case study is a global entity being investigated. This study adopted an embedded case study.

The under-resourced villages of Nqamakwe and Butterworth were used as the case studies for the research. Both Nqamakwe and Butterworth are small village towns situated in the Eastern Cape province. In Nqamakwe, Village A was studied and in Butterworth, Village B was studied. Village A is demarcated under one chief and Village B from Butterworth also has its own chief.

People from under-resourced villages are faced with many challenges including limited access to education, transport, sanitation, and healthcare services (Gazana, 2016). The researcher chose these areas because they have no means of managing e-waste. Based on the researcher's observation, e-waste is discarded inside or next to rivers, dams, and open spaces. This motivated the researcher to use these under-resourced areas to carry out the study.

1.9.3 Research Approach

Although there are three approaches; deductive, inductive and abductive, two are commonly used in Information System (IS) studies.

Deductive and inductive approaches are two approaches mostly used in research on layer 2. Bhattacharjee (2012) states that deductive research is an approach used for testing research, while inductive research is called theory-building research. Silverman (2013) states that the deductive approach is based on pre-existing theory.

The inductive approach permits the researcher to create a theory rather than using a pre-existing one. It is considered a move from specific to general (Bryman & Bell, 2011). According to Berente *et al.* (2018), inductive is a qualitative bottom-up approach. It uses participants' views to build a theory.

This study adopted the inductive approach, as it seeks to develop a cloud-based technology solution for e-waste management through participants' views from under-resourced villages of South Africa. Selecting the inductive approach provides an advantage in that knowledge cannot be fabricated, as the solution is formulated after the study and rejection or acceptance of the outcome is up to the researchers (Zalaghi & Khazaei, 2016).

1.9.4 Research Methods

Two research methods can be adopted by a research study, namely qualitative and quantitative research methods.

Qualitative research encompasses in-depth knowledge and understanding of individual opinions, perceptions and experiences and is used to dig deep into the problem at hand. The data collection of qualitative research ranges from unstructured to semi-structured techniques (Farnsworth, 2019).

Quantitative research, on the other hand, enables the quantification of observations or responses using numbers and figures. It specifies what is measured and how it is measured (Farnsworth, 2019). According to Bhawna & Gobind (2015:49), a quantitative method is for “explaining phenomena by collecting numerical data that are analysed using mathematically based methods (in particular statistics)”.

Table 1.4 summarises the difference between the two methods – quantitative and qualitative research.

Table 1.4: Qualitative vs quantitate research (Streefkerk, 2019)

Quantitative Research	Qualitative Research
Focuses on testing theories and hypotheses	Focuses on exploring ideas and formulating a theory or hypothesis
Analyses through mathematical and statistical analysis	Analyses by summarising, categorising and interpreting data
Is mainly expressed in numbers, graphs and tables	Is mainly expressed in words
Requires many respondents	Requires few respondents
Includes Closed (multiple choice) questions	Poses open-ended questions
Key terms: testing, measurement, objectivity, replicability	Key terms: understanding, context, complexity, subjectivity

Based on the comparison in Table 1.4, this study adopted the qualitative research method because its purpose is to gather non-numerical data to develop a cloud-based technology solution for e-waste management and bring about awareness to people in the under-resourced villages based on their lived experiences. Setia (2017) states that the qualitative method assists the researcher in getting in-depth information on the experiences of participants.

1.9.5 Data collection methods

Data collection is a way in which data is gathered to answer research questions, test hypotheses, and provide evaluation of outcomes (Kabir, 2016). For any research, data needs to be collected, to gather information to answer the research questions. As stated already, the study employed a qualitative research method. The qualitative instruments used were:

- Interviews.
- Document analysis.
- Questionnaires.

Interviews can be unstructured, structured, or semi-structured (Antwi & Hamza, 2015). This study employed the semi-structured interview techniques. This technique is made up of open-ended questions, making it easy for the researcher to pose follow-up questions. Structured interviews are a set of predetermined questions that do not allow follow-up questions (Antwi & Hamza, 2015). In unstructured interviews, the researcher does not prepare questions beforehand. Participants can share their own views without being guided by the researcher and this could lead to poor data that is difficult to analyse (Armstrong, 2009). Structured and unstructured interviews were not used, as they did not suit the purpose of the study. For the benefit of the interviewees, interviews were conducted in Xhosa this is because the participants speak Xhosa as a first language. The responses were then transcribed and translated into English during the analysis phase. During the transcription process, the researcher played the recordings back and forth and used Microsoft Word to type what was said in the recordings to ensure that the correct details were captured.

According to Bowen (2009:27), document analysis is a "systematic procedure for reviewing or evaluating documents, both printed and electronic (computer-based and Internet-transmitted) material". Documents were used to gather information on e-waste studies in other parts of the world. Bowen (2009) states that document analysis is useful to provide background to the study and provide historical insight related to the study. The study used documents to collect data regarding e-waste management around the world and how technology is currently used. Documents from the municipality overseeing device delivery in the two locations were also used in the study to gather information on how e-waste is managed.

Bhandari (2021:1) defines a questionnaire as "a list of questions or items used to gather data from respondents about their attitudes, experiences, or opinions". It is used to gather data by asking participants to respond to the same set of questions (Gray, 2013). This study also made use of questionnaires to gather the data required. Quationare was used to fill in what was missed during the semi-structured interviews. The tool was used to provide participants with options to provide more information. A questionnaire translated into isiXhosa was used to gather data, to ensure that participants understood what was being asked and responded in a language they are comfortable with.

1.9.6 Sampling

Bhattacharjee (2012:65) describes sampling as a "statistical procedure for selecting from a group or population a subset in which the researcher has the interest to observe and provide a statistical report about that population". Babbie and Mouton (2002) state that in qualitative research studies, a

sampling technique is chosen based on the researcher's knowledge of the population being studied. Purposive or judgment sampling was chosen for the study because the population was predetermined and chosen to capture a true representation of the population being studied (Babbie, 2006).

1.9.7 Data Analysis

Data analysis is a process of decoding gathered data to provide meaningful information required to answer the study's questions.

Data collected was analysed using Thematic Analysis (TA) and Activity theory (AT) as lenses to guide the analyses of data for this study. Below are the steps used to analyse data.

- TA was used to analyse data linked to objectives one to three. This objective gathered information on the lived experiences of the participants regarding e-waste and gathered information on their expectations using SCT theory.
- AT was used to analyse data associated with the fourth objective, namely, to identify strategies to adopt in developing the cloud e-waste awareness solution. AT guided the examination of interactions between people, and how technologies shape or are shaped by human activities (Mkhomazi & Iyamu, 2013).

1.10 Delineation of the Study

The study did not consider all under-resourced areas in the Eastern Cape or all those situated in Nqamakwe town. The study was also limited to consulting one local municipality to gather data on how they manage e-waste. This study only looked to develop a cloud-based technology solution for under-resourced villages on e-waste management.

1.11 Consideration of Ethics

The protection of participants in any research is vital not to infringe on the rights of participants. Ethics clearance was acquired from the Research Ethics Committee of the University, where the study is registered. Permission to conduct the study was obtained from the two chiefs who oversee the under-resourced areas being studied. The letter to the chiefs was written in English but the researcher translated it when speaking to the chiefs. The researcher chose isiXhosa as a medium for translation as both chiefs' first language is isiXhosa and are fluent in it. The researcher ensured that responders'/participants' details or information provided during the interview would be kept

strictly confidential. An explanation of the study was communicated to the participant (using Xhosa as a language of communication) and if he/she agreed to participate a consent letter was signed by both parties. Participation was voluntary and participants were free not to participate or withdraw at any time. Collected data was protected and treated confidentially; access was gained by the researcher and the researcher's supervisor only. Collected data was removed from the researcher's storage devices (audio recordings and cell phone recordings) and was therefore stored at the Cape Peninsula University of Technology's data repository. This was done after the study's results were accepted by the university.

1.12 Structure of the Thesis

The thesis is structured into nine chapters, briefly discussed below:

- Chapter 1 introduces the thesis. It principally consists of the research problem, research aim, research questions, and objectives.
- Chapter 2 and Chapter 3 include the literature review sections of the study. Underpinning theories are discussed in Chapter 3.
- Chapter 4 details the underpinning theories used and how they are used in the study.
- Chapter 5 details the methodologies used in the study. It sets out the steps used to achieve the objectives of the study.
- Chapter 6 presents the two cases used in the study. It also includes coverage of leadership of the cases.
- Chapter 7 outlines the data analysis for the study, Thematic Analysis and Activity Theory were used to analyse data based on the objectives.
- Chapter 8 reports findings derived from Chapter 7.
- Chapter 9 describes the system analysis and design of the developed proposed cloud-based solution.
- Chapter 10 concludes the study. It offers limitations, benefits, and recommendations of the study.

1.13 Significance of the Study

The research study focused on bringing awareness for the purpose of protecting people and the environment. This helps improve the lives of the rural people, environment, and livestock of the areas. There is a paucity of research whereby a cloud-based technology solution is driven by the community for e-waste management in under-resourced villages. Such research is significant for

rural people and the municipality responsible for the areas. Another point of significance is that the study can be used as a reference point for other areas similar to where the study is carried out. This is vital for Africa as many countries grappling with the same problem. The study also adds to the existing body of knowledge regarding e-waste management and brings new knowledge based on available literature, this is the first of its kind whereby under-resourced people design a cloud-based technology solution for e-waste management in under-resourced villages.

1.14 Contributions of the Study

Contributions include villagers' perceptions and experiences in designing of the proposed technology-based solution prototype. Contributions to the discipline of design included design patterns and the co-design process. The methodological contribution was the design concept of both co-design and design thinking used in the study and the combined use of the underpinning theories which are SCT and AT. The outcome (practical contribution) of the design process research is the technology-based solution prototype and a conceptual framework of e-waste technology-based application design. Methodological contribution is the usage of Social Capital Theory and Activity Theory to understand the lived experiences of under-resourced villagers regarding e-waste awareness and management. Through the methodological contribution, the study developed the required cloud-based solution for e-waste awareness based on the lived experience of the under-resourced communities. It also adds to the field of informatics and ICT governance. In addition, the study adds to the existing literature on e-waste management or mismanagement in developing countries.

1.15 Clarification of Basic Terms

Activity Theory – a framework to understand human interactions through their usage of systems.

E-waste – electronic waste, old technological equipment no longer in use.

ICT – Information and Communications Technology.

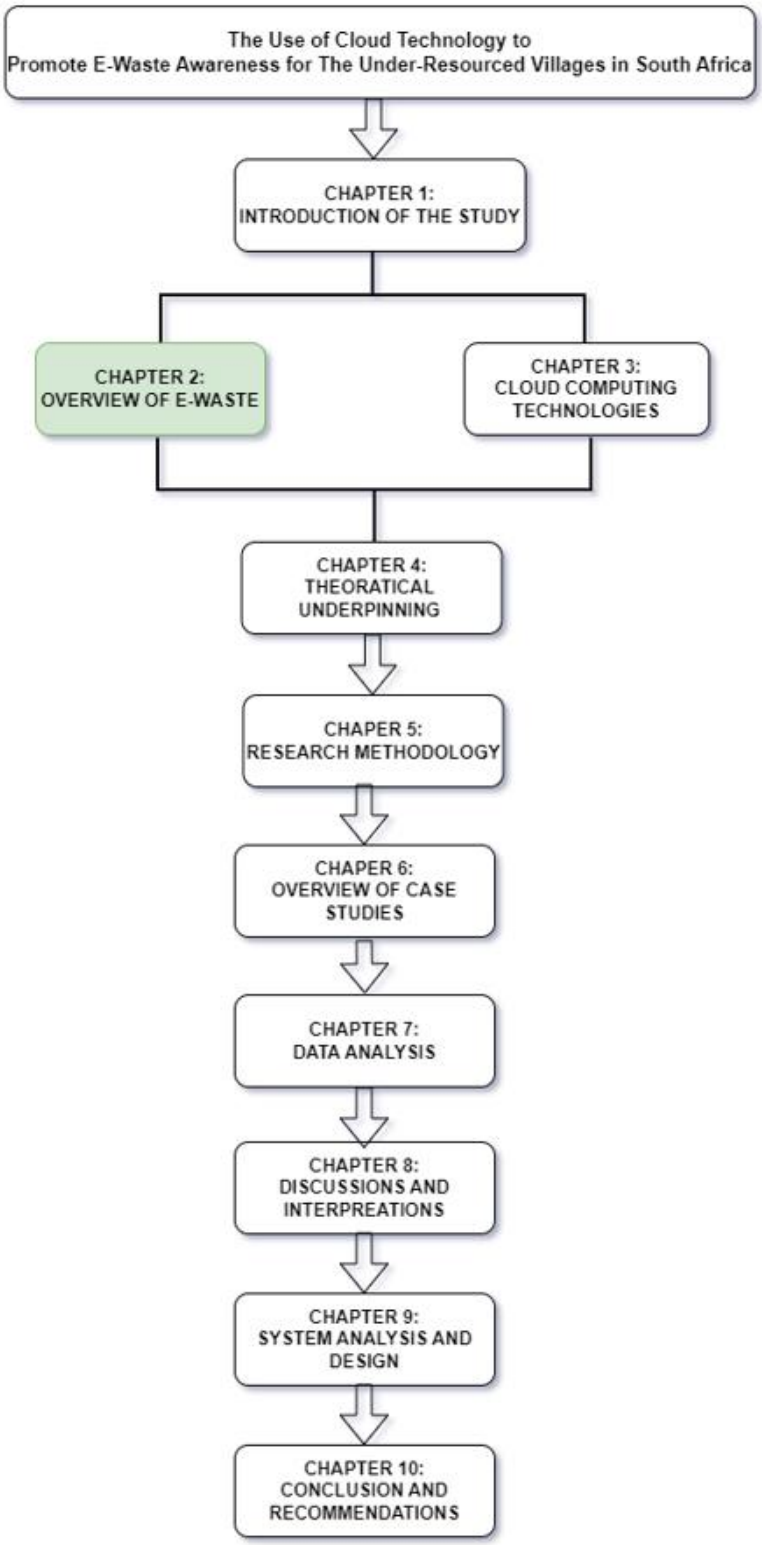
Social Capital Theory – measures how social relationships could benefit communities/organisations for the betterment of their lives.

Under-resourced areas - rural remote areas and villages.

1.16 Conclusion

This chapter aimed to present the overall summary of the study, by presenting all the parts and also by presenting the background of the study. Living in an unhealthy environment puts people's lives in danger in so many ways. This is further worsened when high levels of poverty, unemployment and lack of education exist within the communities. Under-resourced villages lack access to basic services that according to the constitution of South Africa, people from these areas should have access to services such as clean running water, improved infrastructure, and a clean and safe environment. This research study is particularly important, as a starting point to help eradicate e-waste for better living conditions of the rural people. What the study proposes is that through co-design design, people in these areas produce a cloud-based technology solution to help protect the environment. The cloud-based technology solution could then be further used for other under-resourced areas with the same problem. The district municipality can be used as a connection point to oversee that under-resourced areas' e-waste is being taken care of the proper way. The researcher believes for people living in under-resourced to have better living conditions, this research is a starting point. The literature has disclosed that living with e-waste is dangerous to the ecosystem, which leads to many illnesses already mentioned.

CHAPTER 2: OVERVIEW OF E-WASTE



2.1 Introduction

This chapter presents related literature explored in crafting the proposed solution in addressing the identified challenges for this study. It presents the definition of various aspects of e-waste, drivers of e-waste, policies and regulations on e-waste, and policies and regulations on e-waste in South Africa, developed and developing countries. The above-mentioned topics are discussed in detail in various parts of the chapter.

2.2 Defining E-waste

To understand e-waste management, the first thing is to understand the meaning of the term e-waste. E-waste is defined in several ways; however, there is no institutionalised standard definition of e-waste. To determine an appropriate definition of e-waste for this study, various sources were consulted. Below are some of the considered definitions of e-waste:

- Electrical appliance that no longer serves its purpose in terms of doing what the owner bought it for (Honda *et al.*, 2016; Massa & Archodoulaki, 2023).
- Discarded broken electrical equipment with no intention to re-use by its firsthand user (Wath *et al.*, 2010; Haikal & Marlia, 2021).
- Old and non-functioning electronic equipment such as digital video discs (DVDs), computers, televisions, laptops and MP3 players that have been rid of by their original owner (Electronic take back coalition, 2014).
- Used electronics nearing their end of useful life and are disposed of, donated, or handed over to a recycler (EPA, 2021).
- E-waste is Electrical and Electronics Equipment (EEE) that is disposed of without the intention to re-use by its owner (Forti *et al.*, 2020).
- “Any electronic products, such as laptops, mobile phones, tablet PCs, DVD players, mp3 players, etc. that have been discarded or disposed of by their users as they have become old or have reached their end-of-use” (Kumar, 2019:379).
- Any EEE that includes all components, consumables and subassemblies equipment that is obsolete and broken (WHO, 2021).
- “a term used to cover items of all types of electrical and electronics equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use” United Nations University and Step Initiative (2014:4).

EEE examples that may constitute e-waste although they are not limited to e-waste (WHO, 2021), include:

- Computers, wireless devices and other peripheral items.
- Printers, copiers and fax machines, telephones, mobile phones and tablets, video cameras, televisions and stereo equipment
- Cathode ray tubes, transformers, cables and batteries.
- Lamps and light bulbs (including mercury-containing CFL and fluorescent bulbs).
- Large and small household appliances (refrigerators, washers, dryers, microwaves).
- Toys, sports equipment, and tools.
- Medical devices, some microscopes, electronic blood pressure monitoring devices, electrocardiogram machines, and spectrophotometers.

For this study, the definition of e-waste was adopted from the United Nations University and Step Initiative (2014:4) which describes e-waste as “a term used to cover items of all types of electrical and electronics equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use”.

2.3 Drivers of E-waste

Technology advancements have improved how people communicate, operate and move around. This is due to the sophisticated technology being made available through releasing new features to existing tech stacks and the creation of better products. The development and improvement of technology has seen a rapid increase in e-waste mismanagement. In support of this, Avis (2021) argues that technology improvements, lower prices to pre-released tech stacks and consumers wanting better products have worsened e-waste management. This has led to an increase of e-waste drivers. Citizens Information (2019) list the common drivers of e-waste as:

- Huge household appliances (freezers, fridges, dishwashers).
- Minor household appliances (toasters, irons, coffee makers).
- ICT equipment (phones, laptops, printers, computers).
- Consumer equipment (televisions).
- Lighting equipment (globes, electronic lamps).
- Electrical and electronic tools (electric saws, drills, screwdrivers).
- Electronic toys.
- Monitoring and control instruments.

- Automatic dispensers.
- Batteries and accumulators.

The Health and Safety Executive (2022) states that the most e-waste generated globally is from large household items followed by Information and Communication Technology (ICT) equipment and small household items. The lifespan of such equipment is getting shorter because of the rapid development of new products (Ylä-Mella *et al.*, 2022). The shortened period of the equipment leads to the mounting of e-waste mismanagement as the equipment is no longer operational. Below, Table 2.1 lists the life span of some of the common drivers of e-waste.

Table 2.1: Devices and their lifespan (Bisoyi & Das, 2018)

Device Types	**Life span (Years)**
Desktops	5
Laptops	4
Televisions	10
Mobile phones	3
Printers	4
Car batteries	5
Washing machines	5
Light emitting diode (LED)	1-2

Based on the above, the life span of electronic devices is finite which means they end up as e-waste. The short life span consequently leads to copious amounts of e-waste which if not responsibly managed poses a danger to human health and the environment.

2.4 International Standards Policy Guidelines and Conventions on e-waste

Due to safety concerns of e-waste in human health and the environment, conventions and policy guidelines have been set up to manage e-waste. These policy guidelines and conventions are established to guide manufacturers, consumers and retailers on how they should get rid of electronic products once they are no longer working or needed (Rene *et al.*, 2021). The conventions and policy guidelines act as a legal framework to protect human health and the environment. Avis (2021) states

that countries importing EEE lack police guidelines with limited knowledge and lack proper facilities to dispose of such products which results in e-waste mismanagement.

Despite the introduction of these e-waste guidelines, some countries are still lagging in taking up these conventions, for example, Ghana, Chile, Nigeria, Vietnam, Uruguay, Ecuador and Peru (Abalansa *et al.*, 2021). The worldwide policy guidelines and conventions meant to control the flow and delivery of e-waste include:

- The Basel Convention on the Control of Trans-Boundary Movements of Hazardous Waste and their Disposal.
- Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.
- Stockholm Convention on Persistent Organic Pollutants.
- Bamako Convention.

2.4.1 The Basel Convection

The Basel Convention on the Control of Trans-Boundary Movements of Hazardous Waste and their Disposal (referred to as the Basel Convention in this study) originated in 1989 and was effective from the 5th of May 1992. Adopted in the year 1989 the convention was aimed at controlling the export of e-waste and providing strict rules and regulations when exporting hazardous waste from developed countries to developing countries. Khan (2020) states that the Basel Convention provides a stipulation that hazardous waste should only be transferred when the equipment cannot be safely managed locally or when it is required for importation to recycle.

The convention requires that the country exporting and the country importing the hazardous waste have a signed agreement to indicate that they both agree to uphold the Basel Convention values. Khan (2020) supports this statement, stating that hazardous waste movements between Basel parties must have signed informed consent and that there should be documents proving that the export/import is environmentally friendly. The Basel Convention categorises e-waste as hazardous waste because of the toxic elements present in the material used to make EEE devices.

The primary objective of the Basel Convention is to protect the environment and human health against the negative effects of hazardous waste. The United Nations Environment Program (United Nations Environment Program, 2011) suggests other objectives worthy of consideration, namely:

- To promote a safe disposal mechanism of hazardous waste to provide a friendly environment and reduce the production of hazardous waste products.
- To mitigate the hazardous waste movements across countries, unless this is done with an agreement promoting safe environment principles.
- To implement regulatory systems in cases where transboundary imports and exports are permitted.

Countries that are signatories to the Basel Convention are forced to uphold the objectives stipulated above. This serves to ensure that no e-waste is dumped in other countries without their consent. The U.S. Environmental Protection Agency (EPA, 2021) states that each member of the Basel Convention notifies the convention about the amount of e-waste they generate, export and import. The report should include the location of the destination of the hazardous waste and the methods of disposal embraced.

The Basel Convention also presents restrictions when it comes to hazardous waste movements (EPA, 2021). The restrictions listed below require that the exporting of e-waste occurs only if:

- The country exporting cannot safely dispose of or recycle.
- The country exporting does not have facilities to dispose of and recycle e-waste in an environmentally safe manner.
- The e-waste being imported by the country is required as a raw material for recovery or recycling.

The Basel Convention according to Miyamoto and Kobayashi (2020) is the first established framework for hazardous waste transboundary movement. The Basel convention has 53 signatories and 189 parties signed up (United Nations, 2022). The framework's principle is based on prevention, recycling, and reduction of e-waste through avoidance.

2.4.2 Rotterdam Convention

The Rotterdam Convention was established in 1998, and its aim is for the exporting and importing countries to share the responsibility of protecting human health and the environment (Department of Environment, Forestry and Fisheries (South Africa), 2021). Furthermore, the Department of

Environment, Forestry and Fisheries (South Africa) (2021) states that countries involved in the exchange should share information about hazardous chemicals contained in the exported and imported electronics. The Rotterdam Convention has 163 parties and 72 signatories (United Nations, 2021).

2.4.3 Stockholm Convention

Adopted in 2001, the Stockholm Convention on Persistent Organic Pollutants (POP) came into effect in 2004. The Convention is a global framework aimed at protecting the environment and human health from POPs. Members of the Convention are expected to limit POPs released to protect the environment and human health (Bell & McGillivray, 2006). Chemicals classified as POPs are contained in e-waste materials.

The Convention aims to protect human health and the environment against chemicals that remain for an extended period in the land. Some POPs under the regulation of the Convention are used to produce EEE equipment. Based on this Convention, all components containing such POPs should be discarded in an environmentally friendly manner once they become waste. POPs are grouped into three categories namely: pesticides, pollutants released from burning waste, and industry chemicals. The United Nations (2021) states that there are 152 parties and 185 signatories to the Convention.

2.4.4 Bamako Convention

The Bamako Convention was initiated by 12 African countries to fill the gap identified in the Basel Convention. The convention was initiated to prevent developed countries from exporting e-waste to African countries. The Bamako Convention started in 1991 in Mali and came into effect in 1998.

The Convention aims to prevent the importing of e-waste into African countries. Based on this Convention, countries that have not signed the Basel Convention are also prevented from sending e-waste to African countries. The Convention has however allowed the African countries to trade in e-waste between themselves but there should be signed consent between those countries (Kaminsky, 1992). The implementation of the Convention is still low because of the lack of resources by African countries (Umenze, 2019).

The above-mentioned Conventions have a common goal which is focusing on protecting human health and the environment from e-waste and hazardous chemicals. Membership in any of these conventions is voluntary and hence there is a compliance challenge (Lebbie *et al.*, 2021).

Furthermore, Lebbie *et al.* (2021) state that some European countries that signed the Basel Convention ship about 352 474 million tons (Mt) of e-waste to developing countries yearly.

Though these Conventions are developed to be implemented by each member, there is still evidence that most countries signed up as members still do not abide by the conventions they signed onto (Lebbie *et al.*, 2021). The Literature discloses that policies and regulations on e-waste management do exist but not all countries have signed onto them. In countries that signed onto these regulations, there is still poor implementation of the Conventions (Lebbie *et al.*, 2021).

2.5 Policies and Regulations of e-Waste in South Africa

South Africa has its government system divided into three spheres: national government, provincial government and local government. Policies and regulations for waste management are driven by the first sphere which is the national government. The country has a constitutional document that guides how the country is to be led and how its citizens should be protected. In the 2nd chapter of the constitution, it is stated that every South African has a right to live in a safely managed environment to protect their liveliness (President's Office (South Africa), 1996).

In all three spheres of government, different laws were established to ensure that this right is implemented. A framework called the National Environment Management (NEMA), the country's main legislation on environmental matters was established in 1998 as Act 107. The policies and regulations on waste management are controlled by the Department of Environmental Affairs which is a national department. NEMA therefore falls under the Department of Environmental Affairs (DEA). NEMA is composed of different policies and regulations on matters such as quality of air, assessment of the environment, biodiversity and waste. The country also has Act 58 established in 2008 called the Waste Act. The act's primary goal is to provide guidelines and standards on waste management for waste managers and generators (Department of Environmental Affairs, 2008). Table 2.2 provides a list of waste policies and regulations in the country.

Table 2.2: Waste policies and regulations in South Africa

Policy and Regulation Name	Summary	Year
The Basel Convention	Adopted by the country in 1989 and became a signatory in 1994 (United Nations Environment Program, 2009)	1989
National Environment Management (NEMA)	Provides guidelines on different waste policies and regulations on matters such as quality of the air, assessment of the environment, biodiversity and waste	1998
Integrated Pollution and Waste Management – white paper	Proposed that there be development of waste management strategy on land pollution.	2000
Guidelines for waste pickers – South Africa	Provides guidelines for all stakeholders involved in the waste picking process including those buying from pickers.	2020
National Management Strategy of Waste	Its priority is waste management and the establishment of a circular economy	2020
Extended Producer Responsibility Regulations	Signed into law by the Minister of Environment, Forestry and Fisheries. This is to ensure that out-of-life EEE products are safely managed.	2020

The table above lists policies and regulations adopted by the national government of South Africa. The provinces and local government of the country are required to abide by the policies and regulations. In 2020, new regulations for managing the life of EEE material were implemented to manage the ever-growing e-waste stream in the country (McLeod, 2020) . According to McLeod (2020), companies involved in the supply or distribution that did not comply should face financial fines and jail time.

The Extended Producer Responsibility Regulations (EPR) under the National Environmental Waste Management Act requires that companies in the EEE space abide by the regulations introduced in 2020. EPR was designed to motivate EEE producers to be responsible for their sold items once they become e-waste (Ilankoon *et al.*, 2018).

South Africa also has an association named EWASA which was established in 2008. The association's aim serves to guide the country on how to manage e-waste (Lebbie *et al.*, 2021). EWASA is made up of EEE manufacturers, retailers and importers. Lebbie *et al.* (2021) state that the association has difficulties in dealing with the importing of e-waste in the country. As such, Lebbie *et al.* (2021) attribute it to business people being money-driven and not caring about the impacts of e-waste on human health and the environment.

Despite all the attempts done to manage e-waste and waste in general, the country has not improved its e-waste management systems. This is supported by Mouton (2020); by stating that for the past 10 years, South Africa still lacks implementation of its own policies and regulations to manage waste. Furthermore, Mouton (2020) asserts that the country is in the beginning phase of forcing EEE producers and importers to provide incentives for take-back schemes.

2.6 E-waste in Developed Countries

Developed countries are considered to be the main drivers of e-waste and are further reported to have been shifting their e-waste to developing countries as a means of disposal (Abalansa *et al.*, 2021). In support of this claim, UNESCO (2022) asserts that e-waste is a growing environmental issue, though these countries have mechanisms to effectively manage e-waste they opt to process their waste management through the cheaper option which is to export it to the developing countries.

Developed countries have policies, laws, and regulations in place intended to manage e-waste. These include the Basel Convention; however, these countries do not abide by these laws in carefully disposing of e-waste by not sending it to other countries as donations. According to UNESCO (2022), developed countries have stringent policies and laws to regulate the movement and processing of e-waste. However, these policies lack implementation as developed countries continue to pile their e-waste in developing countries.

Developed countries such as Germany, the UK, Belgium, Netherlands have been exporting EEE to Nigeria as a means of disposal (Lebbie *et al.*, 2021). Figure 2.1 illustrates the percentage of EEE exportation from different developed countries to Nigeria in 2021.

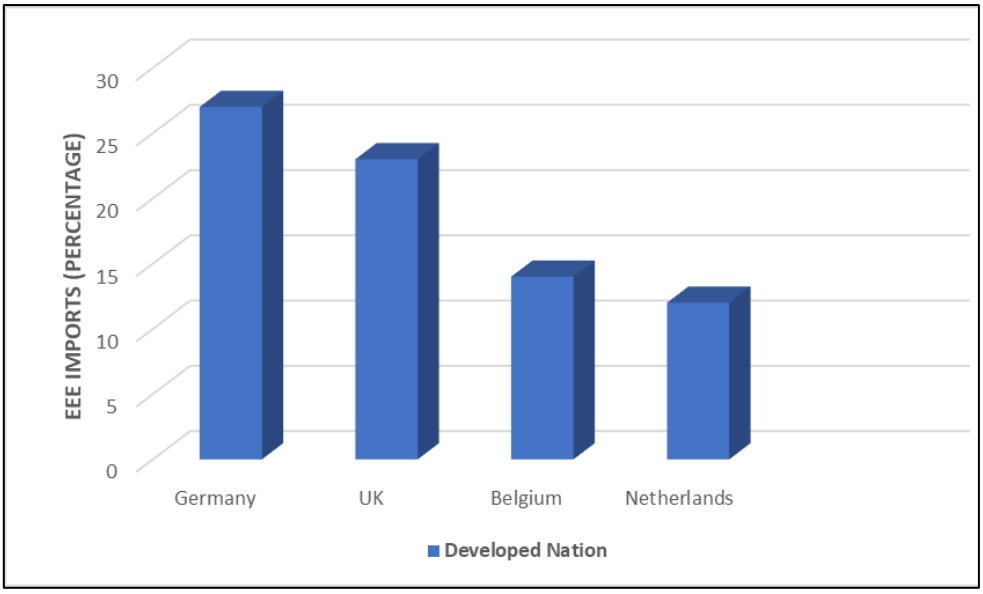


Figure 2.1: Percentage of EEE from each country exported to Nigeria (Lebbie et al., 2021)

The high percentage of imported EEE in Nigeria may have been attributed to the e-waste problem that Nigeria has in managing e-waste. In support, Avis (2021) states that Nigeria along with Ghana has the highest number of imported e-waste which further becomes a burden for the two countries.

A study by Andeobu *et al.* (2021) indicated that the USA is the largest source of e-waste compared to the other countries that were reviewed such as Canada, the UK, France, Nigeria and South Africa. Developed countries' citizens have the means to buy any new technology equipment released. This is due to their economic hub being among the best in terms of growth. As new technology is bought by citizens the old one once it is no longer working is discarded as e-waste and at times ends up being thrown away (Cohen, 2024). The USA is one of the leaders in developing new technology, the World Economic Forum (WEF, 2021) indicated that about 151 million mobile phones are discareded into landfills yearly in the USA. According to the World Economic Forum, it means only 17.4 percent of e-waste is recycled in the USA.

China is considered to be the world's leading EEE manufacturer and contributes the second-largest amount of e-waste globally (Tian *et al.*, 2022). The literature states that the USA is the leading developed country in generating e-waste. China is second and generates 11.17 million tons of e-waste, and Japan is last with 2.83 million tons (Tiseo, 2021).

The UK also being a developed country reported that in 2020 its citizens were estimated to have generated 23.9 kg of e-waste per person (UK Parliament, 2020). A study conducted in the UK revealed that they also lack an awareness of e-waste's effects on human health and the environment.

Based on the above literature, it is evident that developed countries have the means to produce EEE equipment. Of the enormous quantities produced by these countries, only a small percentage is returned for recycling and reuse at the end of life (World Economic Forum, 2021; Avis, 2021; Lebbie *et al.*, 2021). The literature has disclosed that most of the e-waste is exported to developing countries as a means of disposal. Though these countries have signed the Basel Convention, they still do not abide by the conventions' laws and they do not incur any penalty for breaking those laws. This is a clear demonstration that these laws are not fully implemented and international standards are not observed.

2.7 E-waste in Developing Countries

E-waste in developing countries increases between three to five percent annually. This is because of the imported e-waste from developed countries and the waste that developing countries generate (Rasheed *et al.*, 2022). Developing countries lack proper infrastructure for managing e-waste properly, which causes landfills to be polluted as the e-waste is disposed of. The lack of proper infrastructure leads to e-waste being thrown into landfills and burned causing sickness for those working and communities living close to these landfills. Lack of awareness, shortage of technical skills in managing e-waste, and financial constraints have been identified as major barriers to e-waste management in developing countries (Rautela *et al.*, 2021).

Most of the EEE landing in developing countries is exported by developed countries as a means of donations (Perunding Good Earth, 2021). The EEE equipment is considered less expensive and is in high demand in developing countries. According to Lebbie *et al.* (2021), e-waste that was sent by the European countries to the developing countries in 2019 amounted to 352 474 metric tons (Lebbie *et al.*, 2021). Developing countries battle with job creation for their citizens, and e-waste is one of the streams considered to contribute to economic growth as the contents of the waste are sold after dismantling. In support, Owusu-Ansah (2020) states that citizens of developing countries endanger their lives by manually dismantling e-waste so they can sell and find income.

A study conducted in Brazil found that the country only recycles about 3% of its e-waste due to a lack of resources. The study further revealed that the country failed to promote e-waste awareness for its citizens (Mari, 2022). Furthermore, Brazil according to Souza (2020), is the biggest e-waste

generator in Latin America. This is attributed to the enormous amount of e-waste the country imports (Souza, 2020).

Research conducted in India revealed that 60% of the e-waste generated and imported is stored in warehouses, with 40% sent for processing and recycling (Kaushik & Herat, 2020). The researchers argue that though India has strategies in place to handle e-waste, these are not being implemented successfully as there are no consequences for EEE producers for the e-waste they generate.

In Malaysia, e-waste is categorised into two groups: e-waste from manufacturers and household e-waste (Department of Environment Water, 2022). The two categories are handled in two different forms: formal and informal e-waste recycling. The latter is said to have more incentives which leads to it being popular in the country.

The study chose to look at the 3 developing countries since the literature discloses them as the top 3 e-waste generators for developing countries (Souza, 2020). E-waste for developing countries is a huge problem that must be addressed expeditiously. Policies and regulations should be enforced by developing countries to stop the developed countries from dumping their e-waste to them. The existing conventions are not effective enough as e-waste is still sent to developing countries disguised as donations. This is supported by Shukla (2022) who states that after 20 years since the Basel Convention was initiated, developing countries such as Malaysia still receive illegal e-waste from developed countries.

It is worth noting that the Basel Convention was initiated by developed countries. Developing countries voted for a total ban on e-waste transportation across and to their countries but were overpowered by the developed countries Shukla (2022). According to Shukla (2022), this is caused by the political power that developed countries have.

Developing countries are dependent on developed countries for different kinds of support, including financial support and the refusal of e-waste donations from developed countries may lead to them regarding the developing countries as ungrateful. Due to that assumption, developed countries are given the liberty to continue piling their e-waste on developing countries.

2.8 E-waste in Africa

The African continent is considered to be the world's fastest-growing mobile marketing place worth 495 million subscribers, this provides educational and economic opportunities to the people of the continent (The Ellen MacArthur Foundation, 2021). The lack of proper infrastructure has enabled mobile operators to fill the gap in terms of providing services such as banking. This has caused mobile phones to be in high demand in the continent, this statistic is annually increasing by 2.5% (The Ellen MacArthur Foundation, 2021). Furthermore, the Ellen MacArthur Foundation (2021) states that consumer spending on EEE items such as televisions, refrigerators and mobile phones has increased exponentially in Africa with the spending estimated at around $1.3 trillion in 2010 and this is estimated to be doubled by 2030.

In the quest to address the digital divide in the continent, some of the African countries in the continent accept imports of EEE. The imports of the EEE items come to the continent in the form of donations for schools, clinics and hospitals with the required tools needed to provide a better future for the citizens. Avis (2021) states that for African countries to bridge the digital divide, a large amount of used EEE is accepted as donations from developed countries. However, the importation of EEE into the continent leads to increased levels of e-waste which if mismanaged can end up endangering human health and the environment (Avis, 2021).

An estimated amount of 2.9 million tons (Mt) of e-waste was generated by the continent in 2019, this translated to 2.5 kilograms (kg) per capita (Forti *et al.*, 2020). The estimated figure ranks from high to low generators. The documented rate of e-waste collection and e-waste recycled is reported to be the lowest with just 0.9% in the continent. Globally the continent is considered the second lowest e-waste generators per capita, however, 60% of its e-waste is imported from developed countries (World Economic Forum, 2021). Figure 2.2 below depicts e-waste generated per African country.

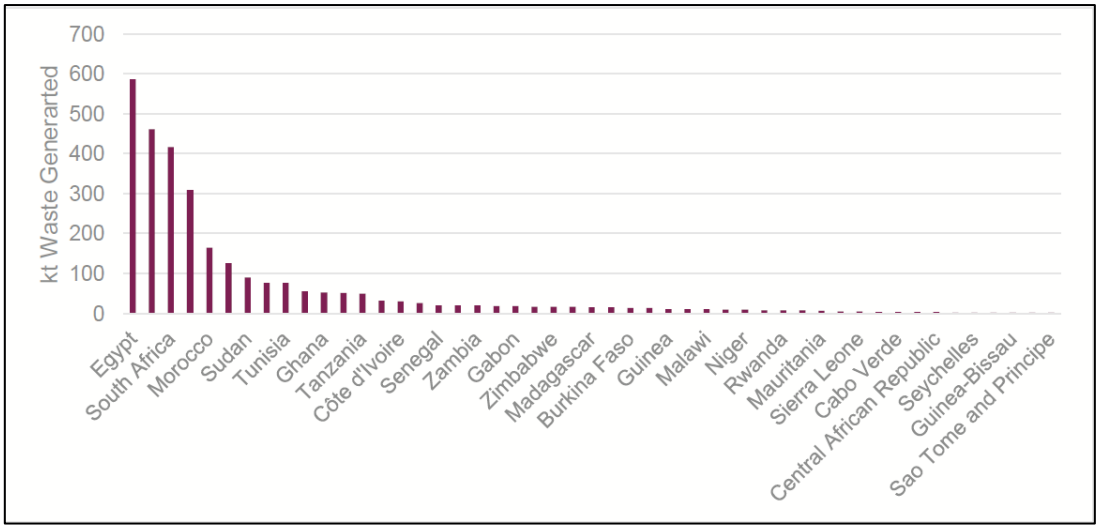


Figure 2.2: E-waste generated by selected countries in Africa (Forti et al., 2020)

Figure 2.2 demonstrates that Egypt, South Africa and Morocco are leading compared to other countries. These three leading countries are the most developed countries on the African continent from an economic perspective.

E-waste in Africa is sourced from the following two categories:

- Locally produced e-waste.
- Used imported EEE.

Locally produced e-waste is EEE produced within the continent. Forti *et al.* (2020) state that e-waste production in Africa during 2019 was at 2.9 Mt, with Egypt, Nigeria and South Africa leading the manufacturing industry. Avis (2021) states that many African countries lack proper infrastructure to manage e-waste properly and this e-waste ends up in dumping sites and informal recyclers.

Used imported EEE comes in the form of donations from developed countries. Avis (2021) however states that within Africa, richer countries also export to poor countries as a means of ridding their e-waste, poor countries being the likes of Zimbabwe, the Democratic Republic of Congo and Mozambique.

E-waste management in Africa is worsened by a lack of awareness regarding its dangers, a lack of finances to build proper management facilities and a lack of policies and regulations to regulate e-waste movement. The Word Economic Forum (2021) states that poor public awareness, poor collection mechanisms, lack of the implementation of policies and poor recycling are factors that

contribute to African countries mismanaging of e-waste. E-waste is managed by informal and formal sectors with the informal sector dominating in Africa due to a lack of regulations and infrastructure to manage e-waste (Avis, 2021).

Policies and regulations have been developed by some African countries to provide manageable means of e-waste. South Africa, Ghana, Nigeria and Rwanda are some of the countries with policies and regulations in place (The Ellen MacArthur Foundation, 2021). Despite having these policies and regulations, it is recorded that 70% of e-waste ends up in dumping sites in these countries (Avis, 2021). It is recommended that Africa should consider having and adopting a central policy document that each country should abide by this improves the implementation of the policies and regulations, especially about the importing of EEE elements from the developed countries.

According to Forte *et al.* (2020), only 13 of the African countries have e-waste policies and regulations. Table 2.3 presents the list of countries that are with and without e-waste policies. The countries that do not have policies are flagged with a red shade, those with policies are flagged with green and those with no information on e-waste policies and regulations are flagged with an orange highlight.

Table 2.3: African countries with and without policies and regulations (Forte et al., 2020)

Central Africa	East Africa	North Africa	Southern Africa	West Africa
Central African Republic	Burundi	Algeria	Angola	Benin
Cameroon	Comoros	Egypt	Botswana	Burkina Faso
Chad	Djibouti	Libya	Lesotho	Cabo Verde
Congo	Ethiopia	Mauritania	Madagascar	Cote d'Ivoire
DR Congo	Kenya	Morocco	Malawi	Gambia
Equatorial Guinea	Rwanda	Tunisia	Mauritius	Ghana
Gabon	Seychelles		Mozambique	Guinea
	Somalia		Namibia	Guinea Bissau
	South Sudan		South Tome and Principe	Liberia
	Sudan		South Africa	Mali
	Tanzania		Swaziland	Niger
	Uganda		Zambia	Nigeria
			Zimbabwe	Senegal
				Sierra Leone
				Togo

Even though some countries have policies and regulations in place, countries such as Ghana and Nigeria, it is recorded that they still receive vast amounts of e-waste from developed countries (Avis, 2021). Though the 13 countries have policies and regulations on e-waste management, e-waste that is illegally imported continues to make its way to these countries. This can be attributed to the poor implementation of these policies by the countries (Avis, 2021).

2.9 E-waste in South Africa

South Africa is estimated to have a population of just over 59 million (World Bank, 2020). The population size contributes to the level of technology usage. The rapid growth of e-waste in the country has increased compared to 5 decades ago (Department of Statistics South Africa, 2019). E-

waste makes up about 8% of municipality solid waste in the country and this figure is expected to grow in the future (Andeobu *et al.*, 2021). In 2017, the country generated waste that was estimated to be around 44 Mt (Department of Environmental Affairs Report, 2018). Out of the 44 Mt general waste, 360 000 tonnes was from e-waste (ewasa, 2020). Ewasa further states that from the 360 000 tonnes, just 12% of e-waste was sent for recycling and the rest ended up in landfills. A study by Forti *et al.* (2020) found that e-waste generated in 2019 in SA was approximately 461 000 tonnes.

South African citizens live in two different settlements, the urban and the rural areas herein referred to as under-resourced villages. E-waste is scattered all over the country as technology usage is common in both areas. Due to a lack of awareness, e-waste from under-resourced villages is thrown into landfills. In support, Lydall *et al.* (2017) state that e-waste management in under-resourced villages is poor as it is either burnt, disposed of in landfills, or buried underground. Furthermore, Lydall *et al.* (2017) state that households in these areas account for 94% of e-waste illegal dumping.

The Gauteng provincial government working with the University of Johannesburg established the Gauteng e-waste management system. The system is aimed at helping the province to curb the mismanagement of e-waste. This aim is to be achieved by teaching residents about the environmental dangers that e-waste brings (Parker, 2022).

A study carried out in Limpopo province found that there is a need to educate and provide awareness to the people of the province, this came about as there was a lack of knowledge on what e-waste is and its impacts (Uhunamure *et al.*, 2021).

South Africa is composed of 9 provinces, each with its government voted for by the people of that province. The national and provincial governments are estimated to be the highest e-waste generators (Bracht, 2018).

Figure 2.3 depicts the percentage of most e-waste generators in South Africa.

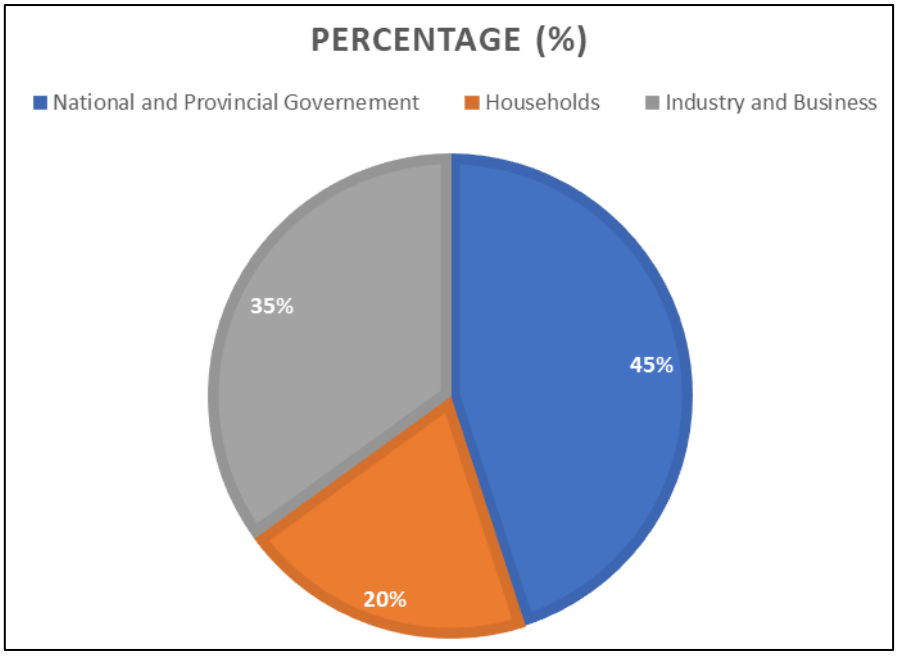


Figure 2.3: The percentage of e-waste generation in South Africa (Bracht, 2018)

The high percentages of the three generators are attributed to the collection and disposal challenges faced by the country and the lack of awareness on how to manage e-waste. The national and provincial government's e-waste is attributed to the failure to enforce e-waste laws and the lack of recycling infrastructure (EWASA, 2020). Household e-waste includes items such as washing machines, cell phones, desktop computers, etc. According to Avis (2021), these items are either burnt or thrown into landfills as a means of disposal. Industry and business e-waste is e-waste generated by the private sector. Most of this e-waste is kept within the premises of the business, which is done to prevent e-waste from ending up in landfills (Currie, 2020).

Figure 2.4 shows e-waste generated by each province, with Gauteng (45%) being the highest in the country and the Western Cape being second (20%).

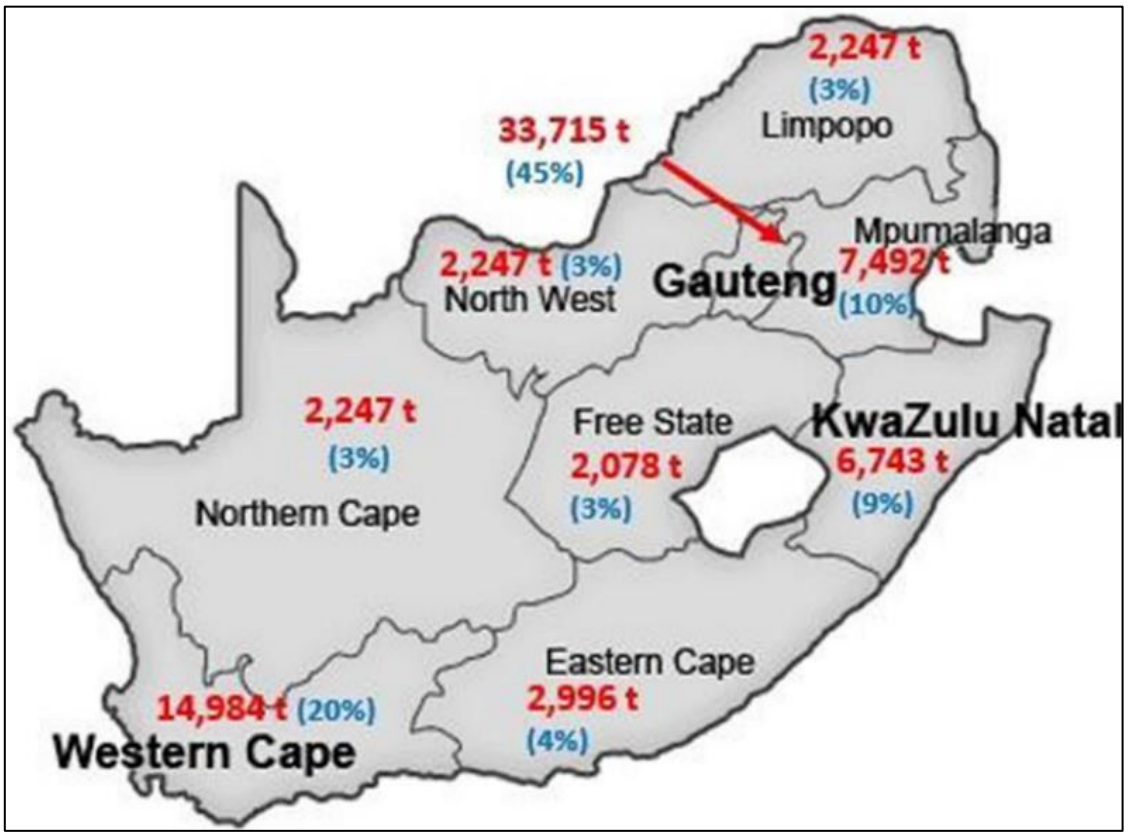


Figure 2.4: E-waste estimates by each province (Lydall et al., 2017 as cited by Mkhwanazi, 2021)

South Africa is one of the most developed countries in the African continent (Avis, 2021). It has policies and regulations in place to guide e-waste management. However, managing e-waste in the country is still a challenge as there is a lack of implementation of these policies, a lack of public awareness and under-resourced villages' e-waste not accounted for (Avis, 2021 & Lydall *et al.*, 2017). The unaccounted e-waste in under-resourced villages ends up discarded carelessly (Bhat & Savale, 2019), which then prompted the researcher to conduct this study to develop a cloud-based technological solution that promotes the awareness of e-waste to mitigate and improve health and reduce the environment hazards of the villages.

2.10 E-waste Impacts on Health and the Environment

E-waste's impact on human health is a major concern, hence policies and regulations described in Section 2.4 had to be initiated. The policies and regulations were done to safeguard human health

from the dangers of e-waste. A study to investigate e-waste impacts on human health found that e-waste mismanagement leads to issues such as birth complications, heart diseases and growth problems for children (Parvez *et al.*, 2021).

E-waste poses a danger to the environment leading to the pollution of air, food, and water which are basic needs for human survival. Avis (2021) states that exposure to emissions of e-waste through soil, water, dust, and food is dangerous to human health.

A study conducted in Nigeria found that people living near recycling sites of e-waste had a risk of inhaling toxic chemicals released into the air through the burning of e-waste and that they were exposed to radiation (Jibiri *et al.*, 2014). In South Africa, Machete (2017) found that people living near recycling sites were exposed to mercury, arsenic and cadmium. In Ghana, toxic elements released into the air due to the burning of e-waste caused respiratory health complications, asthma and eye problems (Acquah *et al.*, 2019). Eye and skin problems were found among workers who worked in informal recycling sites while others suffered from coughing (Acquah *et al.*, 2019).

Table 2.4 below gives a summary of some of the chemicals found in e-waste and their associated human health dangers.

Table 2.4: Chemicals found in e-waste and their associated human health dangers.

Chemical	**Associated human health dangers**	**Source**
Lead	Reduction of intelligence quotient (IQ) in children, high blood lead levels.	Lebbie *et al.* (2021)
Manganese	Small birth weight, child development issues, lung infections	Lebbie *et al.* (2021), (Claus *et al.*, 2010)
Mercury	Chest pains	Lebbie *et al.* (2021)
Arsenic	Delay in giving birth for women, small levels of IQ for children.	(Dong & Su, 2009)
Cadmium	Small levels of IQ for children, peripheral artery disease, respiratory problems	(Dong & Su, 2009)

The table above gives insight into the sicknesses that are dangerous to humans exposed to e-waste. Proper ways of managing e-waste must be initiated to mitigate and protect people from such diseases.

The environment is another aspect that is negatively impacted by e-waste mismanagement. According to Avis (2021) if the environment is not properly protected from toxic items such as switches, beryllium, batteries, cadmium, gold, copper, palladium, zinc, lead, mercury and lithium environmental pollution can present life-threatening diseases.

Figure 2.5 below depicts chemicals found in some of the electronic equipment that pose a substantial risk to the environment if not properly discarded.

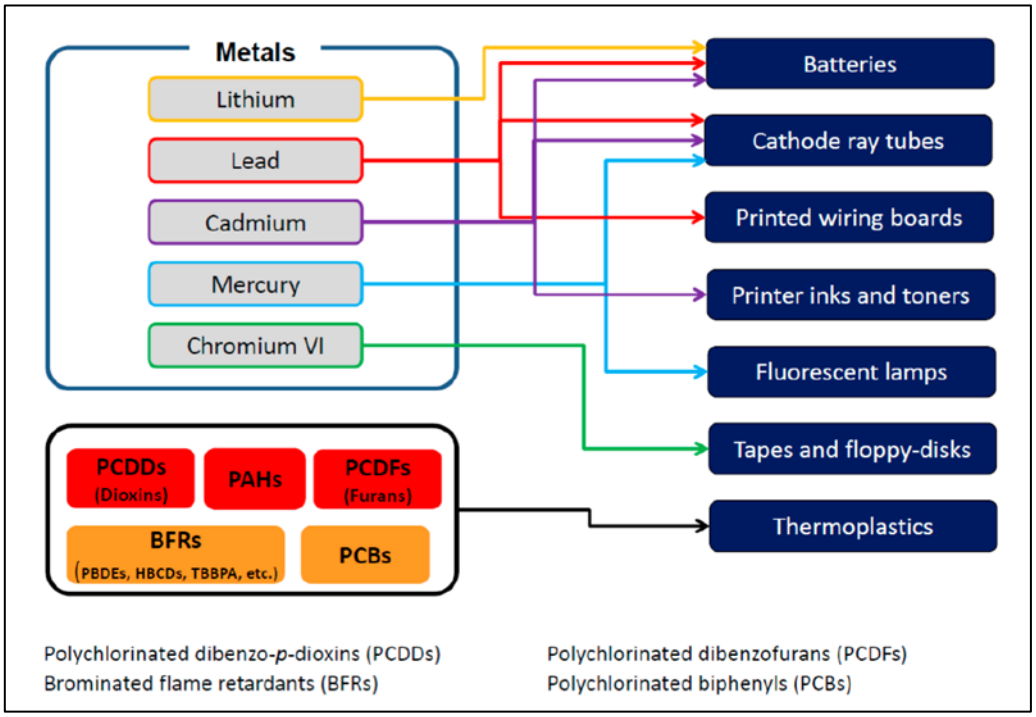


Figure 2.5: Chemicals found in some of the electronic equipment (Lebbie et al., 2021)

Due to the manual processing of e-waste, chemicals in Figure 2.5 damage the environment by leaching into the soil and burnt chemicals pollute the air. Chemicals leached into the soil pollute water underground which then finds its way back to the water stream on the land (Lebbie *et al.*, 2021). This claim agrees with the researcher's observation regarding the e-waste management gap in the investigated villages. These villages are mainly dependent on rivers and underground water for people and animal consumption.

2.11 Carbon Credits vs Social Capital

Carbon credits refer to permits that allow owners to discard a certain amount of carbon dioxide (Sebastiani *et al.,* 2024). Carbon credits are generated from projects that aim to reduce carbon

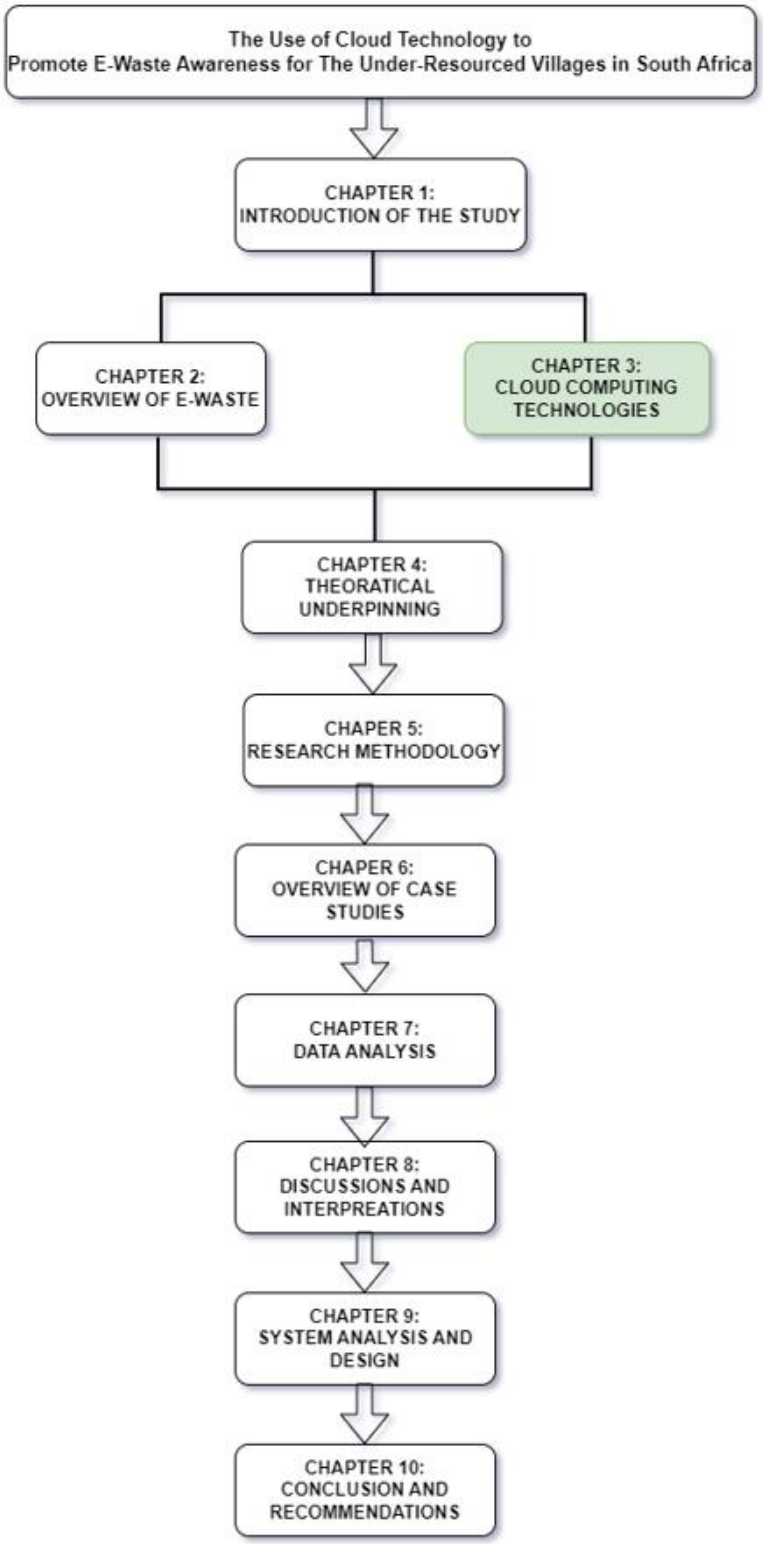
emissions released into the atmosphere (Aldy & Halem, 2024). Carbon credits focus on financial compensation to reduce carbon emissions (Friess *et al.,* 2022). Companies or organisations have carbon credits that decline over time as they release emissions. The companies receive a monetary incentive when they reduce their carbon emissions (Sebastiani *et al.,* 2024).

As opposed to carbon credits, SCT is a community-based approach that does not offer incentives for managing carbon emissions. Utilising SCT, the community drives innovations to develop ways in which the environment can be safely managed, and lives protected against carbon emissions. This study adopted SCT to gather information on how people from under-resourced villages manage e-waste. The study went further to develop a cloud-based solution to promote e-waste awareness among villagers based on the information gathered from SCT.

2.12 Conclusion

This chapter highlighted e-waste policies and regulations adopted by countries around the world to manage the import and export of e-waste. According to the literature, these policies and regulations are not fully implemented, and no country is forced to abide by them. Though some of the countries such as South Africa, Nigeria, China, UK are signatories of these policies and regulations, e-waste export and import to and from them is still occurring. E-waste challenges and negative impacts identified in the literature have been observed in the under-resourced villages investigated for this study. The spread and growth of e-waste prompts an urgent need for a cloud-based technology solution to mitigate challenges posed to the ecosystem, especially for under-resourced villages. The next chapter (chapter 3) discusses the investigation of cloud technologies for e-waste management.

CHAPTER 3: CLOUD COMPUTING TECHNOLOGIES



3.1 Introduction

This chapter presents the investigation of cloud technologies for e-waste management. The chapter defines cloud-based technology solutions for e-waste, cloud computing (CC), cloud computing service models, deployment models, cloud computing architecture and cloud security standards. As mentioned in Chapter 2 the study aims to develop a cloud-based technology solution to promote e-waste awareness in South African under-resourced villages. This was done using co-design and design thinking frameworks, while data was analysed using thematic analysis and Activity Theory (AT). The two frameworks adopted are also discussed in this chapter.

3.2 Overview of E-waste Technology Solutions

In the 21st century, technology solutions to social problems have become part of society, positively impacting people's lives. E-waste management and prevention is no exception to the transformation, offering an opportunity for e-waste management with technology. Technology solutions promote an effective waste management system because they are safe, always available, economical and provide better processing tools (Berg *et al.*, 2020). Below is the outline of some of the technology solutions expected to play a critical role in e-waste management development for this study.

3.2.1 Robotics

Robot Institute of America (1979:1) defines Robot as a "reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialised devices through variable programmed motions for the performance of a variety of tasks". In simple terms, a robot is a machine that is programmed to behave and work like a human being. For e-waste management, the usage of robots is relatively low (Berg *et al.*, 2020). With the benefits they have in e-waste management, robots can also be considered a source of the problem they help to manage. Berg *et al.* (2020) state that once the robots are no longer functioning, they become part of e-waste.

A description of robots used in e-waste management is provided below:

- E-waste management robots designed by Apple computers, are programmed to dismantle about 1.2 million of used iPhones yearly. E-waste products dismantled by the robots include the equipment used to make phones. Items such as aluminium, cobalt and tin which are used to make batteries are recycled after the robot has dismantled them (Apple, 2020).
- BHS, an American company, designed the robot known as MAX AI which uses a vision system to pick and sort which items to recycle (BHS, 2020).
- The Remeo and ZenRobotics company from Finland, designed the robot that recognises items through IR scans and sorts the items based on their category (ZenRobotics, 2020).
- Refined Industries from Sweden designed a robot that sorts battery material once dismantled. Approximately 500 kgs per hour are sorted and the robot is 97% accurate (Berg *et al.*, 2020).

3.2.2 Internet of Things

Internet of Things (IoT) is defined as “the general idea of things, especially everyday objects that are readable, recognisable, locatable, addressable through information sensing device and/or controllable via the Internet, irrespective of the communication means whether via RFID (Radio frequency identification), wireless LAN (Local Area Network), wide area networks, or other means” (Patel *et al.*, 2016:122). IoT is the interconnection of devices via the internet with the primary focus of transmitting information to other devices via communication networks.

For e-waste management and recycling, IOT is used by having containers/bins tagged with sensor devices that transmit the information when the sensor senses if the bin is full. The sensors send information such as the location and fill levels of the containers (Berg *et al.*, 2020). This information is sent to a central point and used to send out pick-up trucks. The tags attached to the containers are identified and tracked by RFID.

Below are a few examples of the IOT used by the developed countries to monitor and control e-waste (Berg *et al.*, 2020):

- Smart bins – remotely monitored waste bins that send information such as fill level and location of the bins (Berg *et al.*, 2020).
- Smart Recycling AB from Sweden - sends out logistics based on the information received from sensors such as bin locations and fill level of containers (Smart Recycling, 2020).
- TeXXmo Mobile Solution GmbH – this is a button attached to the container. It is programmed so that when pressed it sends out a notification to collect the containers (teXXmo Mobile Solution GmbH, 2020).

3.2.3 Artificial intelligence and neural networks

Artificial intelligence (AI) systems are known for solving problems efficiently and independently. Berg *et al.* (2020) state that by using machine learning with neural networks (NN), AI can solve complex problems with speed. IBM (2020) defines AI as computers and machines that mimic human behavior and decision-making to solve a particular problem. For e-waste management, AI applications are used to sort items based on image recognition (Berg *et al.*, 2020).

3.2.4 Cloud computing

According to Berg *et al.* (2020) cloud computing (CC) is a model which allows on-demand convenient access to network resources anywhere and at any time. These can be resources that can be used as storage systems, services, networks and applications. Cloud computing can be used for e-waste management in many ways such as storage of data sent by sensors and software solutions for collection, management, documentation, and administration of tasks (Berg *et al.*, 2020). The study adopted CC based on Mukta and Ahmed's (2020) argument that integrating cloud-based technology solutions in addressing e-waste challenges can provide positive contributions to the environment and human health. Furthermore, the researcher observed that CC is accessible to different communities even those in the villages because they have handheld devices that connect to the cloud.

3.3 Cloud Computing Technologies

Cloud computing technologies are computer virtual resources that provide access to software, files and storage to end users irrespective of their location (Berg *et al.*, 2020).

Cloud Computing is about accessing computer resources and information over the internet (Golightly *et al.*, 2022). Remote servers have virtual computer clients with no knowledge as to where the servers are located. The CC model is distributed to provide on-demand services to its remote clients, the on-demand services could be applications, hardware, servers and databases (Whaiduzzaman *et al.*, 2014). CC is a virtual internet-based computer system that provides users with remote ICT services. According to Abdulazeez *et al.* (2018), the main advantage of CC is that it is cost-effective, provides data fast when requested and can be used by many users at the same time. Two models make up the CC architecture, the service model and the deployment model.

Service models are Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) (Namasudra, 2021). Deployment models are private cloud, public cloud, community cloud and hybrid cloud (Namasudra, 2021).

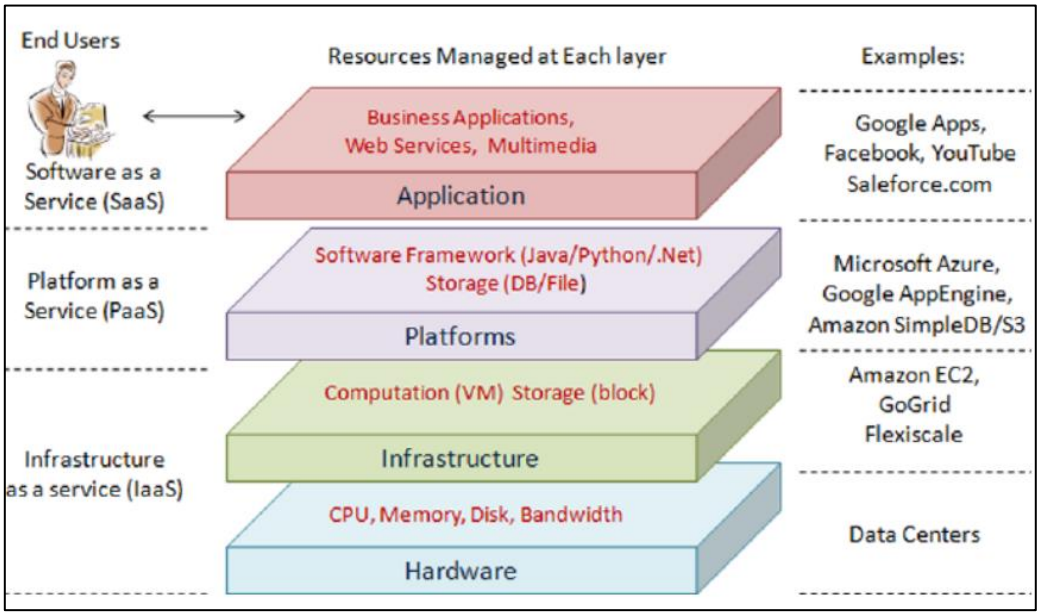


Figure 3.1: Cloud computing architecture and its service models (Parikh et al., 2019)

3.3.1 Service models of cloud computing

Service models contain the various applications (software), and hardware interconnected with the cloud; this is contained in a stack known as a cloud stack. The stack consists of three layers namely SaaS, the first layer, PaaS, the second and IaaS, the third layer. When people communicate, they do not communicate with the infrastructure or platform but with the software hosted by these cloud stacks. Figure 3.2 below depicts the cloud stack.

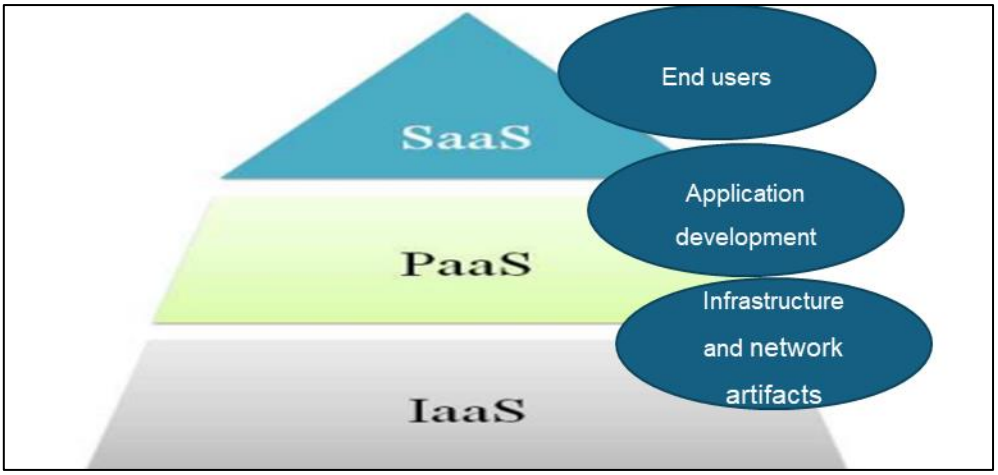


Figure 3.2: Service model cloud stack (Ara et al., 2020)

SaaS provides end users with online software applications delivered via the web. Examples include emails, games, and virtual desktops. End users can access these using the web browser, and mobile phones to name a few. PaaS provides a platform for the deployment of software applications. Programming languages exist in this layer of the cloud stack (Ara *et al.*, 2020). IaaS provides hardware and software such as virtual machines (VMs), IP (Internet Protocol) address servers, servers, load balancers and storage. The service provider is responsible for the infrastructure of this layer whilst the consumer is responsible for the software and storage (Ara *et al.*, 2020).

As this study seeks to develop an e-waste technology-enabled solution hosted on the cloud, the researcher will use the SaaS service model to deliver the application to the end users. This is because the solution would be deployed so it can be accessed by the intended end users from anywhere and at any time via mobile phones. The end users do not need to know the underlying infrastructure.

3.3.2 Deployment models of cloud computing

Literature indicates that there are four categories of CC deployment models; these are private, public, community, and hybrid cloud (Ara *et al.*, 2020; Patel & Kansara, 2021; Winkler, 2011). Deployment models are about the accessibility and ownership of the deployment infrastructure and storage size (Shaptunova, 2021).

Various deployment models described as private, public and community are outlined below:

- Private – A private cloud is owned by a single entity or organisation. Only authorised people have access to the organisation's systems. Security in this model is of the highest standard with the entity owning the model, or a third party managing it. The main advantages of the private cloud are high security, reliability and cost efficiency (Ara *et al.*, 2020).
- Public – The public cloud is made available to the public, owned by third-party service providers. Since anyone from the public domain can access its resources, the model has lower security (Ara *et al.*, 2020). Examples of third-party entities owning this model include Google, Microsoft, IBM Cloud, Amazon (Shaptunova, 2021).
- Community – this model resembles the private one, the difference being that the community cloud model is owned by more than one entity or organisation. According to Ara *et al.* (2020), the model is less secure than the private cloud model but more secure than the public cloud model.
- Hybrid – this model is a collaboration of two or all the above-mentioned models. It allows organisations to mix the other models depending on their requirements. The mixed models though bound together as one still operate as distinct units. Ara *et al.* (2020) list some of the benefits of the hybrid model as cost efficiency, security, scalability and flexibility.

Table 3.1 provides a comparative analysis of the abovementioned deployment models.

Table 3.1: Comparative analysis of the deployment models (Shaptunova, 2021)

	Public cloud	Private cloud	Community cloud	Hybrid cloud
Ease of setup and use	Easy	Requires IT proficiency	Requires IT proficiency	Requires IT proficiency
Security and privacy	Low	High	Comparatively high	High
Data control	Limited to none	High	Comparatively high	Comparatively high
Reliability	Low	High	Comparatively high	High
Scalability and flexibility	High	High	Fixed capacity	High
Cost effectiveness	Inexpensive	Very expensive model	Shared by community members	Less expensive than a private model but more expensive than a public model
Demand for inhouse hardware	No	Depends	Depends	Depends

For this study, a private cloud model was chosen because of the high security and data confidentiality it provides (IBM, 2020; Red Hat, 2019). Also, only one entity has access to components of the system such as updating code and security. A private cloud is suitable only when a single entity is using it (Ara *et al.*, 2020).

3.4 Cloud Computing Characteristics

Cloud computing as defined in the preceding sections offers sophisticated resources and benefits to its users.

Different authors describe a list of CC characteristics (Golightly *et al.*, 2022; Kaur, 2020; Puthal *et al.*, 2015) which include:

- On-demand services – the fundamental characteristic of CC, whereby users can access resources anytime and anywhere at their convenience.
- Unlimited network access – the computing resources that could be accessed using any devices that have internet access, such as laptops, smartphones and tablets. This can be done regardless of where the user is located.
- Resource pooling – the resources are shared by numerous end users. These resources are hosted in virtual machines or servers.
- Rapid elasticity – the computing resources are enabled to be scaled up and scaled down depending on the number of requested services needed.
- Measured services – the computing resources such as the Central Processing Unit (CPU) and usage of bandwidth are monitored and optimised. The monitoring is used to charge the price based on the used resources.

The above-mentioned characteristics motivated the researcher to adopt the cloud as a delivery platform since the communities of the under-resourced villages do not have computers or laptops but most of them owned smartphones which were useful to test the viability of the proposed solution. With smartphones, communities could access the proposed solution without being limited by time and location.

3.5 Cloud Computing Security Standards

Cloud computing security was established from the prescribed processes, technologies standards, and policies intended to protect data and infrastructure. The International Organisation for Standardisation (ISO) developed standards such as ISO 27001 to assist businesses to protect sensitive data processed on the internet (Pandey, 2022). Cloud computing has risks associated with information availability, data integrity and data confidentiality.

The National Institute of Standards and Technology (NIST) stresses that there are seven security standards used to guarantee the security of data in the cloud environment, namely, Authentication & Authorisation, Confidentiality, Integrity, Identity Management, Security Monitoring & Incident Response, Security Policy Management and Availability.

Each of these standards has individual protocols that provide security of data, hardware and the availability of data when required.

3.5.1 Authentication and Authorisation

Authentication and Authorisation refers to the identity of a user/users and the access they have to accessing computing resources. This level has the following standards operating in it: Request For Comments 5246 (RFC): Transport Layer Security (TLS) and Secure Socket Layer (SSL), two protocols responsible for security when communicating via the Internet. They permit communication between clients and servers in a way to prevent tempering of data, eavesdropping and sending false information (Dierks & Rescorla, 2008). RFC 3820: X.509 Public Key Infrastructure (PKI) Proxy Certificate Profile, describes a certificate coming from and signed by X.509 Public Key End Entity Certificate which provides limited proxying and delegation in a PKI authentication system.

RFC 5280: Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile, used to secure the World Wide Web (WWW) when browsing, Hypertext Transfer Protocol Secure (HTTPS) is one of the protocols used. RFC 5849 Open Authorisation Protocol (OAuth) is used for providing access to server resources such as API's. Access tokens are used to provide access. ISO/IEC 9594-8:2008 | X.509 Information technology - Open Systems Interconnection - The Directory: Public key and attribute certificate frameworks, provide two ways of authentication: making use of password verification for identification and using cryptography to create credentials.

OpenID Authentication which resides on top of the OAuth 2.0. provides both authorisation and authentication. Security Assertion Markup Language (SAML) shares information about security such as identity, Authorisation and authentication across an integrated system. Federal Information Processing Standards (FIPS) 181 Automated Password Generator inputs a random number and generates a password based on the input.

3.5.2 Confidentiality

Confidentiality refers to the protection of data against theft and unauthorised access. This level has standards operating in it. RFC 5246 relates to Transport Layer Security (TLS) and Secure Socket Layer (SSL), two protocols responsible for security when communicating via the Internet. They permit communication between clients and servers to prevent the tempering of data, eavesdropping and sending false information (Dierks & Rescorla, 2008). Key Management Interoperability Protocol (KMIP) facilitates communication between enabled cryptography applications and key management

systems. FIPS 197 Advanced Encryption Standard (AES) is an algorithm used to protect electronic data, a symmetric cipher block for encrypting and decrypting information in software and hardware.

3.5.3 Integrity

Integrity refers to the completeness, validity and accuracy of data. This level has the following standards operating in it: Extensible Markup Language (XML) signature (XMLDSig) defines XML processing rules for digital signatures. FIPS 180-4 Secure Hash Standard (SHS) uses hashing algorithms to digest generated messages. FIPS 186-4 Digital Signature Standard (DSS) specifies methods to protect binary data by generating digital signatures. FIPS 198-1 The Keyed-Hash Message Authentication Code (HMAC) uses cryptographic hashing methods to check for data integrity.

3.5.4 Identity Management

Identity management refers to protocols and standards that manage the authentication and verification of users in cloud resources. This level has the following standards operating in it: X.idmcc Requirement of IdM in Cloud Computing, FIPS 201-1 Personal Identity Verification (PIV) of Federal Employees and Contractors, Service Provisioning Markup Language (SPML), Web Services Federation Language (WSFederation) Version 1.2, WS-Trust 1.3, Security Assertion Markup Language (SAML), OpenID Authentication 1.1 OpenID.

3.5.5 Security Monitoring and Incident Response

Security monitoring and incident response use automated tools to supervise the physical and virtual servers, which is done to analyse threats and vulnerabilities in data. This level has the following standards operating in it: ISO/IEC WD 27035-1, ISO/IEC WD 27035-3, ISO/IEC WD 27039, ISO/IEC 18180, X.1500 Cybersecurity information exchange techniques, X.1520: Common vulnerabilities and exposures, X.1521 Common Vulnerability Scoring System, Payment Card Industry (PCI) Data Security Standard and FIPS 191 Guideline for the Analysis of Local Area Network Security.

3.5.6 Security Policy Management

Security policy management is based on layer 3 of the OSI model which is the Internet Protocol (IP), which protects the Information Technology (IT) resources of an organisation using firewalls. This level has the following standards operating in it: ATIS-02000008 Trusted Information Exchange (TIE), FIPS 199 Standards for Security Categorisation of Federal Information and Information

Systems, FIPS 200 Minimum Security Requirements for Federal Information and Information Systems, ISO/IEC 27002 Code of practice for information security management and eXtensible Access Control Markup Language (XACML).

3.5.7 Availability

Availability is a 24/7 availability standard of services to consumers based on the agreed service levels. This level has the following standards operating in it: ATIS-02000009 Cloud Services Lifecycle Checklist and ISO/PAS 22399:2007.

Data confidentiality, protection of personal information and service availability are some of the principal factors for any online system. Most of the above security standards are found in the private cloud, hence it is more secure than the public cloud. The study adopted the private cloud technology based on the security standards it offers. According to Grobauer *et al.* (2011), a private cloud only allows the permitted organisation and people to access its online computing resources, and it has secure channels of data confidentiality and integrity.

The section from 3.5.1 to 3.5.7 addresses data privacy issues and security standards implemented for the cloud solution, these are provided by the organisation hosting the developed solution. As the researcher stated at the beginning of this chapter that network access or connectivity is present in the studied under-resourced villages, so accessing the developed solution would not be a problem for village people.

3.6 Cloud Computing and E-waste

Cloud computing (CC) has been adopted by different industries and organisations such as healthcare, financial services, communication, energy and other organisations that promote efficient usage of information sharing.

The government sector of the developed and developing countries has been seeking solutions on how they can manage the e-waste problem. In the process of the quest for solutions, Bundi *et al.*, (2019) identified CC as one of the solutions that can be adopted to mitigate the effects of e-waste on human health and the environment. Bundi *et al.* (2019) further state that CC technologies provide benefits to e-waste management by providing real-time information flow between stakeholders.

In terms of e-waste management, CC services are considered to be a solution that can transform the environment and human health by providing an eco-friendly landscape. Singhal *et al.* (2020)

investigated e-waste awareness levels in higher educational institutions. Their findings reported that people in higher education institutions lacked e-waste awareness which had an impact on the level at which e-waste is managed. To mitigate this challenge, a cloud-based e-waste reduction model for higher institutions was introduced as a solution.

To promote e-waste awareness in Nigeria, Okewu *et al.* (2017) proposed a cloud computing solution that would educate computer users on how to manage their computers in an environmentally friendly manner. This solution was only limited to computer users and exempted other computing devices such as cell phones, tablets, televisions, etc.

As proposed by Zhang *et al.* (2010), a cloud solution would integrate stakeholders such as the producer, government authorities, recyclers, and service providers. The solution was designed as a SaaS type, ensuring access to information for financial and logistic purposes. This solution exempted end users or consumers at the developmental stages.

The solutions based on cloud computing reviewed by the researcher, lack information on cloud solutions proposed for under-resourced villages and also do not present any solutions co-designed with users. The proposed solution for this study focuses on a cloud-based solution that addresses under-resourced villages' e-waste and further, the researcher worked closely with them to co-design the solution.

Evreka (2023) states that other advantages of using CC for e-waste management are to:

- Provide real-time notification to stakeholders.
- Track dumping site/location.
- Transmit information on the level of fullness.

3.7 Design frameworks

The study embraced two design frameworks, namely co-design and design thinking to underpin the design phase of the study.

3.7.1 Co-design framework

According to the literature, co-design allows non-designers to be team players and collaborate with designers in the design phase (Trischler *et al.,* 2019; Sanders & Stappers, 2008). In the design phase, strategies for design probes such as stickers and videos are used to explain the concept and

to ensure that participants understand what is designed and why it is designed. The approach allows participants to be actively involved in developing a proposed solution. Sanders and Stappers (2008:10) define co-design as "a practice where people collaborate or connect their knowledge, skills and resources to carry out a design task." Mager (2008) and Slattery *et al.* (2020), state that co-design allows a system to be built on the users' lived experiences. This is to ensure that the system built suits the users' needs and expectations.

The Co-design framework is important in dealing with complex social, environmental, political, and technological issues and education where no one individual has the skills and knowledge to solve them (Busse *et al.,* 2023; Sanders & Stappers, 2008). Co-design allows participants to be in control of their lives and the environment they live in.

Slattery *et al.* (2020) state that co-design is useful when there is active engagement between end users and experts of a particular field in the design and research process. The table below depicts the benefits of using co-design when designing for end users or an organisation.

Table 3.2: Benefits of co-design (Steen et al., 2011)

	Benefits for service users	**Benefits for organisations**
Improved Idea Generation	Contribution of ideas from different users.	Improved collaboration across the organisation. Improves creativity among team members.
Improved Services	Fits end users' needs. High service quality. Improved user experience.	Better customer satisfaction.
Improved Outcomes	End users' satisfaction. Individual growth.	Improved relationship between users and organisation. Improves innovations within an organisation.

As illustrated in Table 3.2, the benefits of co-design among others include customer or end users' satisfaction. This is because they designed the system based on their lived experiences, and this could lead to higher levels of adoption and usage of the system.

In this study, co-design was used to design a cloud-based technology solution for e-waste management for under-resourced villages by making use of the community's lived experiences and using design probes such as videos, drawing boards and stickers. This is to ensure that a sense of ownership of the product is also experienced by the community. Gazana (2016) states that involving

end users in the design phase promotes a sense of ownership and eagerness to use the system by users who designed it. Sanders and Stappers (2008:24) state that “Co-design enables people to take ownership of their environments, services or products and, therefore, creates stronger and more meaningful connections among people and these creations”. Design probes were used to explain and gather the requirements of the system to be developed.

3.7.2 Design Thinking Framework

Dam (2021) defines Design Thinking (DT) as a methodology that provides a solution by adopting a user-centric approach. For this approach, solutions are derived from users’ opinions and lived experiences. It is for this reason that DT is used to develop solutions based on the understanding of the users’ requirements. DT is *“*useful when is used to tackle complex problems that are ill-defined or unknown because it serves to understand the human needs, reframe the problem in human-centric ways, create numerous ideas in brainstorming sessions and adopt a hands-on approach to prototyping and testing*”* Dam (2021:1).

There are five (5) important phases used to derive a solution from DT. These phases are described in Chapter 1 of the study Section 1.6.2:

- Empathise.
- Define.
- Ideate.
- Prototype.
- Test.

Each phase has a specific role that supports the design of the solution. The main purpose of these 5 phases is to allow the designers to dynamically develop and bring innovative ideas to complex social problems.

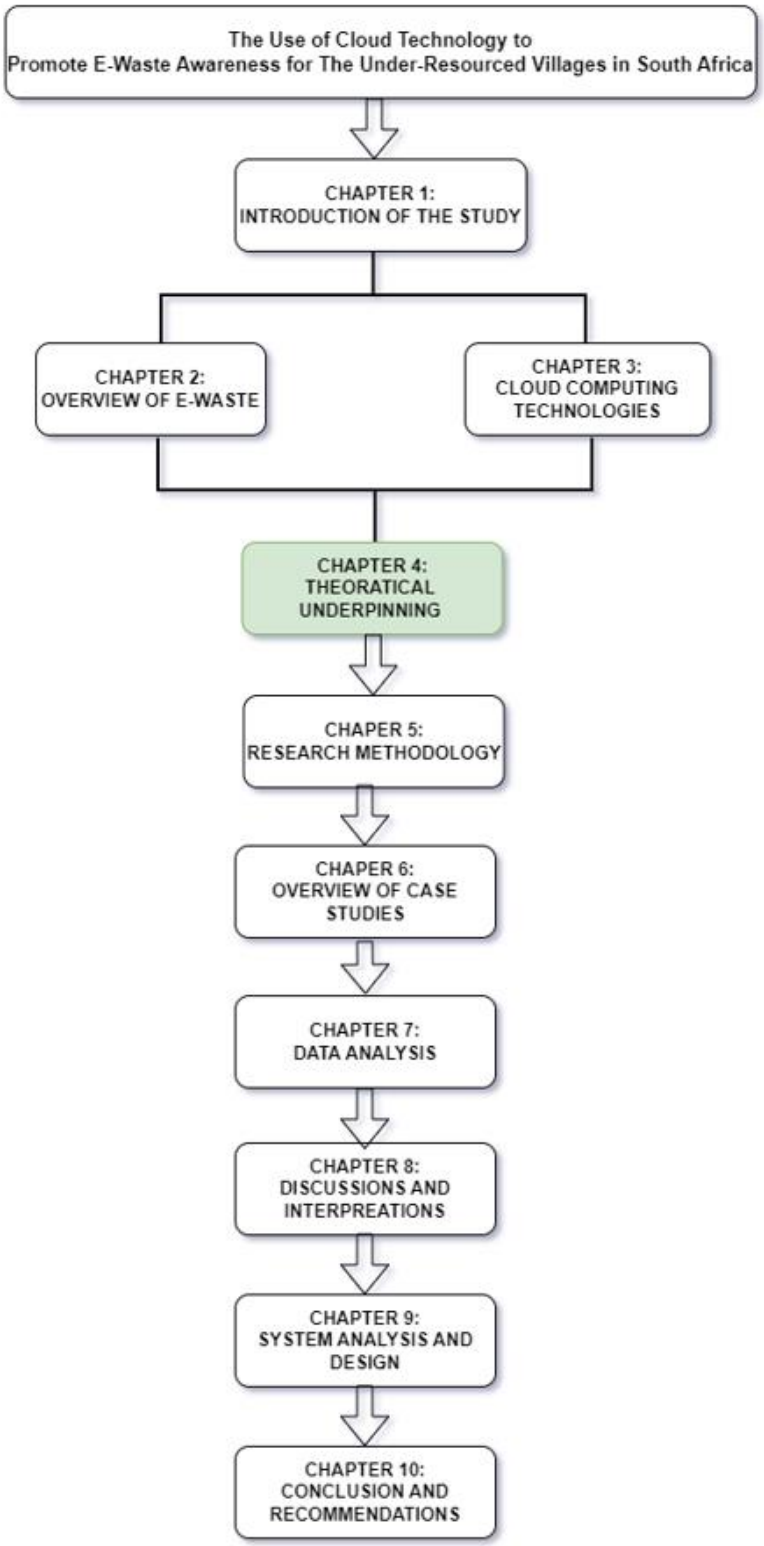
This study adopted the two design frameworks, Co-design and DT, because of their suitability to engage with end users during the design phase of a solution. As depicted in Chapter 1 Section 1.6, the use of the two frameworks allowed the researcher to develop a conceptual framework that defines how the design phases of the cloud-based solution were carried out. At the centre of the framework is the community where the study was carried out. Design probes were used to explain and gather information on the e-waste concept. The community is at the centre, as DT requires the target to be the centre of consultation in the process. The outer part represented the DT framework

with its five stages. The five stages of DT were used to process the information from co-design. From the gathered information, emphasis was put on the problem explained using design probes. The researcher then had to get more information on the problem as to what was done before. The researcher and participants shared ideas based on the information they had regarding the design of the solution. A solution was then developed based on the co-design requirements and the ideas shared. The solution was tested to check if it suited its intended purpose.

3.8 Conclusion

A review of relevant literature was presented in this chapter. The chapter focused on technology aspects used in e-waste management and then moved to Cloud Computing (CC) where CC technologies were discussed. This was done as the study aimed to make use of this technology in its solution. The study also discussed design frameworks used to design the cloud-based solution.

CHAPTER 4: THEORETICAL UNDERPINNINGS



4.1 Introduction

Two theories were chosen to underpin this study: Social Capital Theory (SCT) and Activity Theory (AT). These theories were used to guide the study's data collection and analysis phase. According to Mkhomazi and Iyamu (2013), theories in a research study are used to collect data and analyse data to have insight into the subject being studied. The SCT theory is used to collect data to understand the actions of the communities being studied regarding e-waste management or mismanagement. To analyse data collected through SCT, thematic analysis was used to find themes within the data. The AT theory is used to understand the communities' interactions with technology and the ways technology shapes their activities.

Whilst thematic analysis was used to analyse objectives one to three, data gathered on the lived experiences of the participants regarding e-waste and their expectations, was collected using SCT. AT supported the analysis of data for the fourth objective which was intended to identify strategies required in developing the cloud e-waste awareness solution. This led to the development of a cloud-based technology solution for e-waste management in under-resourced villages.

The next sections discuss the two theories, SCT and AT, which underpin the study. The sections provide an understanding of what these theories are and how they were applied in this study.

4.2 Social Capital Theory

Social Capital Theory allows a group of people to come together and share opinions or experiences and their common social or economic challenges or problems to find a common solution. In support, Fukuyama (2002) states that SCT is a standard for which the co-existence of people is achieved and solutions are developed based on constructive engagements. SCT is based on networking relationships within communities to promote social cohesion and collaborate in finding solutions to community problems.

The World Bank (2020:6) relates SCT to "… institutions, relationships and norms that shape the quality of a society's social interaction … [indicating] … social capital is explicitly relational". SCT is based on trust, beliefs, norms, values, relationships, and friendship for mutual benefit. Putnam (1995:67) contends that SCT has "features of social organisation such as networks, norms and social trust that facilitate coordination and cooperation for mutual benefit". This ensures that groups or communities cooperate for the benefit of all. In agreement, Fari (2015) states that SCT links a group of individuals sharing common goals and provides them with platforms to cooperate so to gain mutual benefits.

As mentioned in Chapter 1, SCT has eight components as depicted in Figure 3.4. These were discussed in detail in Chapter 1.

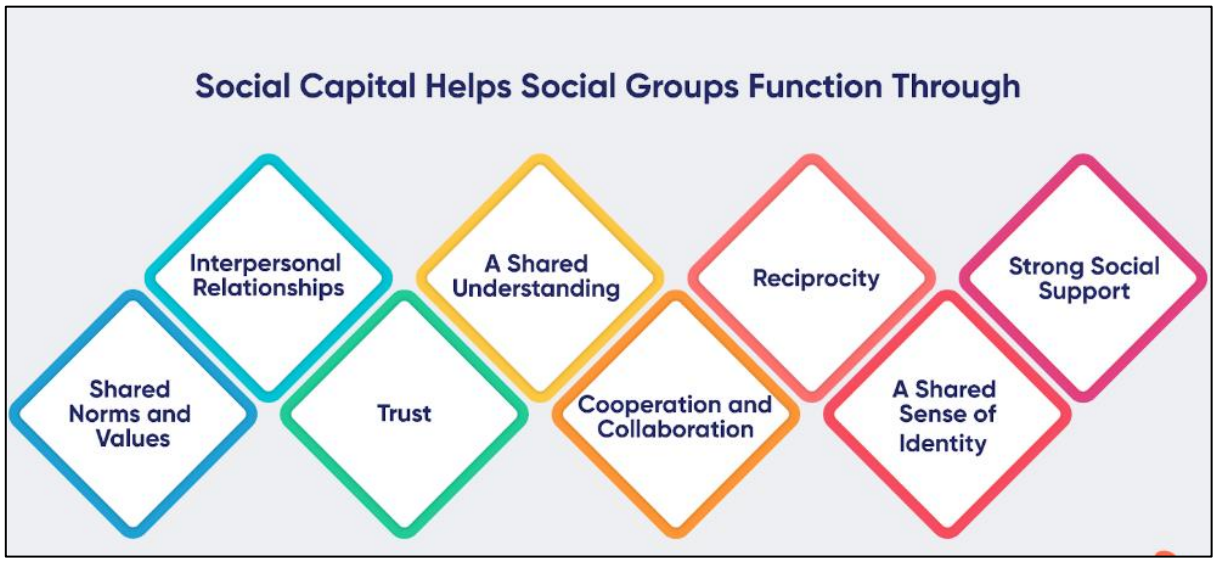


Figure 4.3: Social Capital Theory components (Halpern 2005)

Social Capital Theory was chosen for this study because the theory provides ways to understand vital issues of the characteristics, lived experiences and nature of individuals, their contribution and how they want to benefit. Furthermore, SCT was adopted to get a deeper understating on the e-waste challenges that the under-resourced villages as a community have and what they could contribute and benefit from the cloud-based solution. This was facilitated by having villagers express themselves freely in a group, while those not present would also benefit from the outcomes of the engagements. Fari (2015) and Luoma-aho (2022) contend that adopting SCT allows even the people who were not present in discussions to benefit from the outcomes.

The adoption of SCT was necessary based on the researcher's experiences whereby women's and young men’s views in community meetings are generally not valued by older men. However, the adoption and implementation of this theory have challenged the stereotypical views and allowed different stakeholders to participate equally.

4.3 Social Capital Theory in IS Research

The field of Information Systems (IS) has seen a tremendous increase in terms of research studies. This is motivated by technology and information systems solutions being developed to provide better solutions to social and economic challenges (He *et al.*, 2021). Due to the complexity of IS projects,

collaboration between end users, businesses and IS experts is required. SCT has the means to provide insights into understanding the challenges of end users leading to workable solutions for the identified challenges.

The IS solutions are created by people and used by people, providing a linkage between SCT and IS. To get a deeper understanding of how this is done, a theory is needed to explain these processes which for this study SCT is adopted.

Several researchers have applied SCT in IS research studies. To understand Internet usage among adults, SCT was applied by Neves *et al.* (2018); Wagner *et al.* (2014) applied it to examine organisation performance when using ICT applications; Ahmed *et al.* (2019) applied SCT in their study to explore the adoption of ICT interventions; and Lee *et al.* (2021) applied SCT to examine knowledge-sharing in IS projects.

Similarly, this study has adopted SCT to address the community's e-waste awareness challenges by co-designing a cloud-based solution with communities. This was done by examining the communities' understanding of e-waste and their proposed solution to the identified problem.

4.4 Activity Theory

Activity Theory (AT) originated from the Russian school of psychology by Vygotsky (1978) and has been widely used for social activity studies. According to Vygotsky (1978), AT is composed of components such as Activity, Subject, Object and Tools. The theory has been used in many research studies in the fields of health, education, organisational change, and ICT for the development of IS (Karanasios & Allen, 2018).

Over the past years, AT has been increasingly used to acquire a better understanding of activities by humans interacting with systems (Kelly, 2018; Engeström, 2001). Iyamu (2020) states that AT as a social-technical theory is used in IS to underpin studies. According to Karanasios and Allen (2018) one of the benefits of the theory is that it assists IS researchers to address challenges of studying human interactions (actors) with technology. For this study, the researcher aims to develop a cloud-based technology solution for e-waste awareness and management based on communities' (actors) lived experiences. Therefore, AT is used to guide the study in achieving this objective. AT is used to analyse and understand the activities of an individual, or a group of individuals, using artifacts and tools.

Table 3.2 is based on Figure 1.3 provided in Chapter 1, indicating AT comprises six components namely subject, tool, object, rules, community, and division of labour (Engeström, 2001; Iyamu & Shaanika, 2018), which are used to understand human interactions with systems in a given social context. The following table maps each component to its description.

Table 4.3: Description of the AT components

Component	Description
Subject	An individual or a group performing tasks as activities.
Tool	Instruments used by a subject when performing certain tasks or activities.
Object	Goal or outcome for the activity performed by a subject
Rules	Guide how activities are to be carried out by subjects
Community	This is where (place) the activities are performed by the subject(s), subjects being a group of people sharing a common goal.
Division of labour	Roles including responsibilities of subjects within the system
Outcome	The result of the completed activity

The study adopted AT to identify strategies to be adopted in developing the cloud e-waste awareness solution. This led to the development of a cloud technology-based solution. Hashim and Jones (2007) state that AT is a theory used to analyse and understand how humans interact using artifacts and tools, which tools could be applications, databases or hardware. Furthermore, Häkkinen and Korpela (2007) state that AT assists in understanding user group activities in the development of IS applications and provides information about the relationship between actors in a system.

The study also adopted AT guidelines developed by Iyamu and Shaanika (2018) on how AT can be applied to IS research studies. The guidelines consist of 6 components, namely: what, who, how, when, where and why. Adding these to the AT components provided greater confidence in the data used for the analysis phase. Table 3.4 depicts the 6 guidelines components adopted from Iyamu and Shaanika (2018).

This is a qualitative interpretative study and the adoption of AT as one of the theories underpinning the study is based on the fact that AT is suitable for such studies. Hashim and Jones (2014) contend that one of AT's key points is being suitable for qualitative and interpretative studies. Table 4.2 sets out AT analysis guidelines relating to several components (Iyamu & Shaanika, 2018).

Table 4.4: AT analysis guidelines (Iyamu & Shaanika, 2018)

Component	What	Who	How	Where	When	Why
Tool	What tools exist within an activity?	Who makes use of the available tools?	How are the tools applied in the different activities?	Where are the different tools used in an activity?	When are the tools used for various purposes?	Why are different tools used in an activity?
Object	What objects are available within an activity?	Who makes use of the available objects?	How are the available objects used in the environment?	Where are the objects within the environment used?	When exactly are the objects used in the environment?	Why are the objects employed in the environment?
Subject	What subjects are available and their roles within an activity?	Who are the subjects that exist in an activity?	How do the subjects exist within an activity?	Where do the subjects exist within the activity?	When do the subjects exist in an activity?	Why are certain subjects involved in some activities?
Rules	What rules exist for various activities in an environment?	Who makes the rules, and for whom are the rules made?	How are the rules formulated, and applied for various activities?	Where are the rules applied in an activity?	When are rules applied within an activity?	Why are different rules applied in an activity?
Community	What community exist in the context of the phenomena being study?	Who are the communities that exist from both human and non-human viewpoints?	How do the communities exist in an environment?	Where exactly do the communities exist in an environment?	When are the communities formed within an environment?	Why are communities created in an environment?
Division of Labour	What labour exists in the different divisions, for an activity?	Who is involved in the division of labour for an activity?	How is labour divided into division for an activity?	Where are the divisions of labour in an activity?	When are divisions of labour created for an activity?	Why are divisions of labour created for an activity?

4.5 Activity Theory in IS Research

For the past decade, there have been discussions of AT in IS research studies for analysing and developing frameworks (Zhang & Bai, 2019). Mkhomazi and Iyamu (2013) contend that the IS social context is complicated and the adoption of AT as a guide is important to solve complex issues within environments. The link between IS and AT exists because AT goes deep in understanding people's interactions within systems. These systems need people to develop and use them. Hence the theory is needed to underpin this study in the process of the development of the cloud-based technology solution co-designed by people from under-resourced villages and used by them. The framework acts as a lens in explaining how this is done.

AT enables IS researchers to gain a deeper understanding of technology and what it means to people. A major benefit of AT adoption in IS research studies is its provision of a well-developed framework to analyse complex issues under investigation.

Various fields of IS have embraced AT to understand the transformation of humans within systems. These fields include Human-Computer Interaction (Bødker, 1995; Mwanza-Simwami & Bertelsen, 2003), information System Design (Mursu *et al.*, 2006) and computer-collaborative work (Zurita & Nussbaum, 2007).

IS research studies that AT has been applied to include: a review of studies on health self-quantification (Eysenbach, 2016); examining the mediating role of a software tool in academic abstract sentences (Stead *et al.*, 2019); introducing AT as a lens in the field of information security non-compliance (Khatib & Barki, 2020) and Akintola *et al.* (2019) applied AT to examine the evolving professional practices at work. For this study, AT is used to address the e-waste challenges in the under-resourced villages.

4.6 Social Capital Theory and Activity Theory

Making use of one theory to underpin IS studies might be insufficient, especially for in-depth studies. With the use of two theories, the objectives of the study are covered fully. Iyamu (2013) states that in IS/IT research studies, the complementary use of theories has been increasing. This section is not for comparing the two theories used for this study, but it is for explaining their usage.

While the study was in progress the usage of SCT and AT for similar study was not seen in the literature, which is what makes this study unique. SCT is chosen because the theory provides a way to understand vital issues of the characteristics, lived experiences and nature of individuals, their contribution and how they want to benefit. Furthermore, SCT was adopted to get a deeper understanding of e-waste challenges that the under-resourced villages as a community have and how they could contribute to and benefit from the cloud-based solution.

After getting a deeper understanding of the e-waste challenges from SCT, AT was used to identify strategies to adopt in developing the cloud e-waste awareness solution for addressing them. Hashim and Jones (2007) state that AT is a theory used to analyse and understand how humans interact using artifacts and tools, such as applications, databases or hardware.

The order of the usage of the theories was important for this study to avoid getting inaccurate results. Iyamu (2013) contends that the order of use of two theories in research studies is important as it can influence the study's findings. Hence the researcher must know which theory to use first. This is explained below.

The use of the two theories was necessitated by the need to first determine how people living in under-resourced villages manage e-waste, determine several types of e-waste, challenges, and impacts on the ecosystem in the under-resourced villages and identify strategies in place to eradicate e-waste in the local municipality. To acquire this data, SCT was used as the first theory. Thereafter to address the challenges identified using SCT and build a system to mitigate those challenges and problems, AT was used to understand how the community interacts with systems and to develop the solution.

In summary, SCT was used to collect data for the first three study objectives, which were analysed thematically:

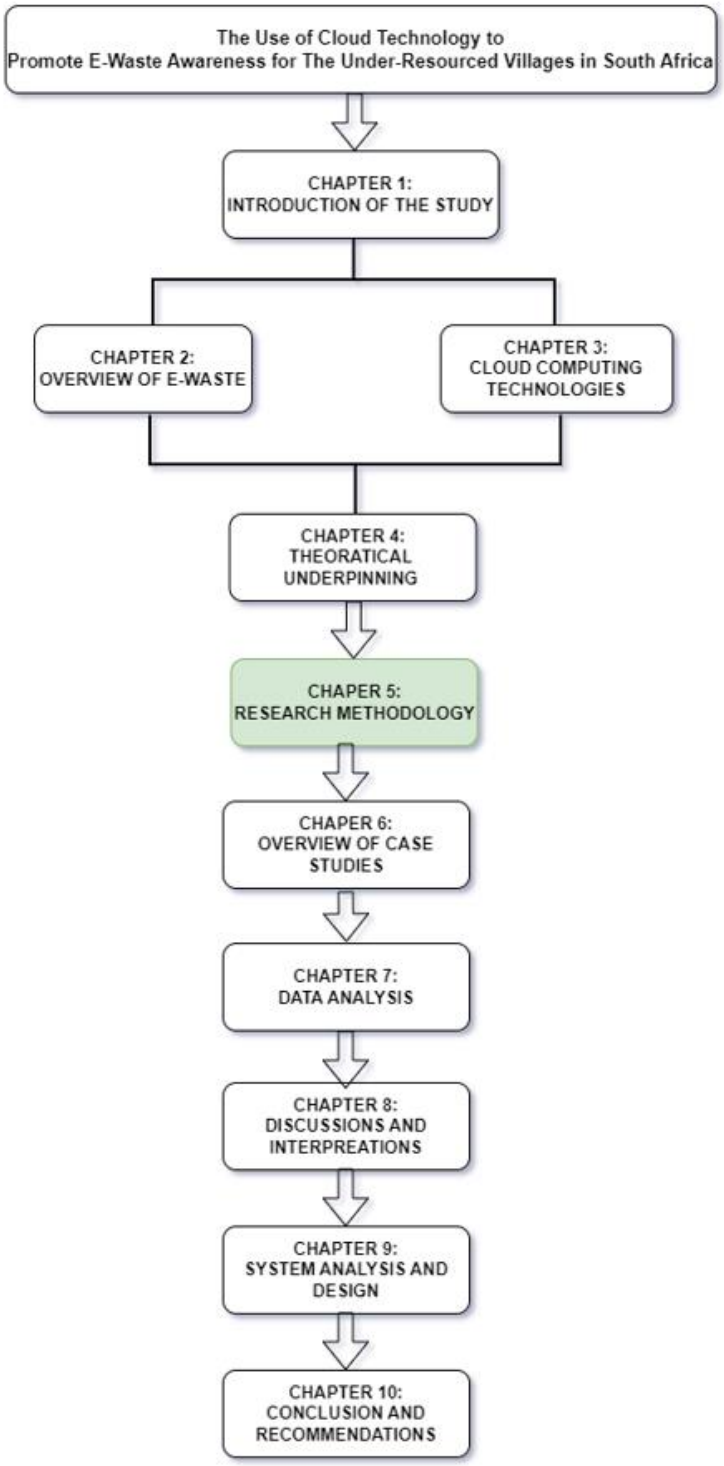
- To determine how people living in under-resourced villages manage e-waste currently.
- To determine different types of e-waste, challenges, and impacts on the ecosystem in the under-resourced villages.
- To identify strategies that could be used to manage e-waste for the under-resourced villages.

AT was used for the last study objective which was to identify strategies required in developing the cloud e-waste awareness solution. This laid the groundwork for the development of the cloud-based technology solution for e-waste management in under-resourced villages.

4.7 Conclusion

Underpinning theories, Social Capital (SCT) and Activity Theory (AT), are discussed in detail. Their roles in information systems (IS) studies are discussed to show their usage in literature. Lastly, a description of how the two theories were used in the study is provided.

CHAPTER 5: RESEARCH METHODOLOGY



5.1 Introduction

The chapter presents the structure of how the research process of the study has been carried out. It achieves that by defining the purpose of the study, executed plan, data collection strategies, data interpretation and reporting of the reporting of findings. There are 11 subsections; the introduction, research philosophy embraced, research paradigm, research approach, research methods, research strategy, data collection, data analysis, consideration of ethics, delineation and limitation of the study and conclusion. Sections 5.2 to 5.6 expand on the introduction to the research design of the study as set out in Section 1.9 in Chapter 1. Section 5.7 addresses data collection while data analysis is set out in Section 5.8. Thereafter, the chapter discusses ethical considerations (Section 5.9), the delineation of the study (Section 5.10) and the conclusion of the chapter (Section 5.11).

5.2 Philosophical assumption

Research philosophy is a process of how data is gathered, analysed and used regarding the studied phenomenon (Chowdhury, 2014). Research philosophy guides the researcher as to how to approach the phenomenon of the study to achieve its aim. According to Walliman (2017), in IS research studies, there are two commonly used research philosophies, these are ontology and epistemology.

5.2.1 Ontology

Ontology is about what exists and what is known regarding the studied phenomenon. Ontology assists researchers in discovering the nature of what exists, and the reality of the phenomenon being studied. Kivunja and Kuyini (2017) state that ontology deals with the assumptions of the researcher on what is existing and what is real regarding the studied phenomenon. The assumptions assist the researcher in posing questions based on what exists and what is real during the data collection phase.

For this study, e-waste mismanagement exists in the under-resourced villages of South Africa, which fits the ontological assumption of the study. Adopting this realistic philosophy for this study, the realities are (1) there is mismanagement of e-waste in under-resourced villages of South Africa (2) there is no means of protecting the ecosystem from carelessly discarded e-waste in under-resourced villages of South Africa. (3) There is also a lack of cloud-based technology solutions to address e-waste management for under-resourced villages of South Africa.

What is not known is how e-waste is currently managed in under-resourced villages, what the impact of e-waste mismanagement is in under-resourced villages and how cloud technologies can help eradicate the identified problem. This then leads the researcher to enquire about what is not known, leading to epistemology inquiry.

5.2.2 Epistemology

Epistemology is the study of knowledge. According to Kivunja and Kuyini (2017), epistemology describes how knowledge is gained. Bryman and Bell (2015) state that epistemology deals with what is acceptable knowledge. Maynard and Purvis (1994:224) state that epistemology is also "concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how one can ensure that they are both adequate and legitimate". Epistemology requires that the researcher should enquire to establish the truth of the phenomenon being studied.

For this study, the epistemology is to enquire (1) how e-waste is currently managed in under-resourced villages, (2) what is the impact of e-waste mismanagement in the under-resourced villages, (3) how can the use of a cloud-based technological solution address e-waste management for the under-resourced villages.

5.3 Research paradigm

A research paradigm is "the set of common beliefs and agreements shared by the scientist on how problems can be understood and addressed" (Kuhn, 1970:25). Antwi and Hamza (2015) state that a research paradigm is about the assumptions, culture and values that the researcher has in a research study. A paradigm is a model that guides the researcher in the process of research. Three research paradigm stances (Section 1.9.1) may be associated with ontological and epistemological assumptions (Saunders *et al*. 2012):

- Positivism.
- Interpretivism.
- Critical realism.

5.3.1 Positivism

Positivism's view is that the world is ordered and structured; it is also known as the scientific method and it focuses on explanation and predictions (Oates, 2005). This paradigm views

knowledge as an objective stance as it believes that knowledge can only be derived from scientific methods. According to Gicheru (2013), the positivist paradigm is of the view that reality is objective and stable and there should be no interference with the phenomenon being studied. In this paradigm, only empirically tested ideas are allowed and considered.

Positivism is all about objective statements and does not cater to subjective statements as it views objective statements as the only means of doing research for a particular phenomenon being studied. The researcher's role is only limited to adopting objective ways when collecting data and research outcomes are quantitative. Based on the above this paradigm is not suitable for this study.

5.3.2 Pragmatism

Pragmatism views reality as what works (Kaushik & Walsh, 2019). According to the literature, pragmatism is about solving real-world problems and not based on assumptions (Creswell, 2014; Hall, 2013; Shannon-Baker, 2016). Pragmatism deals with action-oriented procedures (Cameron, 2011). Pragmatism is commonly considered alongside a mixed methods approach (Maarouf, 2019). Pragmatism considers a phenomenon to be true without proving it is true (Saunders *et al.* 2012).

Pragmatism allows the integration of more than one research philosophy and research strategy. Pragmatism is the view that positivism and interpretivism can be adopted for a particular phenomenon depending on the research question studied (Johnson *et al.*, 2017). For this study, pragmatism is not suitable as the study does not adopt mixed methods but uses one which is a qualitative approach. Thus, only interpretivism is adopted for the study.

5.3.3 Interpretivism

Interpretivism holds a different view than that of positivism and pragmatism and is concerned with subjective views. Interpretivism views the truth through people's views, experiences and opinions. Ritchie *et al.* (2013:22) state that "interpretivism emphasises the importance of understanding people's perspectives in the context of the conditions and circumstances of their lives". Interpretivism holds that the truth is released through peoples' lived experiences. Interpretivism assists the researcher in gaining knowledge using tools such as documents, peoples' views and language (Walsham, 1993). Interpretivism is concerned with understanding complex social lived experiences of the people, including understanding the

meaning and interpretation of a particular situation (Schwandt, 1994). In interpretivism, the researcher makes use of qualitative methods to gather in-depth lived experiences.

As indicated in Section 1.8.1, this study adopted the paradigm. This is because the study aimed to understand peoples' views, perceptions and lived experiences regarding e-waste management in under-resourced villages of South Africa. Also, the paradigm was adopted based on the four objectives of the study (O1 – O4) which are:

- **O1**: To determine how people living in under-resourced villages manage e-waste currently.
- **O2**: To determine different types of e-waste and their challenges and impacts on the ecosystem in the under-resourced villages.
- **O3**: To identify strategies that could be used to manage e-waste for the under-resourced villages.
- **O4**: To identify strategies to adopt in developing the cloud e-waste awareness solution.

To achieve these objectives, subjective views and perspectives from the participants are necessary, hence interpretivism was adopted. Ritchie *et al.* (2013:22) state that "interpretivism emphasises the importance of understanding people's perspectives in the context of the conditions and circumstances of their lives".

5.4 Research Approach

Three types of research approaches can be adopted for research studies namely, deductive, inductive and abductive (Bryman & Bell, 2015; Bell *et al.*, 2022). The focus of this section is on deductive and inductive approaches.

A research approach relates to planned data collection, interpretation and presentation leading to research findings. Saunders *et al.* (2019) suggest that the research approach guides the researcher on how to conclude the findings of the study. Furthermore, the research approach indicates the possible meaning of the emergent results.

5.4.1 Deductive approach

The deductive approach is adopted as a top-down approach. It has the same set of steps as the inductive approach, but the steps are in reverse order (Kim, 2021). The deductive

approach starts with an existing theory and tests its patterns and concepts with data (Woiceshyn & Daellenbach, 2018; Kim, 2021). According to Kim (2021:152), the deductive approach studies what is known, analyses the existing theories of the topic of interest, and then tests the hypotheses that emerge from the deductive methods".

The research moves information from a generic point to a specific point. In explaining what deductive approach Ketokivi and Mantere (2010:18) assert that it "proceed[s] from a set of general premises to a more specific conclusion, with the strict condition that the conclusion must follow analytically from the premises". A deductive approach is associated with quantitative research, with common methods used being surveys and questionnaires. Figure 5.1 below highlights the phases of a deductive approach.

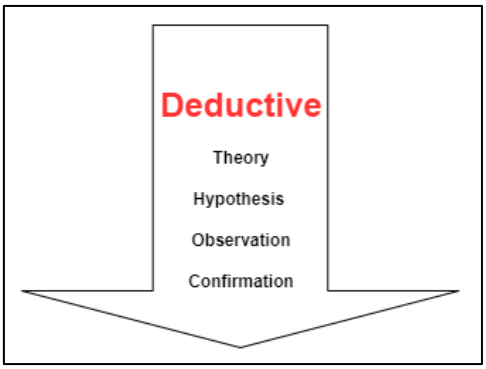


Figure 5.1: Phases of a deductive approach (Kim, 2021).

5.4.2 Inductive approach

The inductive approach is adopted as a bottom-up approach as there is no existing theory to be tested, this means that the outcome of the research is building the theory. The inductive approach moves from a specific point to a generic point. Kim (2021) states that the inductive approach starts with research and moves up to establish a theory. Young (2020) asserts that with an inductive approach, the theory is an outcome of the collected, interpreted and analysed data. The inductive approach is qualitative as it builds a theory based on people's views and experiences (Kim, 2021). The inductive approach is commonly adopted for studies using interpretative epistemology (Bhattacherjee, 2012).

Figure 5.2 highlights the phase of an inductive approach.

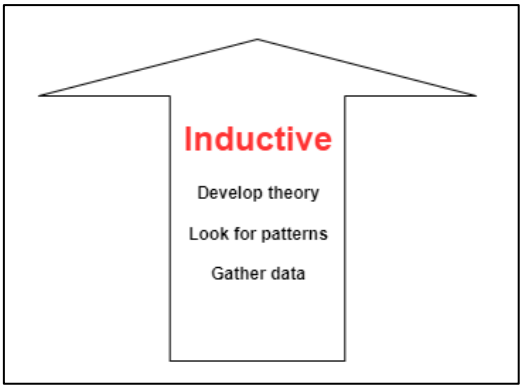


Figure 5.2: Phases of inductive approach (Kim, 2021).

For this study, the inductive approach is suitable based on the study's aim which is to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The development of the cloud-based technology solution is derived from participants' views and experiences. Selecting the inductive approach provided an advantage in that knowledge could not be fabricated as it was being built (Zalaghi & Khazaei, 2016). Thus, this is a qualitative study adopting the interpretative epistemology which as stated above works well with the inductive approach.

5.5 Research Methods

Research methods define how a research study about a particular phenomenon is carried out. Research methods encompass methods, techniques and designs that the study implemented to achieve its aim. According to Creswell (2003), there are three research methods employed in research studies, these are quantitative, qualitative and at times mixed methods. The researcher's choice as to which one to use is based on the research questions and objectives of the phenomena being studied. Below is an explanation of quantitative and qualitative research methods and which one was chosen for this study and why.

5.5.1 Quantitative Research Method

Quantitative research deals with numerical or statistical data (Bryman & Bell, 2011). Studies adopting quantitative research start with the theory or hypothesis and drill down to the results which are then generalised. McGregor (2018) asserts that quantitative research takes the form of a deductive approach, as the researcher formulates a theory, and collects, and analyses data to prove the theory true or false.

Quantitative research embraces methods such as surveys for data collection. The positivism paradigm is seen to be the most usually adopted paradigm for quantitative research studies (Conboy *et al.*, 2012). Researchers adopting quantitative research methods believe that reality should be studied independently from the studied phenomenon. Quantitative research uses numerical data for theory testing, and this is done using objective ontology.

This research method is not suitable for this study as it works with numerical data, experiments, and measurements. The study aims to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The development of the cloud-based technology solution is derived from participants' views and experiences. Thus, the study is inductive in nature whereas quantitative is deductive. A quantitative research method aims to use numerical data and generalise it so to explain a particular phenomenon. This is not what this study aims to achieve.

5.5.2 Qualitative research method

Qualitative research method is adopted in research studies that seek to make sense of social or human problems through people's views, experiences, and opinions (Creswell, 2009). Furthermore, Setia (2017) states that qualitative research is associated with collecting data from the views, experiences, opinions, and feelings of people. Qualitative research deals with texts rather than numbers. Qualitative research takes the form of a subjective ontology as it works with people's experiences and views and is associated with interpretivism paradigm (Conboy *et al.*, 2012).

Qualitative research studies are carried out in natural settings, this means the researcher collects data from the people where they reside. Bryman and Bell (2011) agree that for researchers to understand the phenomenon studied, they have to be part of the setting or environment.

In qualitative research, methods such as interviews, observations, archival materials, case studies and design efforts are used to gather data on people's experiences (Conboy *et al.*, 2012). Qualitative research is inductive in nature as opposed to quantitative research which is deductive (Thomas, 2003; Thorne, 2000). This means qualitative research is a bottom-up process that strives to build a theory from people's experiences, views, feelings, and opinions.

This study adopted the qualitative research method which allowed the researcher to obtain data from individuals residing in the under-resourced villages of South Africa. People's

experiences, views, feelings and opinions on e-waste management were obtained using methods such as observations and interviews. Thus, the study is inductive and adopts the interpretivism paradigm.

5.6 Research Strategy

Research strategies provide guidelines on how research questions and objectives are to be fulfilled. According to Bryman and Bell (2011), research strategies have several types of research design. To address research questions and objectives, the research strategy has procedures that need to be followed (Yin, 2003). Research strategies are different, and a researcher's choice is based on the research questions and objectives of the phenomenon being studied. According to Saunders *et al.* (2009) and Wedawatta *et al.* (2011), distinct research strategies may include surveys, experiments, case studies, grounded theory, ethnography, archival research and action research.

The study adopted the case study research strategy. The choice was based on the study's objectives. Two cases were purposively selected for the study, one being the under-resourced villages under Nqamakwe Town and the other being the under-resourced villages under Butterworth Town. The next section discusses the case study strategy. Purposive sampling is a non-probability sampling method that the researcher uses to choose participants based on the judgment of the researcher. The researcher used a purposive sampling method to choose participants of the study, this was based on the researcher's knowledge of who can best answer questions posed from the two villages.

5.6.1 Case study strategy

A case study is defined as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2018:15). Case study research investigates a particular phenomenon within its real-life context to bring the reality of problems and solutions of the studied phenomenon. The case study strategy is useful when there is no unmistakable evidence between the context and the phenomenon. Mohd Noor (2008) asserts that case studies aim to investigate why and how things happen and permit investigations of the real-life context of the phenomenon.

Case study can be adapted to any research philosophy making it versatile to either being positivist or interpretivist (Dubé & Paré, 2003). Creswell (2009) and Yin (1994) state that there

are two types of case studies namely single and multiple case studies. Furthermore, Woodside (2010) confirms that a case can be a group or an individual, but there are also multiple case studies. Stake (1994) distinguishes between three types of case studies namely intrinsic, instrumental and collective. These types are explained below:

- Intrinsic case has its focus on a single unique problem or concern.
- Instrumental case focuses on developing an already existing theory and provides insight into it.
- Collective case expands to more than one case, this is also known as multiple case studies. It uses two or more cases whilst focusing on one problem or concern.

The rationale behind using collective case studies is to replicate the results to enable the researcher to make a comparison between two or more cases. A collective case study is adopted for this study because the study was carried out in two different under-resourced villages in the Eastern Cape.

According to Benbasat *et al.* (1987), there are three reasons justifying why the case study approach is a suitable strategy for any research:

- Studying a phenomenon in its natural setting.
- Answering the “why” and “how” questions.
- Investigating a phenomenon in which little or no research studies have been done.

Case study strategy is the most used strategy in IS research studies (Rashid *et al.*, 2019). Benbasat *et al.* (2007) suggest three reasons why a case study is suitable for IS research studies, the suggested reasons are:

- Case study allows the researchers to produce theories based on studying IS in its real-life context.
- Case study allows the researchers to answer the “why” and “how” questions to get a deeper understating of the phenomenon being studied.
- The IS field changes rapidly, a case study is suitable to research the phenomenon in which little or no research studies have been done.

The study adopted two case studies to gain a deeper understanding of how e-waste is managed in the under-resourced villages of South Africa. The under-resourced areas of

Nqamakwe and Butterworth were used as case studies for this study. Both Nqamakwe and Butterworth are small village towns situated in the Eastern Cape province.

In Nqamakwe, Village A was studied and in Butterworth, Village B was studied. Village A is composed of four sub-villages and are demarcated under one chief. Village B has five sub-villages composing it from Butterworth and has its own chief. The local municipality that oversees service delivery in these two locations was also included in the study.

Since this is a purposive study, these villages were chosen by the researcher because the researcher observed that they have a huge burden of e-waste management.

5.7 Data collection

The data collection process is key in implementing the chosen research strategy. Data was collected using different methods and tools depending on the research question and objective addressed. Sources of data collection include virtual interviews, focus groups, document analysis, observations, and co-design sessions (Cresswell, 2009; Kabir, 2016; Olivier, 2009).

Primary data was collected by using semi-structured interviews with villagers and municipality representatives. Secondary data was collected using observations and document analysis. Questions were arranged based on the objectives of the study, the study had four objectives, and each objective had its own set of questions. The first objective had 10 questions that looked at how e-waste is managed in the under-resourced villages. The second objective had six questions looking at determining several types of e-waste, challenges, and impacts on the ecosystem in the under-resourced villages. The third objective was divided into two groups of questions as it had questions for villagers and the municipality. The questions looked to identify strategies that could be used to manage e-waste in under-resourced villages. The fourth objective had four questions that looked at strategies to be adopted in the development of the cloud e-waste awareness solution for under-resourced villages.

Interview questions (appendix E) were developed to assist with the data collection process, this was done to ensure that the process went as planned. Interviews took about 50 minutes to one hour to conduct. Open-ended questions were asked of participants.

The first phase of data collection took place at Village A followed by Village B. The researcher and the chiefs agreed that the researcher should identify a group of people to be interviewed. The researcher arranged a community hall for interviews with Village A participants. Interviews

for Village B took place in the chief's place because the village does not have a community hall. The chiefs of these villages supported the researcher. They identified this study as a means that brings communities together and find it presenting an opportunity to work together towards a common goal despite their various locations and jurisdictions.

Before the interviews, the aim and objectives of the study were explained to the participants. Voluntary participation was encouraged, and participants were asked to be open as each participant's views and experiences were of importance. It was explained to participants how the researcher decided on the topic of the study and the possible contribution of the solution to the villagers. Participants were also notified that should they wish to have access to the results of the study, they would be provided with them. Participants were made certain that their information would be kept strictly confidential and that their names would not be used in the study.

When it came to participants' time to sign consent letters, they said the consent letters (appendix C) signed by the chiefs were enough as they trusted them, and it was the chiefs' right to allow what happens in the locations. They mentioned that by tradition, chiefs sign such documents and if the villagers did not agree to participate, they would have not even attended the meeting.

The researcher was told that at Imbizo, chiefs notified their communities of such a study even though the researcher had not chosen his participants at that stage. By the time the researcher identified participants they already knew about the study. The researcher also knows from experience that when a letter or summon arrives at the chief's place he tells the headmen and committee who in turn notify the rest of the community.

Participants were not against signing the consent forms but said according to Xhosa tradition, what is signed by the chief was enough for them as they trust them. There was a condition on this that, chiefs tell them about such letters when they arrive which was done as the participants knew the researcher's visit for data collection.

Pseudocodes were used to identify participants, for example from Village A, the code is labelled as MT01 to MT14 and in Village B, the code is labelled as MP01 to MP12.

Co-design sessions were conducted and arranged by the researcher. Participants from Village B were asked to come to Village A since it had a community hall. Because of the long distance between the two villages, the researcher arranged transport for Village B participants. This

was done so that both village participants simultaneously did the co-design sessions. To ensure that all participants were on the same level of understanding of the designed application, it was necessary to have them in one place. Being in one place ensured that participants' views from both villages were consolidated as one. After deliberations on how the system should work, all participants agreed on the functionality, this included suggestions from the researcher.

Participants for the study were limited to people who were staying in the villages that were identified for the data collection sample group. To be part of the study participants' age limit was 18 years upwards, and participants must have owned or owned any of the electronic gadgets.

The interviews with villagers were conducted in isiXhosa as this is the participants' mother tongue. During the interviews, the researcher took notes and used an audio recorder to record the interviews, participants had agreed to be recorded. The records were listened to by the researcher after the interview to ensure that all that was said was captured. All recorded interviews were transcribed before data analysis. To transcribe, the recorded interviews were played back and forth to ensure that everything that was said was captured, Microsoft word was used to type what was said in the recorder. To identify who said what, the name of the researcher, questions and comments from the researcher were coloured in red. Answers and comments from participants were left black and in bold including their pseudonyms. Recording was stopped when co-design took place. This was because the researcher needed to focus on the design and did not see the need to record the co-design sessions.

The second group of participants for the study was municipality employees. The municipality interview was done via teams, this was because the municipality participant opted for this option. Due to the participant being busy and the researcher based in Cape Town, an agreement was reached that the interview could be done online via teams. This was because the participant stated that during the day when the researcher was doing data collection in the Eastern Cape, the participant was not available. The interview was done online, and only one representative from the municipality had agreed to be part of the study as others said he is the one dealing with ICT policies on e-waste and anything related to electronics in the office. The pseudocode for the employee was coded as EMP01. EMP01 requested to first see the questions he was going to be asked before the scheduled interview. The questions were shared with EMP01 via the work email address, the questions were sent with the consent letter for him to sign.

Data collection was stopped when no new data was coming from the participants, meaning data saturation was reached. For Village A, 14 participants were interviewed and for Village B, 12 participants were interviewed and one participant from the municipality, bringing the total number of the participants for the study to 27 participants.

Co-design

Co-design is about designing with and not for. Co-design is a process whereby the researcher provides guidance to participants when designing their solution (Ylirisku, et al., 2007). Co-design encourages knowledge sharing since the team is made of experts and those who are being guided. It also promotes a sense of ownership of the solution designed.

The process was used to design a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa whereby participants designed the solution. The researcher played videos and made examples of what e-waste is and how participants can design their own solution for the study. Design probes used included stickers, pencils, colouring pencils, whiteboards, videos and games. Participants were required to collaborate with the researcher, discuss and once agreed a feature of the system was placed on the whiteboard.

Direct Observations

Observation in qualitative research is a process where the researcher watches and examines participants' actions and behaviours when dealing with the studied phenomena. In direct observations, the researcher can only watch and not get involved in the studied phenomena, this is to prevent him/her from being biased when making findings (Smit & Onwuegbuzie, 2018).

Direct observation for this study was used to complement other data collection methods and to gain insight into what could have been missed during the interviews. Examples being noting confusions, frustrations and visiting dumping site visits and participants' homes.

Pilot study

The pilot study was carried out to test the interview questions. 10 participants participated in the pilot study; the pilot study took 45 minutes. Out of 33 questions, only three questions were rewritten so they are understandable. The pilot was beneficial as it ensured the flow of questions, ease of answering the questions and recording device's testing. Those who participated in the pilot study were not part of the data collection process for the overall study. According to Oppenheim (1992) and Sproull (1988), pilot studies are carried out to:

- Provide cost estimates and the study's duration and test the study's organisation.
- Test the suitability of research instruments and research methods.
- Estimate response rate and drop-outs.
- Practice data collection in a real situation.
- Evaluate the outcomes of the pilot to ensure that they synchronise with the study's objectives.

Demographics of the participants

Participants' demographics such as age were considered for the study. Participants had to be 18 years or older to be part of the study and had to be willing to participate. Participants had to be residing in the studied under-resourced villages. From the municipality's side, participants had to be in the IT management department and must have worked for the municipality for 2 years and above.

Documentation

To gain additional insight into e-waste awareness and management, documents were obtained from the local municipality's website, the municipality which the studied under-resourced villages are demarcated under. Document review in research is important as it provides valuable information and historical insight that could be missed by the researcher if not catered for (Nollaig, 2021). Documents provided insight into some of the e-waste aspects that could not be covered during the interviews.

The following four documents were labelled as Doc01 to Doc04 for referencing purposes.

- Doc01: Coastal Management Programme 2015-2020.
- Doc02: Waste management policy.
- Doc03: ML01 Local Municipality – 2019/2020 Annual Report 1.
- Doc04: ML01 Local Municipality – 2020/2021 Annual Report 1.

ML01 is a pseudonym, anonymised for the municipality name.

5.7.1 Research population and sampling

Population is defined as a group of individuals with the same characteristics required by the researcher. Babbie (2006) defines a study population as a group of individuals in which a sample is selected to represent the entire study population. This study's population is based in Nqamakwe and Butterworth areas in the Eastern Cape province specifically targeting Village A and Village B. The population included under-resourced villagers from the two locations experiencing e-waste management problems. Two sampling methods can be used to select a study population in research, these are probability and non-probability sampling. Section 4.7.1 discusses each of these sampling methods.

5.7.1.1 Probability sampling

Probability sampling also known as random sampling ensures that each member of the population has a chance of being selected as a participant in the study. Probability sampling consists of different sampling methods such as simple random sampling and systematic sampling and given as:

- Simple random sampling - any member of the population can be randomly chosen.
- Systematic sampling – members are randomly chosen at regular intervals.

Probability sampling advantages include limited biases, findings that can be generalised to the entire population, limited systematic errors and better population representation (Alvi, 2016). Based on this, probability sampling is best suited for deductive research. This study adopted an inductive approach making the probability sampling method not suitable for this research.

5.7.1.2 Non-probability sampling

Non-probability sampling allows for the selection of participants based on the researcher's assumptions (Yin, 2003). Participants are chosen in a subjective manner rather than a random manner. Non-probability sampling consists of different sampling methods such as snowball, purposive, quota and convenience sampling methods. Purposive or judgment sampling was chosen for the study, this is because the researcher had an assurance that the sample was a true representation of the population being studied (Babbie, 2006). According to Malhotra and Birks (2007), purposive sampling allows the selection of participants based on the assumption that they can provide information on what is studied. Furthermore, Saunders *et al.* (2006) contend that purposive sampling enables participant choices that inform the answering of the research questions. In qualitative research, non-probability sampling is used as the research does not aim to provide numerical data as its outcome. The researcher chose purposive sampling based on the reasons stated above.

5.7.2 Sample size

The sample size is the number of participants selected for a research study (Andrade, 2020). Several researchers have argued about the sampling size for qualitative research studies. In a case qualitative research study, to reach the saturation region, the sample size is between 15 – 20 (Sinkovics & Alfoldi, 2012). The selected sample size is managed by the chosen epistemology and research methodology. Reaching the saturation region in qualitative research is important to gain full depth of the studied phenomena. The sample size between 5 and 20 is appropriate for qualitative research (Leedy & Ormrod, 2010). According to Baker and Edwards (2012), for qualitative research, the selected sample size should be between 12 to 60, to ensure that the researcher gains the full depth of data. Based on Baker and Edwards' (2012) guidelines, a sample size of 27 participants were interviewed. The data collection phase was stopped when no new data was coming from participants, this is also known as data saturation**.** According to Charmaz (2006:113), the saturation region is reached "when gathering fresh data no longer sparks new theoretical insights, nor reveals new properties of your core theoretical categories".

5.8 Data analysis

Data was collected from the two case studies as articulated in Chapter 1, also the local municipality that oversees service delivery in these two locations was included in the study.

Data analysis is a process of transforming collected data into meaningful and useful information. Because the study wanted to interpret data that is in a textual format, the thematic analysis approach was adopted. Thematic analysis is further discussed below in Section 4.8.1.

Two theories, Social Capital Theory (SCT) and Activity Theory (AT) were used to underpin the study. The aim of using these two was not to compare the two theories but were used so they could complement each other. How they are used in this study is discussed in Chapter 4. The following section recaps how the two theories were applied.

SCT was chosen because the theory provides means to understand vital issues of the characteristics, lived experiences and nature of individuals, their contribution and what they want to benefit. Furthermore, SCT was adopted so to get a deeper understanding of the e-waste challenges that the under-resourced villages as a community have and what they could contribute and benefit from the cloud-based solution. After data was collected using SCT the following objectives were analysed using thematic analysis. The objectives addressed by SCT and analysed using thematic analysis are:

- **O1**: To determine how people living in under-resourced villages manage e-waste currently.
- **O2**: To determine different types of e-waste, challenges, and impacts on the ecosystem in the under-resourced villages.
- **O3**: To identify strategies that could be used to manage e-waste for the under-resourced villages.

The second theory AT was used to identify strategies to adopt in developing the cloud e-waste awareness solution. This was done to curb the challenges identified using SCT. This led to the development of a cloud-based technology solution for e-waste management in under-resourced villages. According to Redmiles (2002), AT is a theory recognised and known for increasing design practice in Human-Computer Interaction (HCI) and Computer Supported Collaborative Work (CSCW).

AT was used for the last study's objective:

- **O4**: To identify strategies to adopt in developing the cloud e-waste awareness solution.

This led to the development of a cloud-based technology solution for e-waste management in under-resourced villages.

5.8.1 Thematic analysis

Thematic analysis (TA) is a qualitative method used to identify, analyse and report themes found in text data (Dawadi, 2020; Braun & Clarke, 2006). It allows the researcher to make sense of people's lived experiences, views and opinions (Braun & Clarke, 2012). Thematic analysis is flexible and easy to learn (Braun & Clarke, 2006; King, 2004). In analysing the data from objectives one to three, the following six stages of thematic analysis were used (Braun & Clarke, 2012):

- Familiarise yourself with data: Reading data repeatedly and making notes.
- Generate initial codes: the researcher codes interesting parts of the data.
- Search for themes: collate codes into potential themes by categorising them.
- Review themes: check themes against collated data to ensure that no relevant data is left out.
- Define and name themes clearly define each name of the themes produced.
- Produce the report: produce the final report relating to research questions and objectives.

In the study, thematic analysis, a method to analyse qualitative data was used to analyse data for the first three objectives of the study. The data was collected through semi-structured interviews whereby the data collection process embraced SCT as a theory to collect data from participants. Thematic analysis was seen as a suitable method since it makes it easy to analyse data regarding people's lived experiences, views and opinions.

5.9 Consideration of Ethics

The protection of participants in any research is important to protect their rights. Ethics clearance (appendix A) was obtained from the Research Ethics Committee of the University, where the study is registered. Permission to conduct the study was obtained from the two chiefs who oversee the under-resourced villages being studied. The letters (appendix C) to the chiefs were written in English but were translated into isiXhosa for the chiefs so as to fully understand what is required by the researcher.

It took three months to get permission from the municipality. The municipality was contacted via its Facebook page, and LinkedIn, direct messages to municipality workers on LinkedIn yielded no results. The researcher had to ask around for people working at the municipality. Phone calls at times were ignored and if answered the researcher would be sent from post to pillar. At times being asked how the researcher got one's extension number. These numbers were not available on the Facebook page of the municipality. The researcher got the numbers after having asked a friend to ask for municipality phone numbers at their offices. At some point after numerous calls and messages, one municipality worker replied. Upon explaining the aim and objectives of the study, the worker spoke to others, and he conveyed the message back to the researcher. The message was other staff are reluctant to participate but have asked him to participate as he oversees e-waste policy documents. They according to him said this was in his line of duty so he is the best candidate to speak to.

The researcher assured that participants' personal details or information provided during the interview would be kept strictly anonymous and confidential. An explanation of the study was communicated to the participants (using isiXhosa as a language of communication). Voluntary participation was encouraged, and participants were free not to participate or withdraw at any time.

Collected data was protected and treated with the utmost confidentiality; access was gained by the researcher and the researcher's supervisor only. Collected data was removed from the researcher's storage (audio recordings and cell phone recordings) after the study had been marked. Collected data was stored at the Cape Peninsula University of Technology's data repository for some time as this is a requirement from the University. Data collected was transcribed into English as the interviews were being conducted in isiXhosa, this is because isiXhosa is the first language of the participants with which they are comfortable. To protect participants, their real names and identity were not publicised, instead, pseudonyms were used to refer to participants. The university's code of ethics guided the study to protect all those who participated.

5.10 Delineation of the study

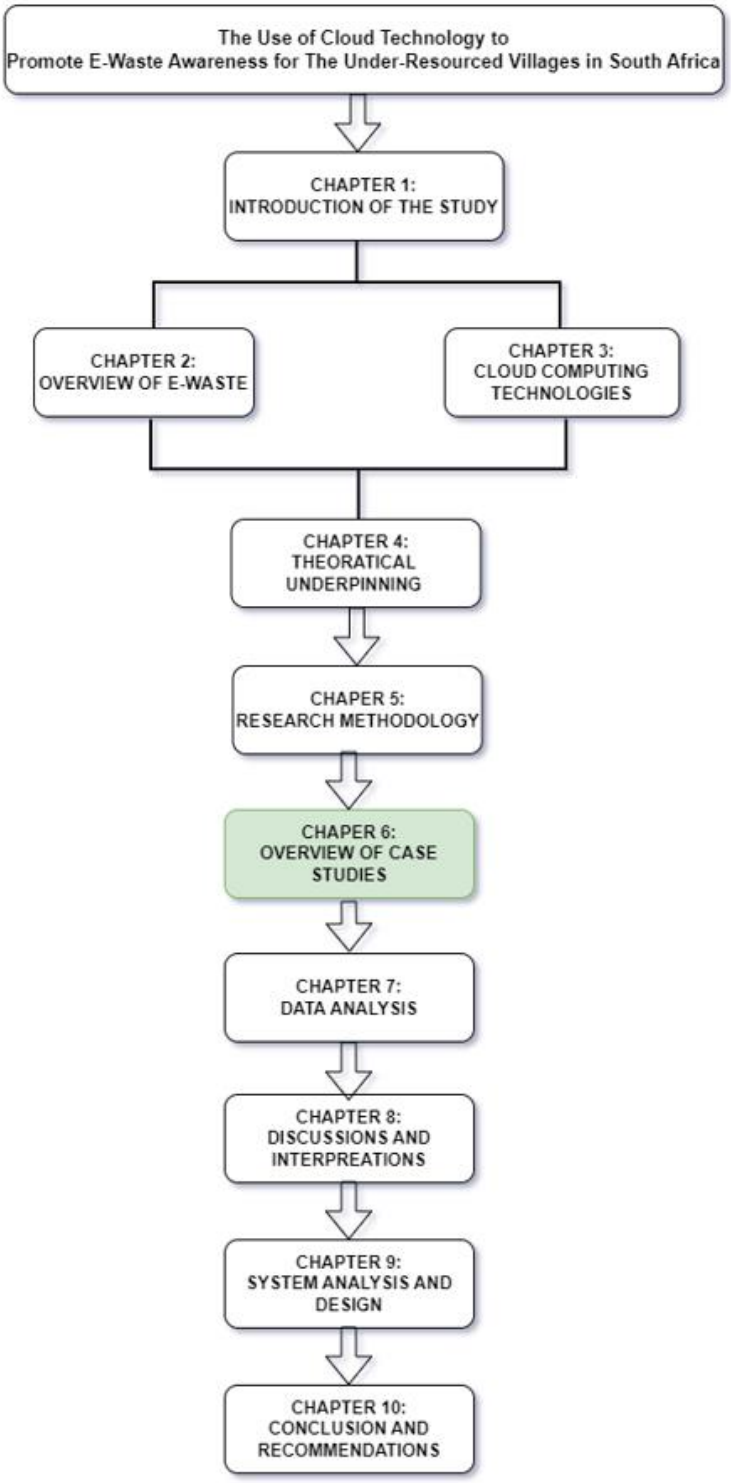
The study did not consider all under-resourced areas in the Eastern Cape or all those situated in Nqamakwe town and Butterworth town. The study only consulted one location from Nqamakwe town and one location from Butterworth town which are Village A and Village B respectively. The study was also limited to consulting one local municipality to gather data on

how they manage e-waste. The study only considered e-waste and not all waste such as plastics, cardboards, bottles, etc. This study only looked at developing a cloud-based technology solution for under-resourced villages on e-waste management.

5.11 Conclusion

The chapter presented the research design and methodology used in the study. The methodology was based on the aim of the study which is to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The chapter was divided into 11 subsections namely: introduction, philosophical assumption of the study (epistemologist), research paradigm (interpretivism), research approach (inductive), research methods (qualitative), a research strategy (case study), data collection (semi-structured interviews, observations and document analysis), data analysis, consideration of ethics, delineation of study and conclusion were discussed.

CHAPTER 6: OVERVIEW OF CASE STUDIES



6.1 Introduction

This chapter presents insight into the two case studies employed for the research. The two cases are two under-resourced villages situated in the Eastern Cape province of South Africa. The two under-resourced village locations were chosen for the study after the researcher observed that e-waste is a huge burden in these under-resourced villages, as there are no mechanisms for managing it. The two case studies were conducted in the same manner but were treated independently from each other, this included data analysis.

The study aimed to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste. The aim applied to both case studies.

The chapter starts by discussing the following subheadings fieldwork carried out, a detailed description of each case and a conclusion of the chapter.

6.2 Fieldwork

Semi-structured interviews were used to collect data from participants from the two case studies and the one municipality employee. This interview technique as explained in Chapters 1 and 4 was chosen as it allowed for more probing by the researcher and the participant. This enabled constant communication and provided a way for any clarifications when needed. Documents from the municipality were also used to close the gap that the municipality employee could have missed.

The two cases from which data was collected for this study are Village A and Village B. Both these locations are based in the Eastern Cape province of South Africa. Each location is controlled by a chief with his/her headman and chosen board. They are responsible for the social well-being of the areas. The local municipality under which the locations are demarcated was also interviewed for the study. Participants interviewed for the two locations were villagers residing in the studied under-resourced villages. To be part of the study, participants' age limit was 18 years upwards, and participants must have owned or owns any of the electronic gadgets. For the municipality, only one representative from the municipality had agreed to be part of the study as others said he is the one dealing with Information and Communication Technology (ICT) policies on e-waste and anything related to electronics in the office.

Data collection guidelines and questions were set up before the interviews took place. This was to ensure a smooth process and that the researcher was ready to engage with participants. During the data collection process, participants' views, perceptions and experiences were captured during semi-structured interviews. For the co-design session, participants were handed out, stickers, pencils, and colouring pencils and a whiteboard was available so they could paste on it what they would like as functionality of the cloud-based solution. Data collection for Village A took place at a community hall arranged by the researcher, for Village B since they did not have a community hall, participants had to go to the 'great place' – the chief's homestead. An interview with the municipality representative was done online via Teams.

An ethical clearance (appendix A) letter had to be obtained from the university before any data collection process could begin. The clearance letter was submitted to both cases and the municipality, this was done to ask for permission letters from both chiefs and the municipality. Before the interviews, the aim and objectives of the study were explained to the participants. Voluntary participation was encouraged, and participants were asked to be open as each participant's views and experiences were of importance. It was explained to participants how the researcher came to study the topic and the research outcomes the study would provide to under-resourced villages. After the co-design phase, the solution developed was reported back to the participants. All those that were involved in the design process were happy with the final product.

6.3 Case study overview

The study aims to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste. The under-resourced villages and the municipality they are demarcated under are outlined in the diagram below. Each case is discussed individually below. The distance between the two locations is approximately 10 kilometres (km). Village A was estimated to have a population of 1558 and covers 1.47 km² (Stats SA, 2011). Village B no information was found on this but the area according to the researcher is bigger than Village A as it has five sub-villages and Village A has four sub-villages. The municipality has a population of approximately 252 390, this is according to Doc004 of the municipality.

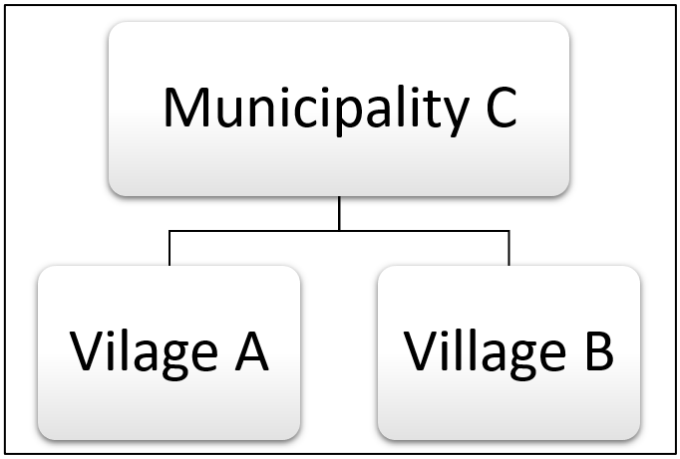


Figure 6.1: Case study overview association

Before visiting the sites for data collection, an ethical clearance letter was obtained from the university. Permission letters were signed by both chiefs and the municipality permitting the researcher to collect data at their respective sites. Participants were assured that their information was kept strictly confidential and that their names would be coded to protect their identity. Data collected from the two cases and the municipality was only used for this study.

The under-resourced villages were chosen because the researcher observed the littering of e-waste in the areas and assumed that there is a lack of mechanisms for managing it.

6.3.1 Village An Overview

Village A is one of the villages located in the Nqamakwe town at the Municipality. This village consists of four sub-villages under one chiefship. The neighbourhood of Village A is another nine villages with a different chiefship. These villages are separated by rivers, grazing fields and forests.

The lifestyle in the villages is slightly different compared to that of people living in the urban areas. The differentiation of the village and urban lifestyle is informed by the scarcity and distribution of resources and services. The scarcity of resources and basic services include and not limited to access to healthcare, clean running water, basic sanitation services and proper infrastructure. The scarcity is not presented by limited resources, but by other attributes such as such limited resources due to distance and poor infrastructure such as roads, shared health resources where access requires financial stability which is a challenge to the village communities. The other limitation the village communities have is the level of the high

unemployment and opportunities for youth. Elderly people rely to the elderly grant support and child grant.

As stated in Chapter 1, there is e-waste littering in the village that the researcher observed. E-waste in the village in dumped in landfills and rivers.

The introduction of the proposed cloud-based solution can present possible small business opportunities for villagers which can be later used beyond e-waste management.

6.3.1.1 Village A Leadership structure

The organogram in the villages vary depending on the lineage structure of the family. This background is important for this study because it presents the format of the administrative responsibilities for each village. Leadership in Village A is presented in Figure 5.2. The chief as a leader of the entire village automatically holds the position of the leader in the organigram. The Chief's role is to oversee all the deliverables in the village and be a contact person with the municipality, local government and political structures. The key role of the chief is to make sure that the community have access to the basic services. For each village the chief has a headman that report directly to him, headmen are voted for by villagers and the chief has no right to choose who is supposed to be a headman. However, the chief is allowed to select his advisers who work with the headmen. The advisers advise the chief on certain community matters. The role of the headman is to lead the local village, oversee the local community needs and other administrative duties. A committee led by the chief work on developing the chieftainship responsibilities such as developing laws, drafting polices and guidelines intended to guide how the area should be governed. The committee is also responsible for land issues. They deliberate on this before it is sent to the chief, the committee does not report to the advisers but the chief after getting submissions from the committee, the chief calls his advisors to update them and map a way forward.

The process of accessing and getting the buy in from the chief went through the entire process hence the participants were already aware of the process before the researcher's interaction with them. The chief's special committee vetted the same process of testing and implementation of the proposed e-waste cloud-based solution to safeguard the communities.

Figure 5.2 illustrates the leadership structure of Village A.

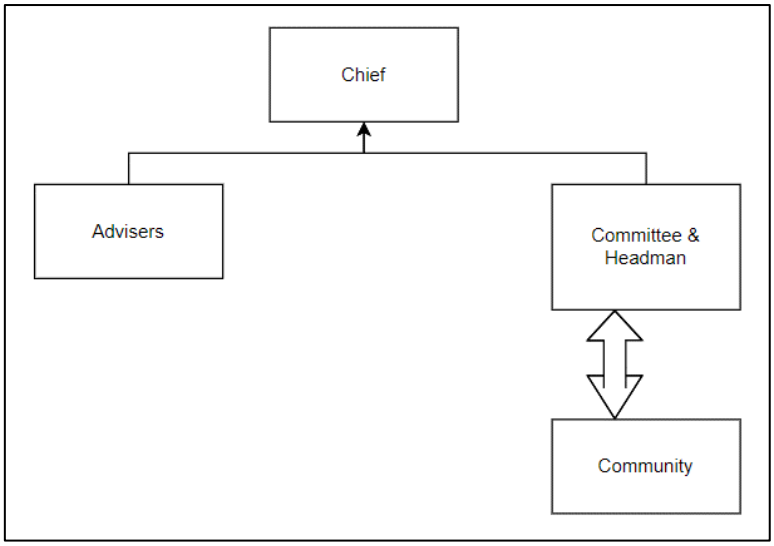


Figure 2: Leadership structure of Village A

The cloud-based solution to be developed is to be used by everyone in the community, however, the traditional rule for the villages is that boys do not talk in the meetings, hence the sample group targeted ages from 18 years and above. The limitation of this rule was addressed by a follow-up study working with the municipality to run a youth awareness campaign whereby the contribution would be captured from different voices.

Figure 6.3 depicts the map of Village A.

Figure 3: Map of Village A

Figure 6.3 depicts the sub-villages found in village A, each of the sub-villages has its own committee and headmen, as for the advisers, each village has representatives to advise the chief. E-waste littering was observed by the researcher in all the displayed sub-villages.

6.3.2 Village B Overview

Village B shares several attributes with Village A in terms of scarcity and access to basic resources. The village is also serviced by the same municipality. It consists of four sub-villages. The special attribute of this village is that this village is considered to have the most academically qualified people than its neighbouring villages. The distance between Village A and Village B is approximately four Kilometres (10km). Despite this village having been regarded as having more people who are academically inclined, the challenges faced by other villages are the same. This observation suggests that services are not informed by villagers but by the municipality that services the communities.

6.3.2.1 Village B Leadership structure

The leadership structure of Village B is different from that of Village A but has common leadership attributes. The difference between the two is that the headmen do not report directly to the chief but to the advisers. The roles of the headmen remained similar for both villages except for the reporting structure. In terms of the rules, the headmen for Village B do not have a committee but govern as sole leaders in their respective extensions They engage with communities once a month to address their business and report to the chief through the advisers. The headmen in Village B, allow the young men to participate in the discussions, which is not the case for Village A. The researcher observed that Village B does not have rigid traditional laws and practices. Village B welcomes input from different people despite their age and gender when drafting laws, policies and guidelines. Input from the youth during data collection at Village B was constructive when it came to co-designing the solution. The youth from this village proposed more of the functionality, this could be attributed to the youth being more advanced in technology awareness than the elders.

Below is the leadership structure of Village B.

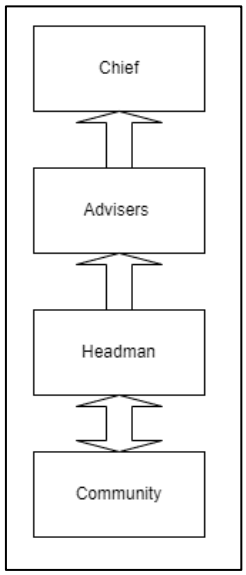


Figure 4: Leadership structure of Village B

Figure 6.5 sets out the map of Village B and its surrounding villages. The location falls under Butterworth town, both Nqamakwe and Butterworth are serviced by one municipality.

Figure 5: Map of Village B and its surrounding villages

As in Village A, each village has a headman, advisers are representative of each village. This is to keep the villages informed of whatever is happening in the community. Like in Village A, E-waste littering was observed by the researcher in all the displayed sub-villages.

6.3.3 Overview of living conditions in the two cases

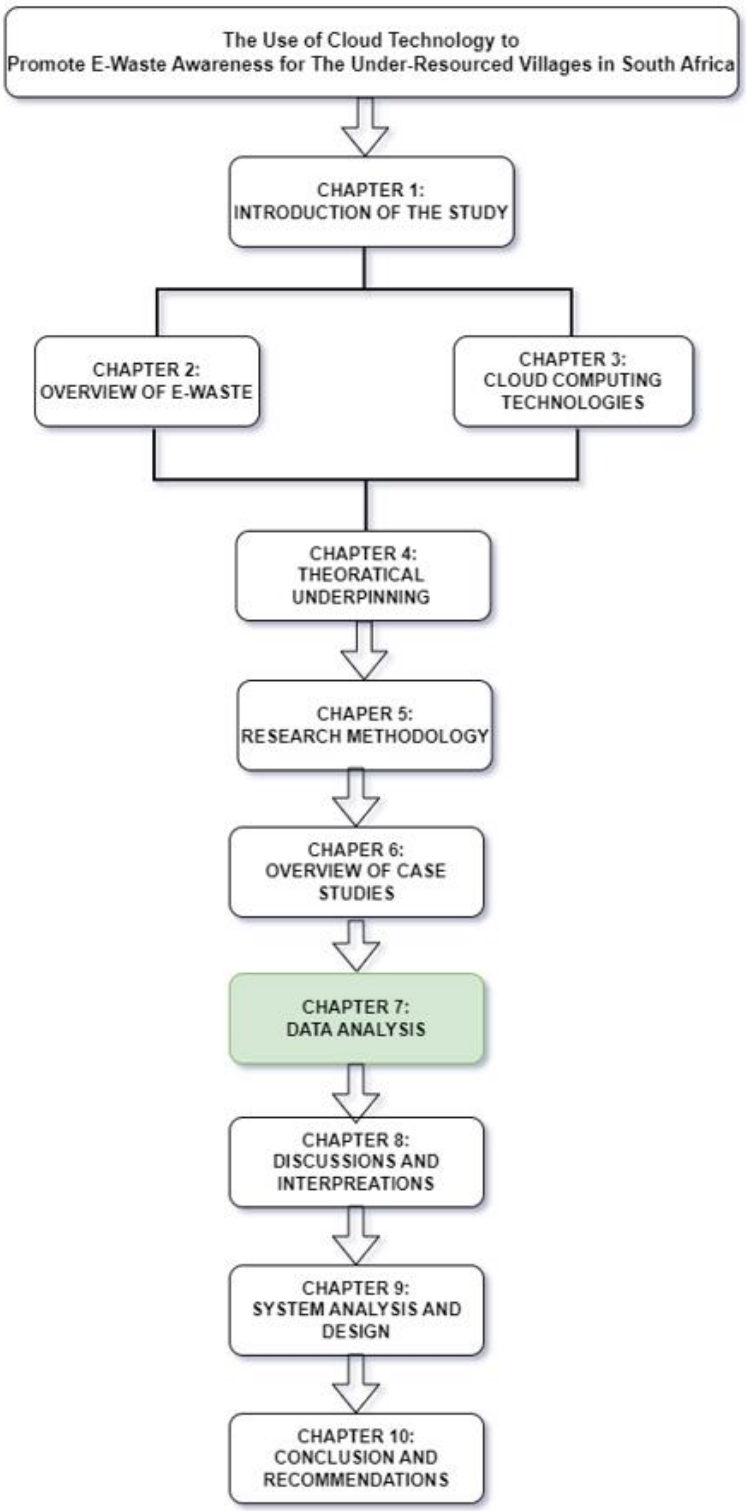
Living conditions and limitations in terms of scarcity and service delivery in the two cases studied, align with the researcher's observation. Access to basic services such as clean water and healthcare services are the testimony of scarcity, hence the villagers showed no knowledge of the e-waste subject. The fact that communities are not aware of the concepts poses an urgent need for the development of a system that mitigates e-waste challenges. Engagement with the communities confirmed the e-waste environmental challenges. Chapters Six and Seven present a detailed report on the findings.

6.3.4 Conclusion

The chapter outlined the two case studies employed in the research paper focusing on how people live, their challenges and representatives from the community. E-waste challenges were outlined so to give a picture of living conditions in the areas. Data collected from the two

cases provided insight into e-waste challenges and how the cloud solution could assist in solving the identified problem.

CHAPTER 7: DATA ANALYSIS



7.1 Introduction

This chapter presents the analysis of data. The analysis of data was guided by thematic analysis (TA) and Activity Theory (AT). Data analysis was guided by how the objectives of the study were defined and discussed. The TA was identified to analyse the first three objectives, namely O1 to O3:

- **O1**: To determine how people living in under-resourced villages manage e-waste currently.
- **O2**: To determine different types of e-waste, challenges, and impacts on the ecosystem in the under-resourced villages.
- **O3**: To identify strategies that could be used to manage e-waste for the under-resourced villages.

The other objective (O4) was analysed through AT. This objective is given as:

- **O4**: To identify strategies to adopt in developing the cloud e-waste awareness solution.

These objectives relate respectively to sub-questions SQ1 to SQ4 as set out in Chapter One Table 1.2

Chapter four justifies how the study applied the theories to achieve outcomes from data analysis. The order of analysis was important. Firstly, the researcher needed to understand the challenges and the current way in which e-waste was being managed, TA addressed these matters. These challenges were then used to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa.

To identify participants pseudocodes were used so to protect their identity. For Village A, pseudocode is MT01 – MT014, Village B pseudocode MP01 – MP12. The municipality representative, pseudocode ML01 was used.

The chapter is divided into four sections, firstly data analysis from case one – Village A embracing TA and AT. Secondly data analysis from case two – Village B also embracing TA and AT and thirdly data from the municipality representative was also analysed as part of the study, this was done to get information on the municipality's stance on e-waste management. Lastly, the chapter's conclusion is made.

7.2 Case 1: Village A: Thematic Highlights

The following are the highlights of the themes (appendix H) captured for this village. Each theme is described with citations from participants' contributions.

7.2.1 Knowledge of e-waste

The findings reported that participants from Village A never heard of e-waste or electronic waste. They revealed that it was their first time hearing of such kind of waste as they thought there was only one type of waste and that is general waste or solid waste.

> *"It is my first time hearing about this kind of waste." (MT04, p1)*

All participants agreed with MT04, that it was their first time hearing of e-waste, and had no idea that there was such a kind of waste.

> *"I think by now whoever knows about it would have said something, so it seems we all have never heard of it." (MT07, p1)*

Since there was a lack of awareness on the subject, for the researcher to move forward, the researcher had to explain and give examples of e-waste. This allowed the interview to proceed to the next questions. According to participants, a lack of awareness of e-waste led them to illegal dumping as they did not know the impact e-waste has on the environment and their lives. Several participants stated that:

> *"I for one just throw them away in the open fields." (MT01, p3)*

> *"I also do the same just throw them away in open fields. Old electronic kettles, refrigerators, electronic stove that no longer serve their purpose I throw them I way." (MT07, p3)*

> *"Well, I throw them in landfills, as I speak now there is a lot of e-waste scattered there that has been thrown, not just by me alone." (MT13, p4)*

Many other participants echoed similar statements as above. Clearly proving that lack of e-waste awareness was general in the location. However, some participants revealed that, old electronic devices used to be collected. Collectors would compensate the villagers with a small

amount of money. Villagers did not know what the collection was for and why some people would come and collect old electronic equipment.

> *"I sometimes hear of people collecting waste, because I do not know what is happening, I just take and give it to them. They pay you whatever amount like 50 cents for example." (MT07, p2)*

> *"I want to mention that at times the women from Durban would come around and ask for these." (MT12, p2)*

Though there would be people to collect e-waste in the location, some never handed in theirs complaining of the small compensation they got. This revelation is further supported by Masoabi (2020), in his research he found that participants refused to give their e-waste to recyclers due to lack of incentives.

Others opted for their e-waste to be fixed by whomever is known to fix electronic equipment. After fixing such items, participants revealed that constant breakdown of the electronic equipment would continue to happen. When the electronic equipment is fixed, it only works for a couple of days sometimes a few months and breaks again and by this time the equipment ends up in open fields.

> *"There are people here in the location who fix these for us when they are broken. But the problem with fixing is that once they fix it, it breaks again and again, or it works for a few months and then it breaks again and again. Whilst fixing you paying, and it only works for few days or months that is how we live here. People say I can fix it, and it works just for now, but all in all it ends up in the open fields." (MT11, p4)*

Participants agreed that if they had knowledge and awareness of e-waste, they could have managed their e-waste better than they are currently doing. This, according to the participants would go as far as paying a licensed repairer. Due to a lack of awareness, one participant revealed that e-waste equipment such as a refrigerator is used for storage of other e-waste items or handy tools. This is done because there is no place to send it for dismantling or handing it in as e-waste and there are no collectors to collect. The storing of these items is prolonged till the owner decides to dispose of them.

> *"Some items we keep, for example, a fridge, once it is no longer working it is no longer a fridge then you can use it to store other e-waste or general waste items. You can also use it to store your tools." (MT02, p2)*

The participant in MT02 understanding is supported by literature, Mouton (2020) states that, in South Africa, a lack of e-waste awareness and lack of proper disposal methods contributes to prolonged e-waste storage.

One participant revealed that there is no dedicated place to dispose of e-waste in the location, anywhere where one sees fit can just throw it. Other participants also agreed and mentioned that dams, rivers and open fields are used to dispose of e-waste. At times, such items are even burnt as a means of disposal method. According to Miner *et al.* (2020), lack of awareness and lack of education on the handling and management of e-waste is a challenge for developing countries due to limited resources and government support.

Participants revealed that as they plough the land for food in their gardens, they would dispose of items such as old and non-working cell phones, batteries and cables in their gardens. They do not know what happens in the food they grow and the danger it poses to them.

7.2.2 Environmental pollution

Participants did not know how e-waste impacts the environment when it is carelessly disposed of. They explained that had they knew of the environmental challenges posed by the inappropriate mismanagement of e-waste they would have done better in terms of e-waste management. Two participants stated that:

> *"Well let us be honest, we do not know the dangers of throwing e-waste into open fields. All I know is that if it no longer services its purpose, I then throw it away that is all." (MT01, p5)*

> *"We just throw away; we do not know how it impacts the environment, and I don't think one cares." (MT07, p5)*

Participants revealed that, in the location, the majority of the people still fetch water from the nearby rivers, fountains and dams. These according to the participants are places where

discarded e-waste equipment could be found. Other places included grazing lands where livestock graze.

Participants also revealed that they had no knowledge of the chemicals contained in the e-waste equipment and how they impact the environment they live in. The researcher explained the environmental challenges posed by e-waste when it comes to carelessly disposing of e-waste using Chapter 2 of the study. Upon hearing of these challenges, the researcher observed participants' facial expressions that displayed some level of discomfort and unhappiness. One participant revealed that he had just dismantled his refrigerator to use the pieces for his chickens to have a place to nest. He further revealed the rest of the pieces left; he intended to take them to the nearby dam to dispose of them. Upon hearing of the dangers and challenges of what he had planned to do, he was uncomfortable to continue.

> *"That is frightening because I have just dismantled my fridge because it was not working, I did this so to put in my chicks so they can nest in those pieces I have dismantled. Now you mention all these dangers I doubt I will go ahead with that." (MT07, p5)*

Upon explaining the dangers of burning e-waste to participants, they were able to state that this was polluting the air they breathed, and this was also endangering their lives. It was also revealed that participants had no knowledge of e-waste toxic emissions released into the land by throwing e-waste into landfills.

The researcher observed that in Village A, discarded e-waste ended up back in households, this was so because children would go play at the landfills and bring this e-waste equipment back home. Participants furthermore revealed that even elders would go to the landfills to find something useful or when they need a part to replace on a particular device that is broken. These items would then be disposed of in households' gardens where participants grow their own food.

Another observation is that e-waste equipment was kept with some other working electronic devices in some households. The kept e-waste equipment was used as grocery cupboards, tool storages and decoration. The kept e-waste equipment was not sorted and was kept with other general waste such as gas cylinders, plastic bags, containers and wooden waste. Participants alluded that they kept e-waste for reuse or refixing not knowing that the air they breathe and food they plough was not conducive due to environmental pollution. Participants

seemed concerned about their environment, especially for the children who play at the landfills. One participant stated the following from what he had learned during the interview:

> *"Through breathing the dirty air and other staff, it also causes asthma, others burn these and as mentioned throw them in the garden and we plough in that affected land." (MT10, p5)*

Participants also revealed they did not know that the burning of e-waste, and landfill disposal affects the underground water which ends up as a drinking water source for them and their livestock.

Upon discussing the dangers and challenges of e-waste participants were eager to get assistance from the municipality. They stated that the process should speed up and they can no longer continue with how they handled e-waste as it was dangerous.

> *"The intervention should be a speedy thing because now we know how dangerous e-waste is and we are now scared of the non-functioning electronic devices." (MT09, p8)*

> *"We were not aware of e-waste dangers, but now we have insight. We are now worried because we have many of these things at home." (MT07, p11)*

7.2.3 Disposal Compensation

The majority of the participants were concerned that they should hand in their e-waste equipment and not get compensated for it. This was confirmed by some participants who stated that even if their staff is no longer working there, there should be some form of payment from the municipality.

> *"What I want to know is by handing in your electronic devices, what are you as the owner getting back?" (MT03, p3)*

The response from the municipality participant captured that handing in of e-waste, would not have any payment attached to it as the people would benefit from free WIFI and have young men and women employed. The lack of compensation for handing in e-waste was met with resistance from the participants.

> *"One of the things I want to be clarified is the issue of handing in my staff but not getting paid. We should get paid for these because we own them, the municipality should at least give us something because we bought these besides the youth employment and WI-FI installation." (MT11, p8)*

Participants revealed that though they need assistance from the municipality, they should get paid for handing in their e-waste. They indicated that compensation would encourage people to have their e-waste collected and would uplift environmental protection. The researcher observed that participants were not happy with the municipality's stance on non-compensation. One participant when giving his response showed emotions as his voice was raised and speaking in anger.

> *"We bought these things and now after their life span, we have to send them for e-waste management when the municipality collects, is there no incentive left to us, it cannot be" (MT12, p9)*

Based on the participants' submissions, getting some form of compensation for handing in their e-waste was important as it would be a source of income. Also, this would be an encouragement to them in terms of complying with e-waste collection by the municipality.

Participants acknowledged that e-waste management creates employment for young people and that there would be free internet access but stated that was not enough. One participant intervened on this by stating that, when it is time to meet with the municipality then they can mention this and discuss it, as the researcher was merely here to assist them.

> *"When the time is right, they are to talk to us if they do, we will raise this point." (MT09, p9)*

The types of e-waste that participants owned and were adamant that they must be compensated for when handing them in, include refrigerators, electronic irons, electronic kettles, televisions, electronic stoves, washing machines and cell phones. Participants mentioned that they are grouping these as they have more than one of these items that no longer operate.

7.2.4 E-waste Awareness

Participants acknowledged that there is a need for e-waste educational sessions to bring awareness to the communities. Participants highlighted that they want to learn more about e-waste and the dangers it poses to their lives and environment. One participant further stated that their participation in this study has given them an insight into e-waste and its dangers, but they want to have more awareness sessions.

> *"We are now aware of the e-waste and the chemicals it contains, its dangers to our health, the environment we live in and our livestock." (MT01, p8)*

Participants suggested that the municipality should do roadshows to educate their communities about e-waste.

> *"I suggest that the municipality should send out its people to spread the word on e-waste awareness and management." (MT01, p8)*

All participants agreed with the above statement, they further added that spreading the word through radios and some other forms of media would be beneficial. It was also suggested that education should entail how e-waste should be dismantled, the importance of recycling, dangers of e-waste in health and the environment.

Participants showed interest in learning about e-waste, they even stated that through this study they have learned a lot but need more education on the subject. It was suggested that the municipality can work with the chiefs to educate people by scheduling monthly meetings to educate people about e-waste and its impact. Participants also encouraged each other to start spreading the word to the rest of the communities.

Few participants had concerns that those not present may have many questions on the topic. After deliberations, it was finalised that the chief should call a meeting and explain what was said during the interview as that would be the first way to spread the word.

One participant urged others to spread the word and not wait for the municipality citing corruption and the infighting in municipalities. The participant mentioned that without proper education on the topic, the villagers' lives are in danger. An example was made of children

who died playing with refrigerators that were not working but kept inside the house, the participant stated:

> *"I remember five years back, with these old fridges that we keep, it happened that children were playing and went inside the fridge, the door closed since they could not get out, they all died inside that fridge, e-waste is dangerous in many ways." (MT09, p7)*

Participants were open to any assistance they could get from the municipality, stating that what they have learned is important for their own benefit and the environment they live in. They all agreed that the e-waste challenges they are experiencing need to be addressed and that would require them and the municipality to work together.

The next phase looks at Active Theory (AT) analysis which assists the study in identifying strategies needed in developing the cloud e-waste awareness solution. Before the development could take place, it was important to first get insight into what challenges needed to be addressed to understand the requirements of the solution.

7.3 Case 1: Village A: Activity Theory

Activity Theory (AT) is derived from Vygotsky and Leont'ev (Hasan & Kazlauskas, 2014), it was developed as a psychological theory. AT encompasses a collection of activities, division of labour, rules and community that indicate the social context in which activities occur Uden (2022). It is used as a guide to gain a deeper understanding of human activity within systems, using its properties namely subject, tool, object, rules, community, and division of labour (Engeström, 2001). AT has been applied in many studies before, Kuutti (1996) applied it to study human-computer interactions, Uden (2022) used it to design a mobile learning application, Simeonova (2018) used AT and explored the role of WEB 2.0 and transactive memory systems.

The theory was discussed in Chapter Four, Section 4.4. The theory is applicable in this study because the study looks at the activities of the people regarding e-waste awareness and its management. Thus, the study aims to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste. Allen *et al.* (2019) state that AT is beneficial for studies that look to develop, implement

and manage systems and technologies. Furthermore, Allen *et al.* (2019) state that developing, implementing and managing systems can be seen as social technical activities.

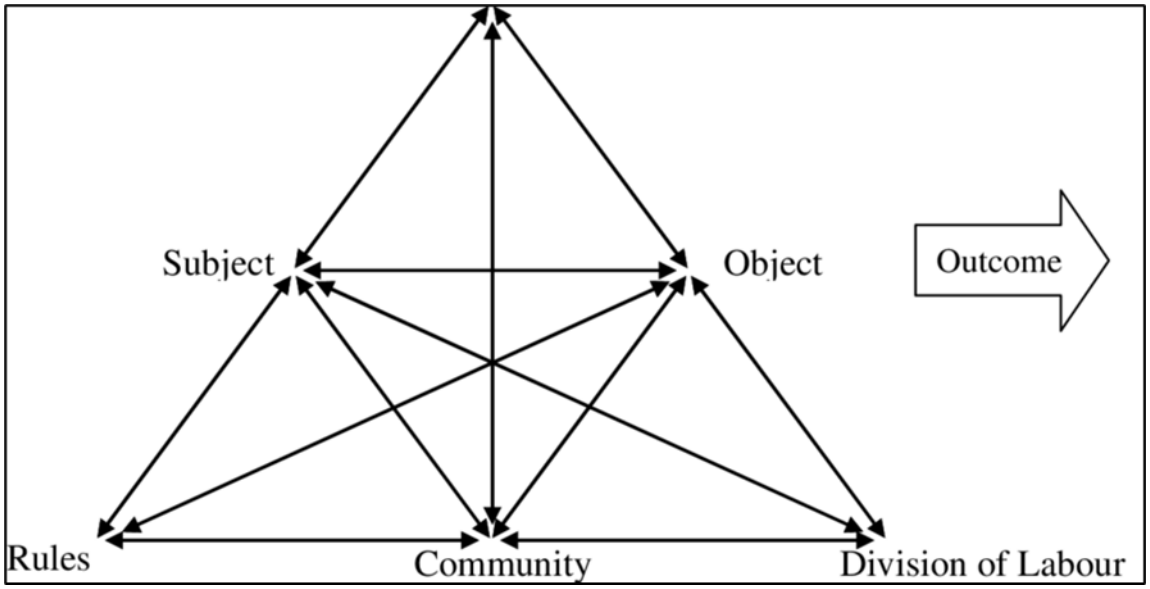


Figure 7.1: Activity Theory Model (Engeström, 2001).

7.3.1 Tools

AT Tools are technical or non-technical elements such as databases, mobile devices, and language used by the subject in executing a particular task (Adamides, 2023). Iyamu and Shaanika (2019) state that these tools consist of non-tangible or tangible things and either physical or psychological tools.

Awareness about these tools is critical as they shape a way forward toward developing the required solutions for problems. Currently, there are no tools for e-waste awareness and its management in Village A. As explained earlier e-waste is disposed of in landfills, kept at home or burnt, this study needed to find tools that would help curb this problem.

Some of the tools identified for the cloud solution included technical tools such as smartphones, internet and databases. Non-technical tools included language and end users. These tools influence how the e-waste solution is to be implemented and supported.

Smartphones are needed as the solution to be developed is a mobile application. The researcher observed during the interviews that participants had smartphones and were willing to have the application developed to help curb the e-waste challenges they faced.

The users would need to register to have access to the app, and register staff for collection from different homes, storage tools (databases) were also seen as vitally important for the solution. It was also noted during the interviews that internet access would be required to

access the application. Of the participants, only two knew what the internet is and helped explain it to others. It was explained to the participants that the government had committed to installing free WIFI for rural people and that their local municipality had also committed to seeing this happening.

The participants had different views of the language proposed for the application, after discussing this item, the participants agreed to have the application using English and not isiXhosa. They said this was part of them learning something new as part of the digital change. They urged that if they allowed the application to be written in isiXhosa, they would have learned nothing as there would never be another application written in isiXhosa. They were willing to use this application to learn. As for the Short Message Service (SMS) that the application would send, it was finalised that this service would be in isiXhosa for easy reading and understanding.

IT specialists such as software developers, IT managers, system analysts and database administrators are also considered as technical personnel in this matter. They are responsible for the development and maintenance of the solution.

Adamides (2023), indicated that transformation of the objective is possible through the identified tools that are used to enable the subject to transform the objectives into a desired outcome.

7.3.2 Subject

In AT, a subject is an individual or a group engaging in an activity. A subject can be human or non-human. The subjects involved in the e-waste activity include villagers from Village A. These subjects came together to provide support and requirements for the development of the e-waste management solution. The subjects needed to be trained on how to use the developed solution. Their views and opinions of what they would like to have in the solution have to be integrated into the solution. The integration and adoption of their input gave them a sense of ownership.

Each subject brings along experience on how the activity system should function. All the views shared must be deliberated and well communicated to all relevant stakeholders, including the municipality.

7.3.3 Rules

In AT, rules are regulations that govern subjects when performing or engaging in an activity. Rules govern subjects when using the tools. Rules also provide boundaries for each subject, to ensure peace and success in executing the activity (Uden, 2022). The rules ensure that no subject uses the solution for his/her personal gain no matter their position in society.

Part of the rules is the drawing of the memorandum of understanding between the villagers to ensure that whoever is found still disposing of e-waste carelessly is punished. These rules should be in line with the country's policies guiding e-waste management. This ensures stability between the location and the municipality's rules.

Another rule that should be in place is the issue of compensation that was suggested earlier by participants. There should be a rule to state the minimum and maximum amount that can be paid to the subject for handing in his/her e-waste. This rule would be informed by the category of e-waste handed in, for example, a refrigerator or washing machine, and the number of years the item has been out of order can get a fixed amount related to that category. This ensures that subjects do not keep these items in their homes for a long time which according to the participants' submissions, leads to the items being dumped illegally.

To avoid theft and break-ins, a rule was suggested such that during collection or handing in of the items, only items registered on the application should be handed in. There should be tracking of who logged the item on the application, who fetched it and when this occurred.

Rules are crucial in maintaining peace and stability. It is recommended that all rules should be implemented the same for all the subjects. The municipality is expected to draw the rules and policies for under-resourced villages on e-waste management. Villagers need to be taught about the rules and taught of the consequences of not implementing them. There should be monitoring to enhance compliance with the rules to ensure that desired outcomes are achieved within the activity. According to Iyamu and Shaanika (2018), the lack of rules in a community would provide difficulties in achieving outlined objectives.

7.3.4 Object

The object is defined as the problem or the reason the activity occurs. According to (Nardi, 1996, cited by to Iyamu and Shaanika (2018), an object motivates an operation. The problem is the e-waste littering by under-resourced villages of Village A. At the time of this study, e-

waste was disposed of illegally in the location of Village A. There was no intervention from the municipality. Thus, the municipality itself had no means of managing the e-waste, none of their documents explicitly made mention of e-waste and how it should be managed.

This illegal dumping leads to people in the location polluting the environment and endangering their lives in the process. To improve the situation in the location, interventions need to be made such as educating people, awareness campaigns and developing a tool that assists with the awareness and collection of e-waste.

An object can be defined as a goal of an activity, the goal is reachable by making use of the tools. The first goal then is to use the tools to make informed decisions about e-waste management for villagers. The second goal would be to have the municipality come to the location to fetch e-waste handed in by villagers. The application to be designed is to send notifications to the municipality once a certain threshold is met so they can dispense trucks for collection. The system to be developed is at the centre of the activity system.

7.3.5 Community

In AT, a community is a group of subjects or people who are involved in the activity being performed within the same social context. The community is the people involved in the littering of the e-waste. The community needs to work together in solving the e-waste challenges, starting with providing requirements for the application to be developed.

The community must collaborate with other stakeholders such as the municipality, to get their desired results. The community must hold each member into account who does not abide by the rules set out when disposing of e-waste. The community should encourage those who do not have smartphones to have one so they can be able to use the application for the community's own good.

For the collection points in the location, it is up to the community to decide which site of land to use, and the size of the land needed. This would mean collaborating with their headmen and the chief, one participant stated that:

> *"I think since this has to do with the land, and the land is managed by the chief, I think what we should do now is to meet with the chief and discuss how we can go about doing all this." (MT11, p8)*

The municipality stated that they would hire local village men and women for collecting and sending to dedicated collection points for each village in the location, it is up to the community to decide the criteria of the hiring process. One participant mentioned that the hiring process for it to be fair, there should be no qualifications used and that for all to get a chance a contract of six months for each employee would be required. This is to stop infighting and quarrels that may happen due to the high number of unemployed in the location.

For the application, the community played a vital role in giving requirements of what they would like to have, such as the security features, what should be accepted during the time of collection and what should not. They stated these to minimise house break-ins and theft of other people's goods.

According to the researcher technical people such as IT specialists should be considered as community members for this activity as they develop, manage and maintain the application to assist with e-waste awareness and management.

7.3.6 Division of Labour

The division of labour entails the different jobs and functions given to each subject of the community. Shaanika and Iyamu (2015) state that the division of labour enables the sharing of power and activities between community members. Subjects are given tasks to perform within the activity system. The villagers, IT specialists and municipality representatives all have dissimilar roles to play in the development and implementation of the application.

The role of the villagers should include that no one disposes of e-waste into landfills or burns it. They should ensure that each subject within the community hands in their e-waste to the dedicated collection centre. That all rules they documented with the municipality are adhered to by each subject. The IT specialists' roles would be to develop, support, maintain and assess the solution. This would include also training end users on how to use the application. The municipality's role is to draft policies and ensure that by the time of e-waste collection, all items handed in are collected. The municipality should build a relationship with the villagers, this includes discussing the issue of compensation.

Tasks for the chief, headmen and committee would be to oversee that everyone in their respective villages adheres to the drafted laws. The chief is responsible for calling meetings to educate people about e-waste and its dangers. It should be compulsory for those employed to have smartphones so they can access the application.

Should these tasks not be allocated to the right people, the danger is that e-waste littering continues to occur. People of Village A continue to stay in an environment where e-waste is illegally disposed of.

7.4 Case 2: Village B: Thematic Highlights

The following are themes that were generated using Thematic Analysis for Village B (appendix H). Each theme is described with citations from participants.

7.4.1 Knowledge of e-waste

Like participants from Village A, participants from Village B do not know about e-waste and have never heard of it before. Participants revealed that they thought there was only one category of waste which is waste in general.

> *"I have never heard of e-waste, what I know is waste in general. This one is new to me." (MP03, p2)*

> *"E-waste, I have no idea what it is, I think it is related to waste in general". (MP05, p2)*

> *"I too have never heard of it". (MP02, p2).*

One participant explained that he knows the term e-waste but cannot define what it is. The researcher had to make an example in defining e-waste, so the interview could proceed. Only after the researcher explained and made examples that participants were aware of what waste is and what is it composed of. Participants stated that they keep their e-waste at home or throw it away in landfills. Several participants stated that:

> *"I throw them away" (MP06, p2)*

> *"They are thrown away there is no other way." (MP08, p2)*

> *"I do not throw mine away, I keep them in my house, so I can refix or take parts, then burn if it does not work." (MP03, p3)*

Participants stated that they did this because they did not know how they could manage it. All other participants made similar statements as they revealed that they had no dedicated place

to dispose of them, one chooses where to throw them away, they either throw them in dams, rivers, gardens or landfills.

> *"We do not have a dedicated place to throw them away, such as a dumping site. Either we throw them away in the garden or outside the yard." (MP01, p3)*

Participants at Village B stated that they knew about recycling but did not know that e-waste could also be recycled. They indicated that they disposed of their e-waste in these places because there was no place to take them for recycling. They also indicated that even if there was a place, there would be transportation issues and cost related. One participant mentioned that there used to be a car that would go around the location collecting all kinds of waste.

> *"At times there used to come a car that will collect all waste in general, and they would take it to wherever they are taking it." (MP10, p3)*

The participant indicated that there are people who have been collecting waste items including e-waste. These people were never asked where they were taking these items and for what cause. According to participants, they stopped giving away their staff due to the lack of compensation for their items by the people who were collecting them. Participants acknowledged that they did not know the categories of e-waste. They further indicated that the e-waste and general waste were never sorted when disposed of but dumped in the same spot. Participants indicated that if they had an awareness of e-waste management, they were going to handle it differently. They suggested that if the villages had a common spot to dispose of e-waste, they were going to use it. Villagers strongly feel that they should be compensated for their e-waste items.

The common e-waste items identified by participants included equipment such as electronic irons, electronic kettles, televisions, car batteries, cell phones, cell phone batteries, refrigerators, electronic hairdressers, radios, electronic cables, globes, electronic stoves and washing machines.

7.4.2 Health hazards

The participants confirmed that they did not know the health complications caused by the disposal of e-waste. They acknowledged that the researcher's explanation of e-waste in the form of examples enabled them to have an awareness of the e-waste dangers in their lives.

They noted that the dangers could present harm in their lives, including the lives of children and livestock. One participant stated that:

> *"Because we throw them away carelessly, an animal like a cow for example might eat that and that would endanger its life. Some of the electronic staff is made of plastic which is dangerous to livestock once eaten." (MP11, p3)*

> *"We grow our own food in the garden, and you will find some items there, that may also cause food poisoning. At the end of the day, we eat that food." (MP12, p3)*

Based on the participants' responses, e-waste is a threat to the villagers in diverse ways, as one of the participants pointed out that the livestock is in danger and villagers eat meat from the same animals.

The food they grow in their gardens, according to one of the participants might be poisonous because of the e-waste items disposed in the gardens. Participants also confirmed that the burning of e-waste pollutes the air they breathe which might cause health problems such as asthma.

> *"It pollutes the air we breathe, meaning if the air is dirty, it may have a negative impact on our health." (MP11, p5)*

Participants further raised their concerns for children's health as they normally play with e-waste items. They indicated that children normally go and play in the dumping fields and at times they bring the e-waste items from the dumping fields back home.

> *"Children take the items thrown away and play with them, which may lead to sicknesses." (MP12, p5)*

The findings presented by participants from Village B presented an open and honest contribution regarding their feeling and understanding of the e-waste after the concept was explained to them Participants further acknowledge that they did not know the concept of e-waste and its dangers. One of the participants, with the rest agreeing with him stated:

> *"We do not know about this topic" (MP03, p5)*

Since the participants from Village B did not know about e-waste, most of their answers were more aligned with the definition and explanation of the concept that was presented to them. Participants confirmed that if they understood the e-waste and its impact on the environment and people's lives, they would have done things differently. They all agreed that something must be done so they could live a healthy life and would welcome any assistance.

7.4.3 Environmental pollution

Participants stated that they did not know how the careless disposal of e-waste impacts the environment. Two participants stated that:

> *"I throw them away unaware that the environment is being negatively affected." (MP01, p5)*

> *"We just throw away; it is a waste to me because it is not working as required." (MP06, p5)*

In support of the participants, communities confirmed that they had a lack of e-waste awareness. Both villages confirmed that some of the people in the location still drink water from fountains, rivers and dams. These are places they identified as dumping places. They indicated that they did not know that throwing e-waste near or in these places would harm water streams. They also had no knowledge that e-waste contains chemical elements that leach into the land to underground water.

The researcher observed that Village B's discarded e-waste ended up back in households, participants stated that children bring it back to play with it.

Upon hearing the dangers, one participant indicated that assistance is needed and should come sooner than later as they cannot continue to dispose of e-waste as they currently do. Participants also indicated that they have never been told about how electrical items should be managed after their lifespan. They also stated that they have never been educated about e-waste and its dangers.

> *"No people are going around teaching people about how to care for the environment, regarding e-waste. The municipality is doing nothing in terms of teaching people how e-waste should be handled." (MP01, p5)*

7.4.4 Education

Regarding awareness and educating communities about e-waste, participants indicated that the municipality should engage in a drive that empowers communities about the e-waste, its impact and recycling They attributed what they have learned during the interview as a starting point of learning. Participants suggested that the municipality should present awareness to all the villages as the problem is common to all rural locations in the Eastern Cape.

Participants suggested different awareness platforms the municipality can use to present the e-waste awareness such as radio adverts because the radio is accessible to almost every household in the village. One participant stated that:

> *"The municipality can make use of radios, and the department should send people to rural areas to teach people about e-waste." (MP01, p6)*

Other participants indicated that television adverts can also be beneficial as many households in the location own a television, this would also make it easier to spread the word.

> *"They can also create advertisements on television, many households have televisions." (MP02, p6)*

Participants showed great enthusiasm in learning about e-waste as they stated that the dangers they have learned in the interview session were concerning as their lives are at risk. They indicated that waiting for the municipality to execute the proposed e-waste awareness may not be achieved urgently since the municipality is generally taking a long time to execute its plans and projects. They proposed that the awareness should start with the piloted group that attended the interviews to reach out to the broader community. The chief stated that a community meeting including those younger than 18 years would be called, so they can teach others what they have learned in the interview.

Some participants suggested that the content that was shared during the interviews should also be shared with the local Junior and Senior Secondary Schools. Sharing with schools serves as a strategic tool that educates youth about e-waste and its challenges and the mechanisms that can be used to mitigate e-waste challenges. Some participants suggested that continuous reminders of e-waste management during traditional ceremonies should be communicated.

Participants agreed that villagers should have guidelines and or laws that stipulate the penalties or charges for the people who would be found guilty of polluting the environment by carelessly disposing of the e-waste. Participants further indicated that the proposed laws should be adopted as a village standard law, and all villagers should be introduced to it to get buy-in.

7.5 Case 2: Village B: Activity Theory

Sections 7.5.1 to 7.5.6 outline perspectives of Case 2 – Village B concerning the concepts built into Activity Theory.

7.5.1 Tools

Literature indicates that AT tools are non-tangible or tangible objects such as procedures, instruments or systems used by subjects to perform an activity (Karanasios, 2018). Subjects use these tools to mediate their actions and activities. This research identified and embraced these tools as technological instruments required for the realisation of the object.

It is noted that the awareness about these tools is critical as they direct progress in developing the required solutions for problems. The two villages' findings suggested that these villages do not have tools for e-waste awareness and its management. Participants have confirmed that e-waste generated by the participants from their respective locations is not effectively managed due to a lack of awareness. Identification of relevant tools to assist in developing the cloud solution to improve the spreading of awareness of e-waste was suggested as one of the critical requirements.

The identified tools for the cloud solution included technical tools such as network connectivity, smart mobile phones and storage capabilities. Non-technical tools identified were the communication language and collection centres for each village in the location. Communication language is suggested as a tool due to the fact the proposed cloud-based solution is to send out notifications. The proposed cloud-based solution is to use a certain language to interact with users.

Despite low resource access by the villages, a need for network connectivity was identified as one of the key features needed for the proposed e-waste solution. Access to network connectivity allows participants to access tools for the proposed e-waste solution anywhere and anytime. The researcher has observed that the villages under study have access to

network connectivity. The researcher further observed that the majority of the participants had smart mobile phones. The researcher advised the municipality to register the details of the users to avoid registering every time one wants to use the systems. A dedicated database whether it is in the cloud was suggested. The tracking of collection centres for each village was also identified as a tool needed for collection. It was suggested that the municipality should identify a piece of land that would be used to build the storage or collection point for e-waste items. To prevent unlawful access and for children and animals to enter the site, a need to fence the collection point was suggested. Communication language was identified as a tool, villagers agreed to use both isiXhosa and English, but language preference is isiXhosa whereas Village B preferred to use English. Both villages agreed that English should be used to interact with the proposed e-waste solution. Participants stated that they want to use this study as a learning phase to learn how to use other applications. The training to familiarise the communities with how they would use the tools would be arranged.

Tools are meant to influence and shape human behaviour so as to transform the environment through their usage (Ditsa, 2011 & Karanasios, 2018).

7.5.2 Subject

A subject is an individual or a group of people taking part in an activity. A subject can be non-technical or technical people. In AT's context, subjects use tools to perform an activity. For the successful development and implementation of the e-waste solution, both non-technical and technical subjects should be involved. These are people who would be taking part in the activity of e-waste awareness and management.

Village B communities are subjects of this study as they are involved in the process of establishing the processes they follow or embrace in terms of the disposal of e-waste. The same subjects play a vital role in the process of developing the proposed e-waste solution and are playing a non-technical role in this study.

IT specialists such as software developers, software testers, IT managers, system analysts and database administrators are considered subjects. They are responsible for the planning, development, and maintenance of the solution and are technical subjects.

Each subject brings along experience on how the activity system should function. All the views shared must be deliberated and well communicated to all relevant stakeholders, including the municipality. Subjects are important in the implementation of the proposed e-waste solution.

The participation of all the relevant subjects is important as they play a vital role in the success of developing the desired outcome, which is a proposed awareness e-waste application for this study.

7.5.3 Object

The object is the problem or the focal point of the activity (Iyamu & Shaanika (2018). An object is acted upon by the subject.

An object is needed to assist villagers with awareness and management of e-waste. To achieve this task, the subject would be required to use some tools, of which for this study the proposed cloud-based solution for e-waste awareness and management is the tool. An object can be referred to as the aim within an activity which justifies why the proposed solution.

The goal of the object for this study is to (i) use the tools to make informed decisions about e-waste management by villagers, (ii) to have the municipality play a role in collecting e-waste from the villages as it is handed in by villagers, iii) educate the villagers about e-waste and e-waste management. The proposed cloud-based solution has a feature of sending notifications to the municipality once a certain threshold is met so they can dispense trucks for collection. Shaanika and Iyamu (2015) state that an object is a tangible or non-tangible entity that provides a direction for the activity to proceed.

The direction for the cloud solution is to assist with e-waste awareness and its management in Village B. This is to assist in curbing the careless disposal of e-waste in landfills, rivers, dams, fountains, households and gardens.

7.5.4 Community

A community is a group of people or subjects within a social environment who partake in activities within systems (Iyamu & Shaanika (2018). The communities for Village B were selected for sampling in the investigation of the study. Community members were also brought in as collaborators in the development of the proposed e-waste solution. In the development of the solution, non-technical and technical subjects would be involved. The role of the subjects is defined in Section 7.5.2 above. Collaboration of non-technical and technical subjects strengthens the solution, there is the likelihood that if these subjects do not collaborate the proposed solution may fail or provide a solution limited to the technical subject's perspective.

7.5.5 Rules

Rules are there to govern and regulate the activity. Rules apply to all subjects when performing activities. Rules can be laws, policies or procedures that guide the direction of activities within the systems. Rules are needed to keep order and maintain cohesion in a community or organisation.

Rules are needed to ensure that no subject illegally disposes of e-waste in unauthorised locations. The rules should be developed and agreed upon by all the villagers. The rules that have been developed and agreed upon can be implemented only when they have been approved by the chief and his headman.

Participants suggested that rules should contain the penalty for villagers who continue with the illegal disposal of e-waste equipment. The method (s) of disposing of e-waste by villagers should be outlined and integrated as part of the rules. These rules would be applied the same to all subjects in the location.

The approved rules should also be presented and kept in the municipality achieves. The municipality must participate in the development of the drafting of the rules as they are also seen as a stakeholder.

7.5.6 Distribution of Tasks

Section 7.5.6 lists the distribution of tasks undertaken during e-waste management, namely:

- This refers to the allocation of different tasks to the community members and municipality. The distribution of tasks would be allocated based on the specialties of subjects for communities and the municipality. The distribution of tasks includes the following.
- Team that would be monitoring the implementation of the guidelines and regulations.
- People who would be responsible for collecting the e-waste equipment from households.
- The Chief and headmen regulate the implementation of the e-waste management guidelines and regulations,
- The municipality to provide relevant resources such as training, and a collection truck.

The allocation of responsibilities enables the efficiencies of achieving the outcome of the activity, it also streamlines the reporting of the deliverables. The proposed process assists the villagers and municipalities to manage and handle e-waste. This assists because, according to the researcher's document analysis, there are no policies and guidelines that direct the management of e-waste.

7.6 Municipality Findings

The municipality which is the custodian of providing services to the communities was found to be one of the important stakeholders for this study. The following areas were investigated during the interview session with the municipality which presented the current state of e-waste understanding and diverse knowledge by the candidates that were interviewed.

7.6.1 Knowledge of e-waste

Findings presented that people working at the municipality lack the understanding of the e-waste but are well vest in waste in general. They therefore do not have a structure that categorises e-waste from general waste. According to EMP01, there is a separate department that is dealing with waste management, strategies and waste budget at the municipality, but access to e-waste information is extremely limited. Limited information at the department responsible for e-waste prohibits the employees from developing a plan for e-waste management.

> *"We have little knowledge about the e-waste as employees of the municipality. We know about e-waste by reading about it. Our department has access to certain information, regarding waste in general but does not have access to how we manage e-waste. Waste management or solid waste in ML01 has its own department that has its own strategies and budget on waste management." (EMP01, p2).*

It is noted that e-waste is collected with general waste as it is confirmed by the participants, hence this study is critical in terms of addressing such gaps. The pilot also presented positive feedback in terms of the villager's uptake which shortens the implementation timeline.

> *"In my opinion only in the next 10 to 20 years you will hear about e-waste awareness in this municipality. E-waste is currently not*

separated from general waste, for now, I can say we know it as general waste, it is not treated separately." (EMP01, p2).

The waste categorisation states the process of arranging different waste is a critical item due to different waste challenges in the environment and human health hazards if not categorised (Lenkiewicz, 2021). The lack of e-waste awareness in general is a concern for the municipality. This is so because, in terms of waste categorisation, electronic staff must be collected separately from general waste to prevent polluting the environment and endangering human health. The participant confirmed that:

"One will see network cables, old electronic equipment that has gone obsolete taken as general waste because they do not have value anymore So, in terms of knowledge and awareness on e-waste, we do not have or know about it." (EMP01, p2 - 3).

It is assumed that a lack of awareness of e-waste management may have resulted in the illegal dumping of e-waste equipment by the communities and municipality personnel. The municipality dumping site is close to the residential site. Participants described the dumping site as follows:

"It is a solid waste site where the municipality throws waste. So primarily we use it while it is not full. The site is packed with different types of waste including e-waste" (EMP01, p3).

Based on the above analysis, it is evident that there is a lack of awareness of e-waste and its complications in the municipality. The non-categorisation of waste during collection and transport has led to poor management of e-waste. According to the participant's feedback, it is assumed that the municipality uses illegal systems of managing e-waste. It was also observed that from the four municipality documents that were analysed, there is nowhere the e-waste concept is mentioned.

7.6.2 Recycling infrastructure

The municipality is a custodian for recycling waste to protect human health and the environment (Department of Environmental Affairs Report, 2018). Despite the effort of the municipality trying its best to recycle the general waste, it was however recorded that the municipality lacks the recycling infrastructure for e-waste equipment. It is assumed that the

lack of recycling infrastructure for e-waste has led to the illegal dumping of e-waste. According to the participant's responses, e-waste is generally not managed well:

> *"You will find that there is illegal dumping, and it is not just general waste that is dumped but the e-waste too. The challenge of not knowing where to recycle the old gadgets like computers you end up dumping them." (EMP01, p6).*

The lack of a dedicated recycling site hinders progress in terms of the required cleanliness standards, and environmental and human health hazards. The participant suggested that an urgent identification of dedicated recycling sites within a reasonable radius for e-waste is vital.

The participant's responses to support the proposal of the dedicated recycling site are captured below:

> *"There should be dedicated places that generate funds through recycling of the e-waste. But it is not the case since there is no reference point where one can direct you to e-waste recycling sites." (EMP01, p6).*

The participant strongly believed that the provision of dedicated e-waste recycling sites does not address health hazards only but also provides some sort of income and job opportunities. The participant confirmed that the limited access to the e-waste dedicated recycling sites is a challenge for other neighbouring municipalities presents further challenges.

7.6.3 Environmental pollution

The environmental pollution theme came across as one of the important themes since the dumping of e-waste harms the environment. Environmental pollution is identified as a source that endangers human lives, and livestock and compromises the national laws when it comes to rights to clean water, environment and provision for presenting efficiencies in the municipalities.

> *"It is not safe, people plough, livestock grazes and drinks water from the areas close to the dumping places. The land and the environment need to be safely guided." (EMP01, p6).*

The environmental pollution points back to theme one which suggests the lack of awareness, the participants suggested that if there had been awareness and proper e-waste management strategies, the illegal dumping could have been minimal.

In the process of the municipality documents analyses, it was observed that documents did not mention how the municipality manages e-waste in an environmentally friendly manner. It was further noticed that the documents do not cover laws, policies, and regulations on the handling of e-waste by the municipality.

7.6.4 Education

The participant highlighted that to manage e-waste and its challenges, awareness educational drives would play a role. This would drive awareness around the municipality and its residents. Thus, leading to the municipality and residents gaining knowledge on how to manage e-waste.

> *"As indicated before, the e-waste knowledge is limited, we do not know about it. To improve e-waste management the starting point would be to bring awareness to the people, by using events such as road shows for the under-resourced villages." (EMP01, p4).*

The e-waste awareness days suggested by the participant can be used to educate communities and municipality employees. The awareness drive can cover different topics such as e-waste challenges and risks posed by illegal dumping. Educating communities in the under-resourced villages should take priority as they are the most disadvantaged in terms of not having even solid waste collection.

> *"As a municipality, we have limited options because we are rural and very far from places that we can use to sell these online devices or recycle them." (EMP01, p4).*

One respondent indicated that a strategy of having an automated system can assist with notifications. The automated system can enable the communities and municipalities to communicate in terms of e-waste collection. The notification would be sent when enough e-waste is collected, the municipality can send the trucks for collection.

> *“An automated system that will notify the municipality of certain under-resourced villages having reached the threshold of e-waste collected staff, then they can dispense trucks.” (EMP01, p5).*

It is noted that other than awareness and roadshows, the participant believed that digitisation of the solution improves the e-waste illegal dumping, which may lead to the protection of the environment and health hazards.

Table 5: Summary of Thematic Highlights from Villages A and B

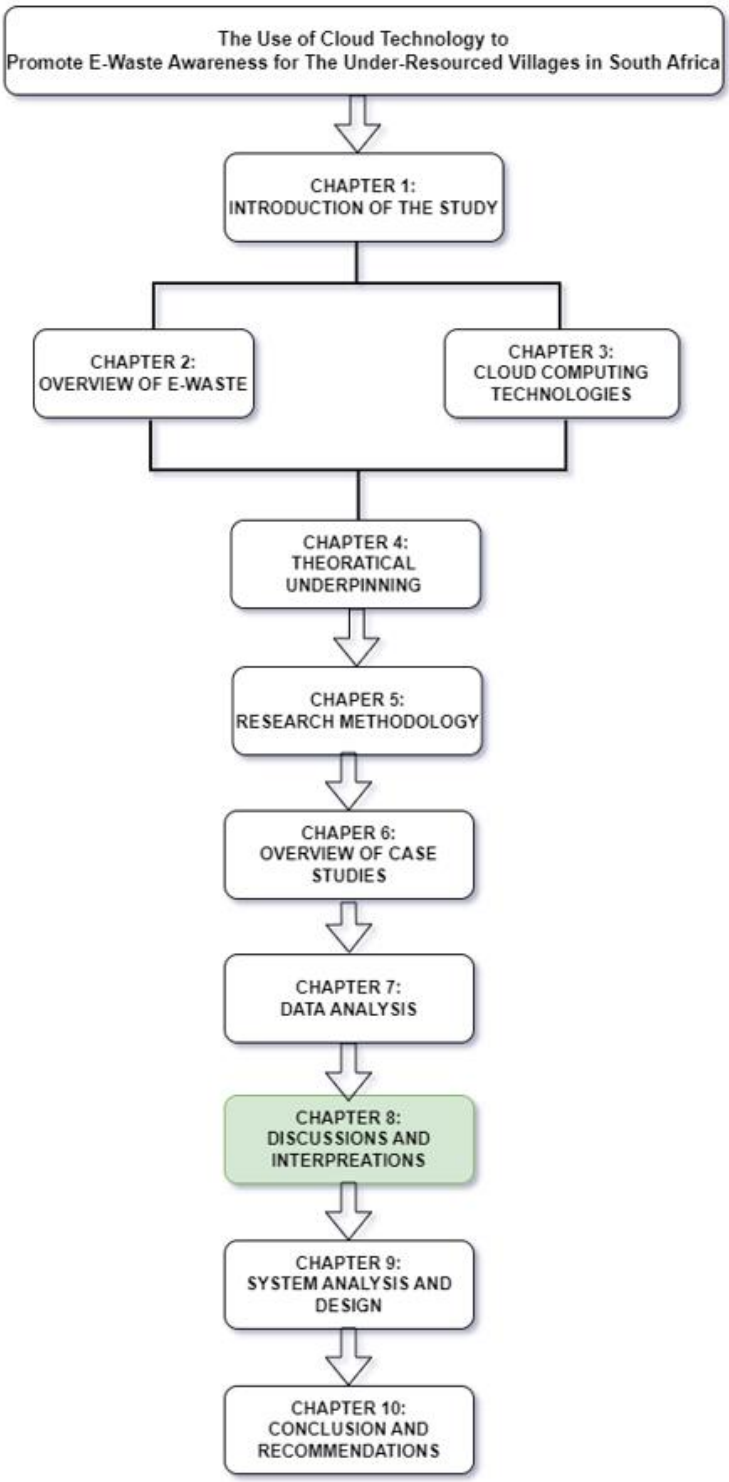
Village A	Village B	Summary
Knowledge of e-waste	Knowledge of e-waste	Participants from both villages stated that they had never heard of the term e-waste. They further stated that they had no idea there was such a thing as e-waste as all they knew was waste in general.
Environmental pollution	Environmental pollution	Participants relied on the examples made by the researcher to state that e-waste endangers the environment they live in. They also stated that this was impacting their livestock and land which they use to plough.
Disposal compensation		For handing in their e-waste items, participants from Village A stated that they would like to be compensated to encourage them to do the right thing by not packing their e-waste indoors or illegally disposing of it.
E-waste awareness	Education	Participants acknowledged a need for e-waste educational sessions to bring awareness to the communities. The participants highlighted that they want to learn more about e-waste and the dangers it poses to their lives and environment.
	Health hazards	Participants from Village B stated that they did not know about e-waste's impact on their lives. They acknowledged that the researcher's explanation of e-waste in the form of examples enabled them to have an awareness of the e-waste dangers in their lives.

7.7 Conclusion

The chapter presented findings of the analysed data from Village A and Village B and the municipality. The SCT was embraced to guide the data collection process for the first three study objectives. The thematic approach was used to analyse data. The Activity Theory tools were used to analyse data for the last objective of the study. The findings presented common trends for the two cases and the municipality in terms of lack of awareness of e-waste and its dangers, a need for educational awareness and a better solution to address the e-waste

challenges. It became evident that the under-resourced villages are willing to participate in the process of improving their community's environment and curving health hazards.

CHAPTER 8: DISCUSSIONS AND INTERPRETATIONS OF FINDINGS



8.1 Introduction

This chapter presents the findings of the study based on the investigation of the two case studies and data analysis from the municipality representative. Data analysis is presented in Chapter 6. The two cases are the representatives of Village A situated in Nqamakwe town and Village B situated in Butterworth town. Analysis of data was guided by thematic analysis for the first three objectives (O1 to O3) of the study. The last objective (O4) was guided by the Activity Theory.

The chapter consists of five sections. The first section provides an introduction (Section 8.1), the second, third and fourth sections discuss findings from the two cases (Sections 8.2 to 8.3), Section 8.4 discusses the findings concerning the municipality, and the last section (Section 8.5) concludes the chapter.

8.2 Village A and B: Findings

Based on data analysed for Village A and Village B, the following four common themes were found to have a significant impact on e-waste awareness and management:

- Knowledge of e-waste.
- Environmental pollution.
- Disposal Compensation.
- Education.

In the analysis of Activity Theory (AT), three themes emerged:

- Requirements (technical and non-technical).
- Governance.
- Stakeholder collaboration.

Below is the discussion of what was found for each theme/factor listed above.

8.2.1 Knowledge of e-waste

The findings of the analysis suggest that Village A and B, lack e-waste awareness and how it should be managed. It was discovered that the term e-waste was a new terminology to most of the participants such that they could not define it. It was further deduced that due to a lack

of awareness, e-waste was disposed of in landfills, burnt or kept in households. Some e-waste devices were kept and used as storage for groceries, and tools and some for decorations.

The volume of e-waste generated by each household was unknown. As part of the investigation, the researcher presented a few examples of e-waste devices to enable effective participation through the interview process. The participants indicated that they did not know the dangers posed by the illegal dumping of the e-waste, hence they did not take adequate measures in managing the disposal of the e-waste. The lack of resources for e-waste recycling and qualified people to fix the electronic devices came as another challenge leading to illegal dumping.

The participants listed different dumping sites such as backyards, gardens, rivers and dams, land pits, open fields and home storage. The disposal of e-waste was mainly disposed of together with the generic waste.

Participants highlighted that most of the community households have different e-waste types including but not limited to refrigerators, electronic irons, electronic kettles, televisions, electronic stoves, washing machines and cell phones.

8.2.2 Environmental pollution

E-waste is composed of chemical elements, that when it is not safely disposed of can contaminate underground water and the soil (Gupta & Nath, 2020). The leaching of these chemicals affects underground water which ends up in river flows. Ilankoon *et al.* (2018) stated that electronic equipment is made up of 60% metals, 11% of Liquid crystal displays (CD's) and Cathode-ray tubes (CTR), 15% is made of plastic and the other 14% is metal plastic, mixed pollutants, and metal-plastic cabling.

Participants from the two villages, Village A and B confirmed that they did not know the chemicals that are released by the e-waste devices and the impact they have on the environment. It raised concerns among the villagers when they learned that these chemicals could leach into the ground, causing more harm to the environment and thus endangering human life. The participants demonstrated a positive response in terms of participating in improving e-waste management awareness as they wanted to protect their environment because i) they drink from the dams and rivers that stand a risk of being contaminated by the e-waste chemicals, ii) they grow their plants and vegetation in the gardens and fields where the e-waste is mainly disposed, iii) their animals graze in the open fields where the e-waste is

dumped, and iv) the danger the disposed e-waste may have in their lives and lives of their children that plays with some of the e-waste remains.

8.2.3 Disposal Compensation

Many participants flagged the disposal compensation. The participants believed that their e-waste equipment handling should be compensated because their handling role contributes to assisting the municipality in preventing pollution and clean environment. They also believe that the recycled items generate revenue for the municipality.

The request for compensation has been identified by researchers such as Masoabi (2020), and Mouton (2020), who indicated that whereby communities are not keen to give away their e-waste for recycling without compensation. These authors further anticipate that the lack of incentives may contribute to the increase of illegal dumping of e-waste equipment.

Despite the determination of villagers for compensation, the municipality representative asserted that there would be no compensation as people get access to the free internet and a possible employment of the villagers would be collecting e-waste for proper recycling.

8.2.4 Education

The findings of the study established that communities living in the villages do not have an awareness of the e-waste, its definition, impact and how it can be controlled in their environment. The participants suggested that education in the form of awareness should be prioritised by the municipality regarding e-waste management in their respective villages.

The participants further suggested different awareness programs for the municipality such as roadshows, radio and television advertising, and word of mouth. They further suggested that the education forums that bring together the government entities, municipalities and communities with the chiefs hosting the sessions for the educational forum should be established. The proposed subjects for these awareness programs included but were not limited to e-waste description and its impact on human health and the environment, e-waste management, and e-waste recycling.

8.2.5 Health hazards

It was found that there was a lack of knowledge on health complications caused by e-waste. The researcher made examples of how e-waste impacts human health. Participants stated that through the examples made, e-waste was dangerous to human health, and livestock. It was further found that children's lives were more at risk as they played in the dumping fields or landfills where e-waste is thrown.

The burning of e-waste was found to be another concern, relying on the examples made, participants said this can be caused by respiratory problems for the young and old in the location. It was found through the interviews that participants had used this study as a learning curve on e-waste awareness and management. Diseases that could emanate from food poisoning caused by e-waste littering in the gardens were not known to participants.

8.3 Village A and B: Activity Theory Findings

Three factors emerged from Activity Theory analysis when engaging with the villages. The identified factors contributed to the strategies for the development of the e-waste awareness cloud-based solution. These factors are discussed below:

8.3.1 Requirements

The requirements that defined what is needed to achieve the objectives were identified as technical and non-technical requirements. The identified strategies were adopted in the process of developing the cloud-based e-waste awareness solution. The technical and non-technical requirement was viewed from a software development perspective.

8.3.1.1 Technical requirements

In the software development context, technical requirements refer to factors needed in building and delivering the desired system. Identified technical requirements for the villages included access to internet connectivity, smartphones for the use of the cloud solution, and training for users on how to use the cloud solution.

Access to the internet was confirmed as already available as this requirement was addressed through a government priority plan for the villages as confirmed by the municipality representative.

Regarding the availability of smartphones for villagers, the researcher observed that the majority of participants were in a position and owned smartphones. The participants who did not have devices such as smartphones supported the proposed solution since they believe in the shared values.

Training the users on how to use the application was identified as a technical requirement. People who are involved in developing, maintaining and supporting the application are considered as technical requirements. These people include IT specialists such as software developers, database administrators, system analysts and software.

8.3.1.2 Non-technical requirements

Non-technical requirements include the end users of the system and policy drafters (municipality), herein referred to as non-technical personnel. These are the people who would be using the application and have provided non-technical specifications or functional requirements of the system. The contribution of the non-technical people was facilitated through the co-design sessions by involving end users before the start of the design process. This was done to learn about their challenges and requirements before the development of the application.

For example, during co-design sessions, participants stated that they would like the application to send SMS reminders to the people. The SMS should remind participants of e-waste collection, and why it is important to manage e-waste in a user-friendly environment.

8.3.2 Governance

Governance is about resource management in an organisation. It is important to promote the operations of the organisation. For governance to be effective, policies and regulations are needed (Bandler, 2024). These policies and regulations guide end users or employees of the organisation.

Policies, regulations and standards are needed to ensure that e-waste littering is managed in the villages. Guidelines can be drafted by the municipality in collaboration with villagers, to ensure that there is mutual understanding from both parties.

The villagers agreed that policies and guidelines are important and can be enforced.

8.3.3 Stakeholder collaboration

The findings present that different stakeholders are key to the success and efficiencies of e-waste management and recycling. The important stakeholders include the municipality's relevant representative, communities from the villages, presiding chiefs and retailers, recyclers and environmentalists. Having these stakeholders collaborate would be beneficial for the environment and improve human health in the location and other parts where e-waste is carelessly disposed of. It is anticipated that the stakeholder collaboration will improve and relieve a burden for the municipality and villages in terms of e-waste management.

8.4 Municipality: Findings

The municipality was part of the participation group in the investigation of the level of e-waste awareness. Municipality representatives were interviewed, and the findings from the municipality were scoped from the following themes:

- Knowledge of e-waste.
- Recycling infrastructure.
- Environmental pollution.
- Education.

8.4.1 Knowledge of e-waste

The theme intended to gather the level of understanding of the e-waste at the level of the municipality, and it was established that municipality lacks the awareness of the e-waste. According to the findings, municipalities do not define e-waste differently from solid waste. This has resulted in disposing of the e-waste with the solid waste without separating the e-waste from the solid waste. The findings also confirmed that the municipality is currently functioning without strategies that address e-waste disposal and recycling.

Like the villagers, the municipality disposes of their e-waste in the landfills. The landfills used by the municipality are situated close to the informal settlements. By law, the municipality is supposed to be the custodian of the e-waste regulations, however, the findings, presented a different scenario because it is recorded that the representatives of the municipality did not demonstrate an understanding of the e-waste and the documents that were analysed did not cover e-waste and e-waste management.

The findings further noted that the municipality has a dedicated department that deals with solid waste management. However, this department has limited resources to draft strategies regarding e-waste awareness and management.

8.4.2 Recycling infrastructure

The findings noted that the municipality does not have a recycling infrastructure for e-waste. The lack of recycling infrastructure has driven the municipality to dispose of e-waste in landfills. The lack of e-waste recycling infrastructure compromises the requirements of providing a clean environment and reduction of pollution.

8.4.3 Environmental pollution

The findings highlighted that the municipality is aware that its dumping of e-waste in landfills is polluting the environment. Furthermore, it was confirmed that dumped e-waste was endangering human health as chemical elements are leaching into the soil and the air is polluted. The environmental pollution links back to a lack of e-waste management, recycling infrastructure, and awareness by the investigated municipalities. The documents that were analysed did not capture the policies, procedures and regulations of e-waste management.

It is assumed that a lack of regulations, policies and procedures for e-waste management can directly contribute to elevated levels of illegal disposal of waste and e-waste.

8.4.4 Education

The findings around education in terms of awareness came up high across all the interviews. The municipality participants that were interviewed strongly believed that an awareness program on e-waste management, disposal, recycling and training of municipality employees is needed. It was assumed that if the municipality employees understood e-waste management, they would be the right people who do e-waste roadshows for different communities.

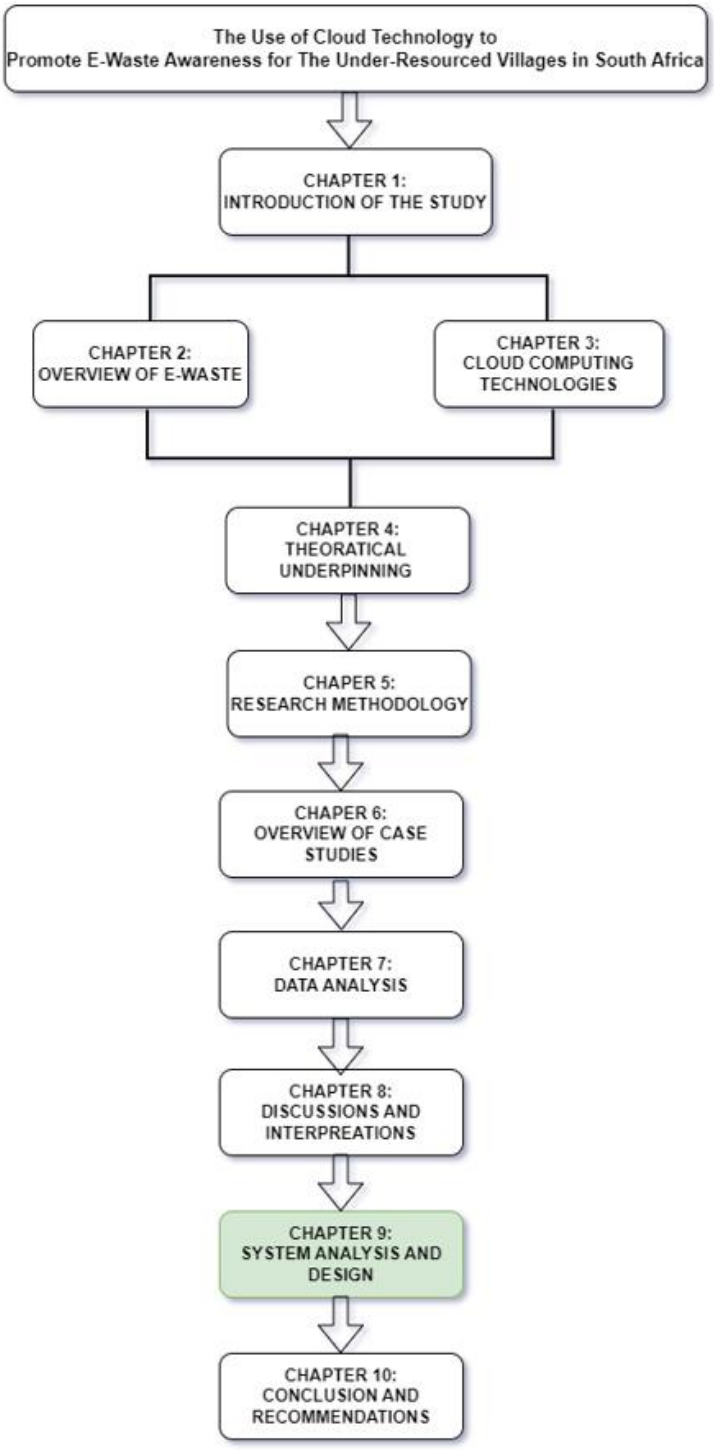
The importance of integrating technology as a vehicle to drive awareness was noted.

8.5 Conclusion

The chapter presented findings of the cases of two villages and the municipality presentative as participants. Findings on different themes of the study were presented whereby the lack of

e-waste awareness by the villagers and municipality is captured, SCT was used to gather data which produced the theme identified by the study. The adoption of AT to identify strategies leading to the development of the cloud e-waste awareness solution is defined in this chapter. The next chapter discusses the system analysis and design of the proposed solution.

CHAPTER 9: SYSTEM ANALYSIS AND DESIGN



9.1 Introduction

This chapter presents the process embraced for the proposed solution development. The development of the solution is developed based on the primary and secondary data presented in different chapters of the study. The proposed solution is developed based on what is known. The study embraced Activity Theory (AT) to understand what is needed by the communities for which the solution is developed. The co-design approach was embraced to design with the users.

The study aims to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste.

The chapter is divided into nine sections, as follows, introduction (9.1), the requirements based on AT findings (9.2), system design (9.3), database design (9.4), design model (9.5), use case diagram (9.6), system functionality (9.7) and test cases (9.8). Section 9.9 concludes the chapter.

9.2 System requirements based on AT findings

The AT identified technical and non-technical equipment and personnel, rules, goals, communities impacted by the careless disposal of e-waste and task allocation as strategies required to be adopted in developing the cloud e-waste awareness solution.

Technical - software developers and system analysts are needed in developing cloud solutions for e-waste, of which the researcher fulfilled these roles. The solution was tested by the researcher's colleagues who are software testers. Non-technical end-users who provided specifications on how they would like the system to function were identified as subjects. The researcher with his experience guided the specification from end users. Rules included system validation to ensure that the required functionality satisfied end users. These included requirements that end-users should meet to use the solution. The object (adopted from AT) is the solution developed to promote e-waste awareness in the under-resourced villages. Both communities of Village A and B were identified as the recipients of the solution who are impacted by e-waste littering. Distribution of tasks including solution administrators and employees was identified as a strategy to adopt in developing the cloud e-waste awareness solution.

9.3 System design

System design is a process of outlining the system architecture, data format, interfaces and the flow of data in a system. This process assists technical personnel in understanding the flow of data and system requirements. System design presents key components of a system and its interconnections (Martin , 2018). The following diagrams depict the architecture of the e-waste awareness solution for the under-resourced villages. Technologies utilised in developing the system architecture are also explained in this section.

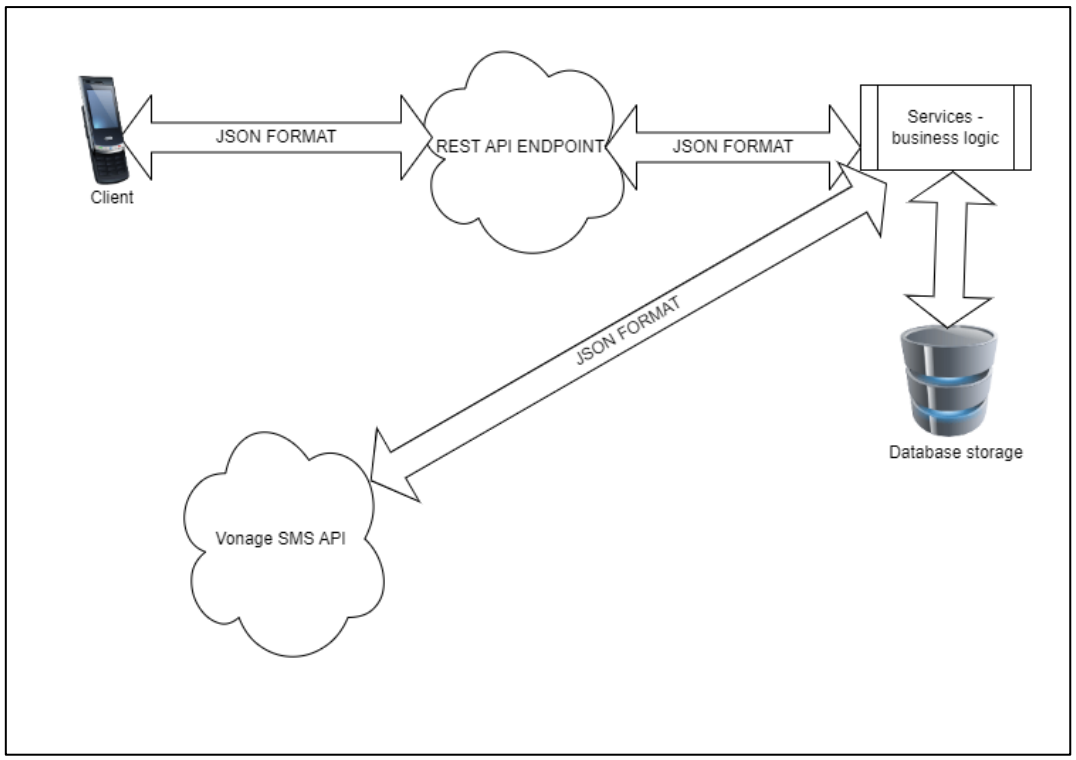


Figure 9.31: Cloud system architecture of the proposed e-waste solution

Figure 8.1 depicts the technical components and flow of data that the proposed solution is to use, namely:

- The user interface was developed using Reactive Node/React and the backend was developed with NodeJS, Node JS web application framework was used as a framework for the development of the backend. Reactive Node/React is a JavaScript library used to build web applications (Sumangla, 2022).

- Data format is JSON (JavaScript Object Notation), The advantages of using JSON include fast data execution and allows the sharing of different data sizes like video, text and audio.
- Rest API (Application Programming Interface) endpoint is the entry point into the application, calls from the user interface enter the system via the rest controller, which then calls the underlying services.
- The proposed solution adopts the microservice architecture which allows a collection of independent components to communicate over HTTPS/HTTP (Hypertext Transfer Protocol Secure / Hypertext Transfer Protocol) protocols. The architecture permits that code is loosely coupled. Each service performs a single function.
- Vonage SMS (Short Message Service) allows client applications to transmit SMSs to end users, this is done by the client application consuming Vonage REST (Representational State Transfer) APIs.
- Data storage, Mongo DB (Data Base) was used to store data. Mongo DB is a non-SQL database that stores data in JSON-like format. Mongo DB is an open-source software.

The proposed e-waste solution is to be hosted in the cloud for easy access. Cloud computing (CC) provides the ability to provide security of data as a service (SaaS). The cloud service provider ensures data is secured in the cloud. On the client side security is provided using a username and password to login into the system, user roles ensure that no user has access to data or screens he/she is not supposed to. The password and data flow in the system are encrypted using JWT (*JSON Web Token*). JWT is a security open-source standard for transmitting JSON data between applications, the data transmitted is digitally signed. JWT is used for authentication to the system and information exchange.

9.4 Database design

Data storage is a vital component of any system because it allows the system to reuse the stored data (Mazumdar *et al.*, 2019). Database design organises how data is to be stored and how it is related to each other. Figure 9.2 illustrates the database architecture of the proposed system.

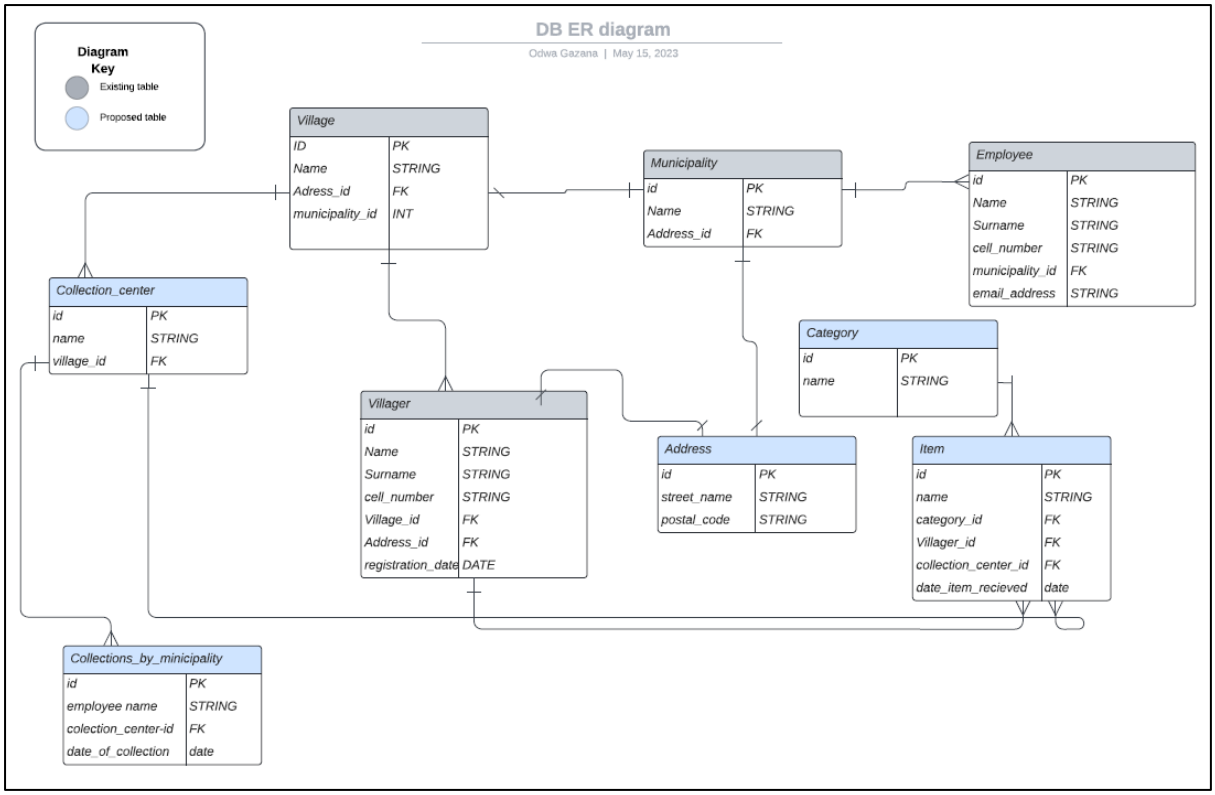


Figure 9.42: Database design of the proposed e-waste solution

Figure 9.2 depicts how the data for the proposed e-waste solution is to be saved and organised. Nine tables were identified for the system and the interconnection demonstrates the relationships between the tables. The first table is the Villager table with an ID as its primary key. The tables store village information such as name of the village, its address and the municipality under which it is demarcated. Address and municipality are foreign keys to this table as they have their own tables. The relationship between the village table and the municipality is one-to-one. This means a village can only belong to one municipality. The same relationship exists between the village and the address.

The Villager table stores information about the person/subject from the village. Information such as the name, surname, and cell phone number are stored. The table is linked with the Village table. This is because the Villager belongs to a village. A villager is also linked to an address table. Each village has one or more collection centres. This is defined as the collection centre table. The Collection centre table is linked to the Village table by a one-to-many relationship. This means that a Village can have one or more collection centres. The collection--by-municipality table stores information about collections done by the municipality per collection centre.

The municipality table stores information about the municipality such as the name of the municipality. It is linked with an address table via a one-to-one relationship. The table also links to the employee which is the employee of the municipality. Employee stores information about the employee such as name, surname, cell number, and municipality id (foreign key). The relationship between the Employee table and the municipality is a one-to-many as one municipality can have one or many employees. The Item table stores information about collected items, item names, the date it was collected, the village it was collected from, and the collection centre are stored here. This is done so it is documented as to how many items were collected from which village and from which collection centre of the village.

9.5 Design model

The Unified Modelling Language (UML) is a map that illustrates how a proposed system is to function (Anjani *et al.*, 2020). UML's importance is that it is a diagrammatical representation of a system. Figure 9.3 below is a UML of the proposed e-waste solution.

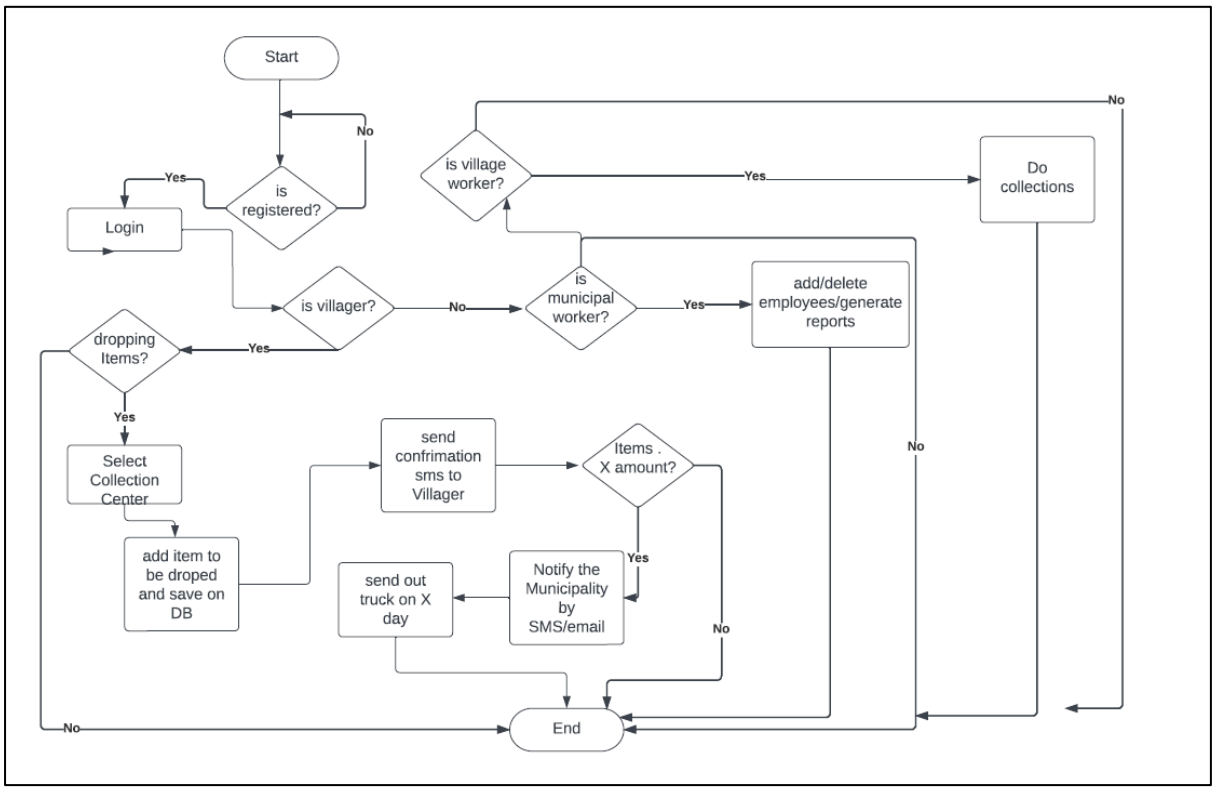


Figure 9.53: UML diagram of the proposed e-waste solution

Figure 9.3 demonstrates key components of the system and how they interreact, this helps the developers to know the required functionality of the system. It is documentation that assists developers know potential errors and helps them understand the outcome required.

The system starts by requiring a user to register. It then checks if the user is registered, if not, it sends the user back to the registration screen. If the user is registered, the login screen is displayed. Depending on permissions, if the user is a villager, the user is taken to village screens, to drop items the user wants collected. The user does this by selecting his/her collection centre, and providing the names of items, once this process is complete and items are submitted into the system, the user receives an SMS (Short Message Service) to confirm his/her items have been saved in the system. The system periodically checks the number of items submitted per collection centre when X amount (threshold) is reached the system via an SMS notifies the municipality.

If the user logging in is a municipality employee, the user is taken to administrative screens, such as adding, deleting, and updating user information, villages, and collection centres. The functionality of the system is documented in full in Section 9.7.

9.6 Use case diagram

Use case diagram provides a visual representation of interactions between the system and actors (end users). It provides ways in which different actors interact with the system, and what an actor can or cannot do. The diagram below is the use case diagram of the proposed e-waste solution. There are four actors for the system, given:

- The villager – end users from the studied under-resourced villages, who use the system to submit his/her e-waste items.
- Village employee – village end users employed by the municipality to collect items from households after they have been registered on the proposed solution.
- Municipality employee – responsible for dispatching trucks for collection and motoring collection centres, villages and employees. This actor has the same privileges as the admin.
- Municipality employee, same privileges as the municipality employee also responsible for CRUD (create, read, update, delete) in the system.

Figure 9.4 illustrates the proposed e-waste solution use case diagram.

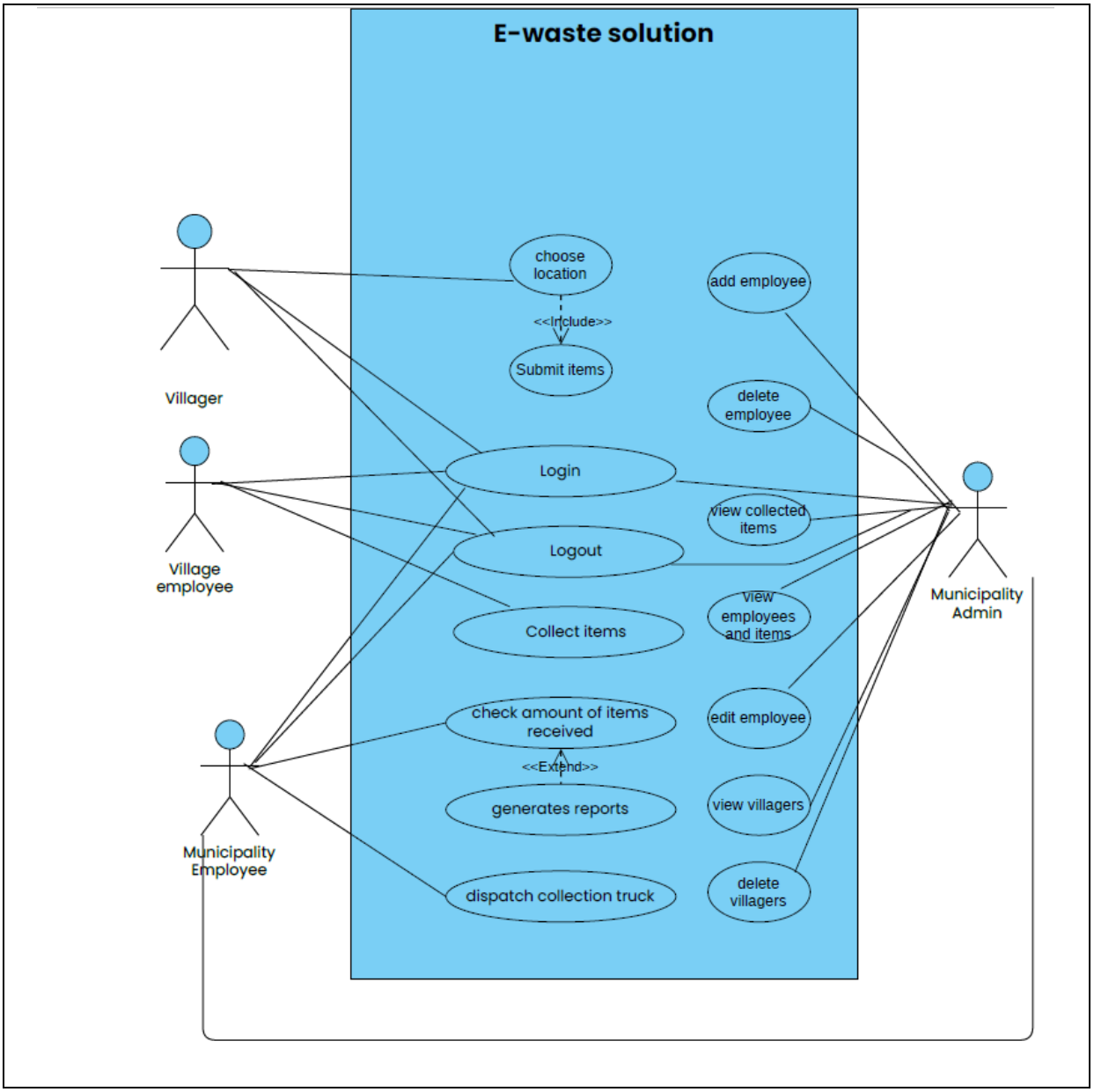


Figure 9.64: Use case diagram of the proposed e-waste solution

9.7 System functionality

System functionality refers to the system's behaviour, these are activities that a system should do depending on the user roles and what the user aims to achieve (Pecoraro & Luzi, 2022). All system users should register on the system before they can use it. Registration requires that a user provide first name, last name, phone number, postal code, street name, village

he/she is residing at from a dropdown menu, password, and reconfirmation of the password (encrypted). The system validates the inputted data.

The following list outlines the functionality of the proposed e-waste solution based on user roles:

- Villager – upon registering, the villager can log in to the system using his/her phone number and the registered password. After logging in, the user can input his/her e-waste items that need to be collected from his/her household. The villager also selects a collection centre of the village he/she resides in that the items need to be sent to and press submit. After submitting the user receives an SMS confirming that his/her e-waste equipment has been registered on the system. The SMS also reminds the user that e-waste is dangerous to the environment and human life.
- The system sends out notifications to all registered villagers, informing them about the dangers of e-waste, and that villagers should not forget to register their unwanted e-waste on the system for collection. This type of SMS is sent twice a month to each registered user, on the first of the month and the 15th of the same month.
- Village employee – this is a villager employed by the municipality, after a villager submits his e-waste equipment, the village employee receives a notification that a villager (name and surname) has submitted e-waste equipment X, Y and Z on the system. These items need to be collected and sent to the collection centre chosen by the villagers. The user makes a collection and registers on the system that he/she has collected items from villager X. The system then notifies the villager who submitted the items that his items have been collected and sent to the collection centre.
- Municipality employee/admin – the user has the administration roles of the system which include:
- Adding, deleting, updating, and viewing (CRUD) of villagers and village employees.
- Create collection centres, and villages and update them.
- View the total number of items collected for each village or collection centre.
- View the items that have not been collected by village employees and take the necessary steps to have those collected by village employees.
- Depending on the threshold set for collection centres receive an SMS that the threshold has been reached for a certain collection centre or centres, he/she can then dispatch a truck for the collection of submitted e-waste equipment.

- Has privileges of CRUD for municipalities, villages and e-waste categories. E-waste categories are necessary for sorting e-waste when it arrives at collection centres.

9.8 Test cases

The table below presents the test results that were conducted to test the usability of the proposed e-waste solution. This was to ensure that the solution worked as required. As indicated before, the researcher's colleagues completed the tests. The researcher explained to the colleagues the aim of the study and how the solution is to function, they then created the test cases defined in the table below.

Table 9.6 Test case and results

ID	Test Case	Expected Result	Status
1	User can register	User registered	PASS
2	User can log in after registering	User logs in	PASS
3	Village user can submit e-waste equipment	e-waste equipment submitted by Village user	PASS
4	Village user receives confirmation SMS upon submitting equipment	Village user receives a confirmation SMS	PASS
5	Village employee receives an SMS to go and collect submitted e-waste equipment	Village employee receives SMS for collection	PASS
6	Village employee collects and marks collection on the system	Collections marked by Village employee	PASS
7	User receives a confirmation SMS that the e-waste equipment has arrived at the collection centre	User receives a confirmation SMS	PASS
8	Admin can create employees/collection centres/villages/categories/municipalities	Employee/collection centres/villages/categories/municipalities created	PASS
9	Admin can edit employee/collection centres/villages/categories/municipalities	Employee /collection centres/villages/categories/municipalities edited	PASS
10	Admin can delete an employee/collection centres/village/categories/municipality	employee/collection centres/villages/categories/municipalities deleted	PASS
11	Admin can view employees/collection centres/villages in the system/categories/municipalities	Admin views employees/collection centres/villages/categories/municipalities in the system	PASS
12	Admin delete villager	Villager deleted	PASS
13	Admin receives SMS if threshold reached	SMS if threshold reached received	PASS

ID	Test Case	Expected Result	Status
14	Admin can view a list of collected e-waste equipment	Admin views list of collected e-waste equipment	PASS
15	Admin can view a list of un-collected e-waste equipment	Admin views list of un-collected e-waste equipment	PASS
16	Village user receives notification SMS about e-waste dangers twice a month	SMS about e-waste dangers sent twice a month to registered village user	PASS
17	Village user can log off the system	Village user logs out	PASS
18	Village employee can log off the system	Village employee logs out of the system	PASS
19	Admin can log off the system	Admin logs out of the system	PASS

9.8.1 System validations

System validations include the following processes:

- Input – this is data inputted in the system, should there be issues with the provided input, the system validates and provides the user with error messages. The user then must re-input the correct data.
- Login - The user enters his/her phone number as the username and then inputs the password. Should these not match what was used during registration, an error message is displayed that “incorrect username and password provided”. The password length is eight characters. The username should start with 27, for example, 2774569874.
- Deletion – when deleting information from the system, a validation message asking the user to confirm if he/she is sure of the procedure displays with two buttons “Yes” and “No”. This is to avoid deleting information by mistake. Pressing “Yes” will delete the information whilst “No” will not.

9.8.2 User interface designs

The proposed system is a mobile application. The user interface designs for the application are presented in Figure 9.5 below. The functionality of each user interface is provided in section 9.7. User interfaces are numbered as 9.8.2.1 to 9.8.2.3.

9.8.2.1 Demonstration of the Interface for a Villager

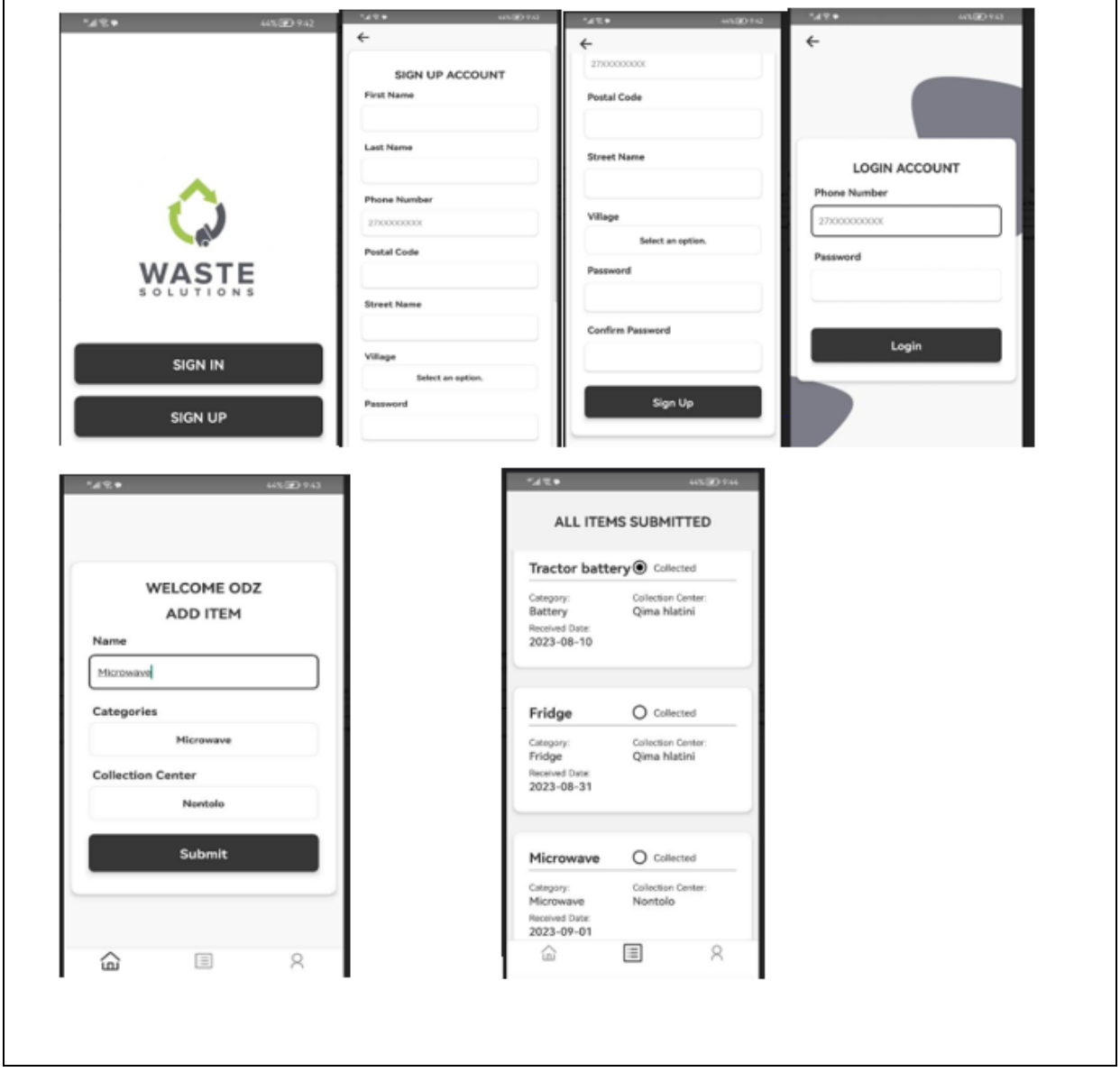


Figure 9.85: Villager's user interface design

9.8.2.2 Demonstration of the Interface for a Village Employee

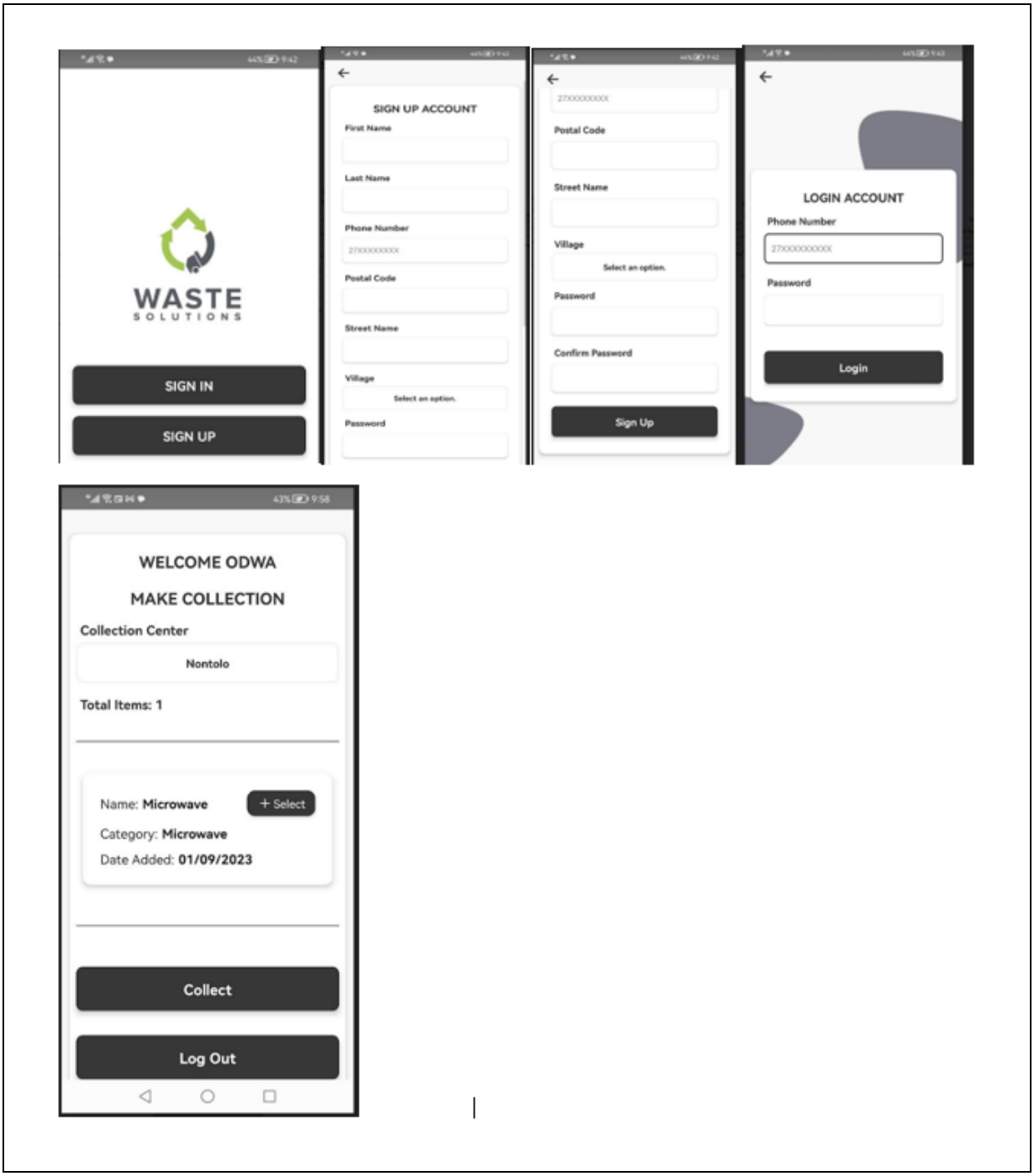
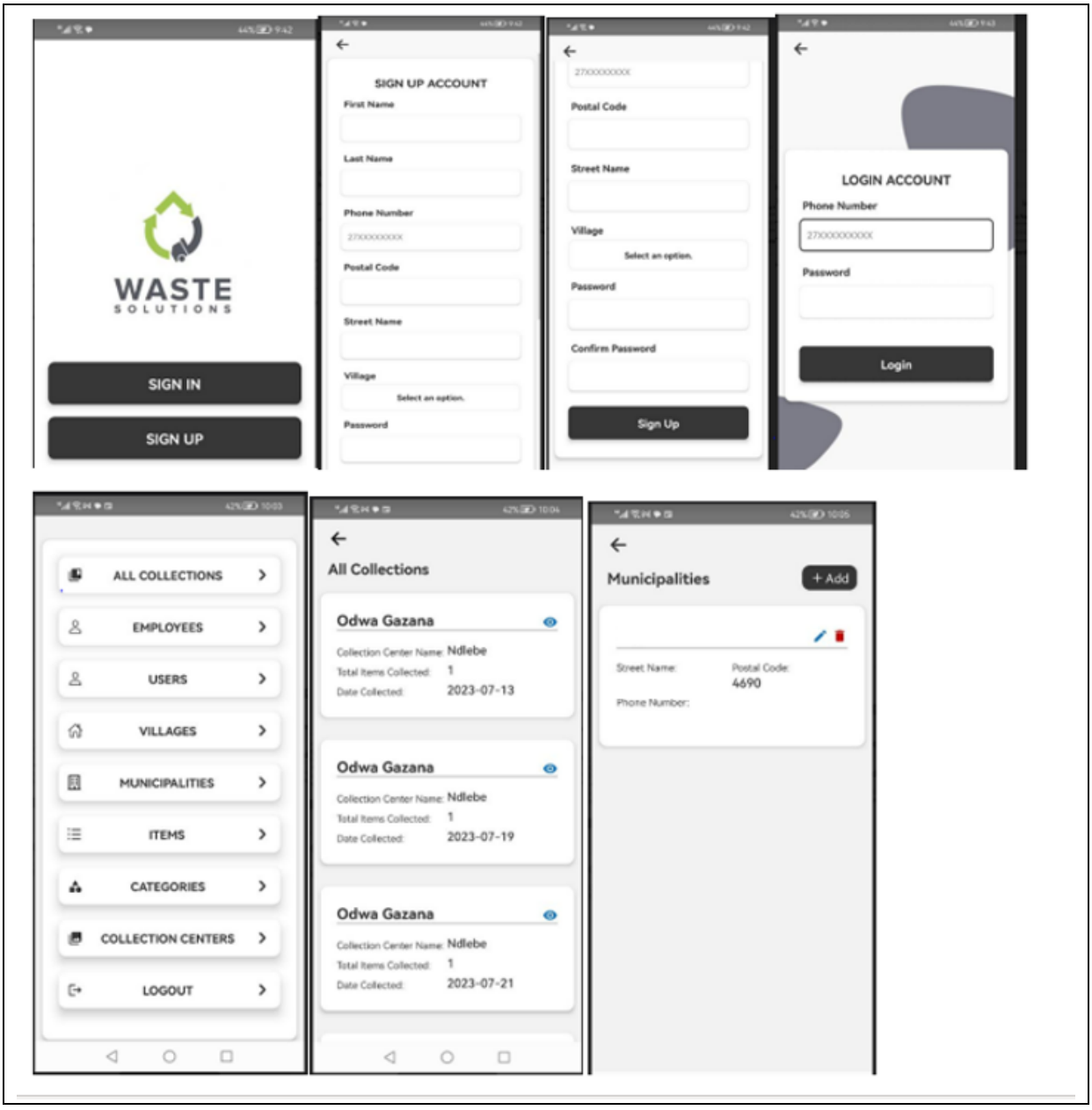
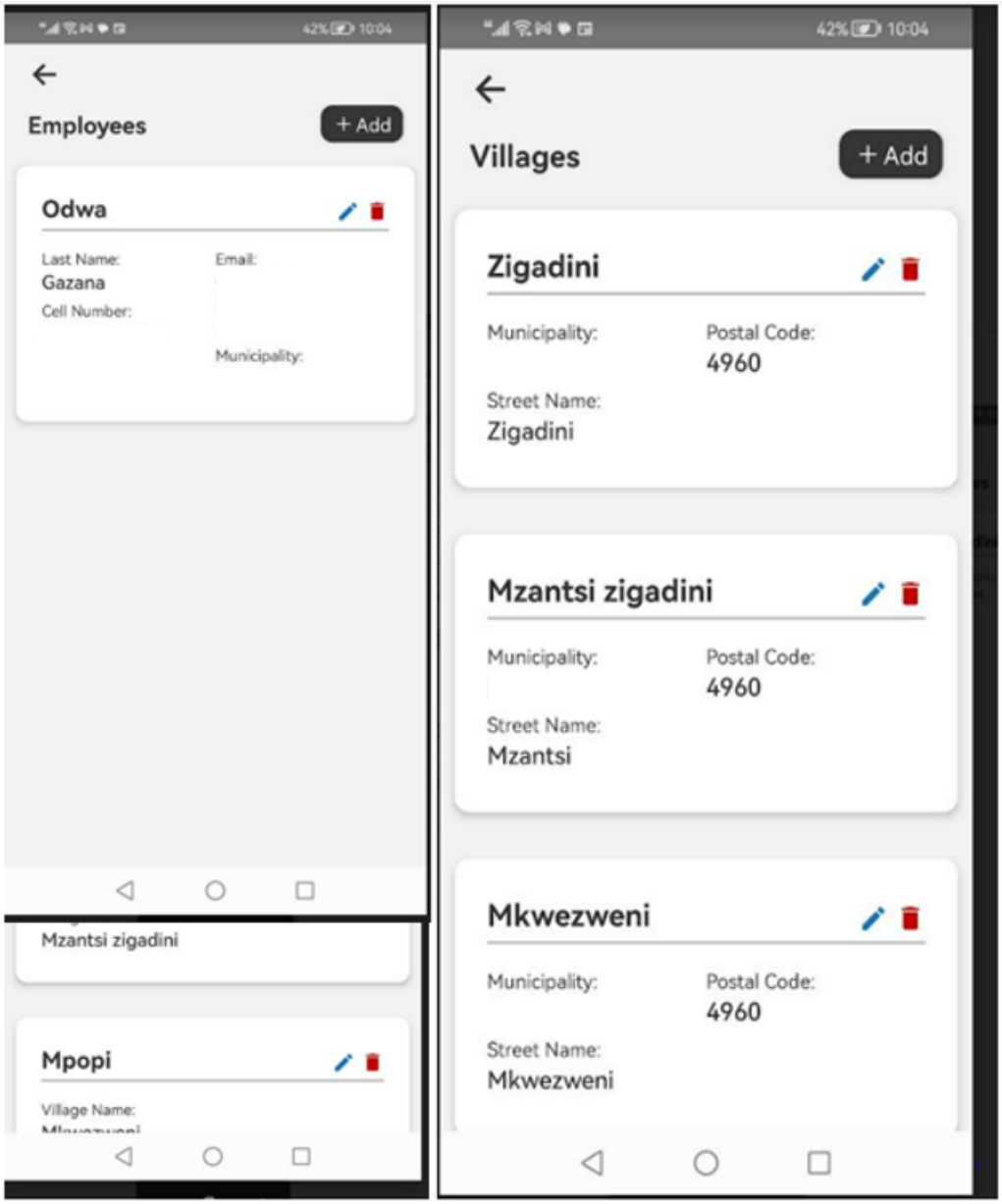


Figure 9.86: Villager Employee's user interface design

9.8.2.3 Demonstration of the Interface for an Admin

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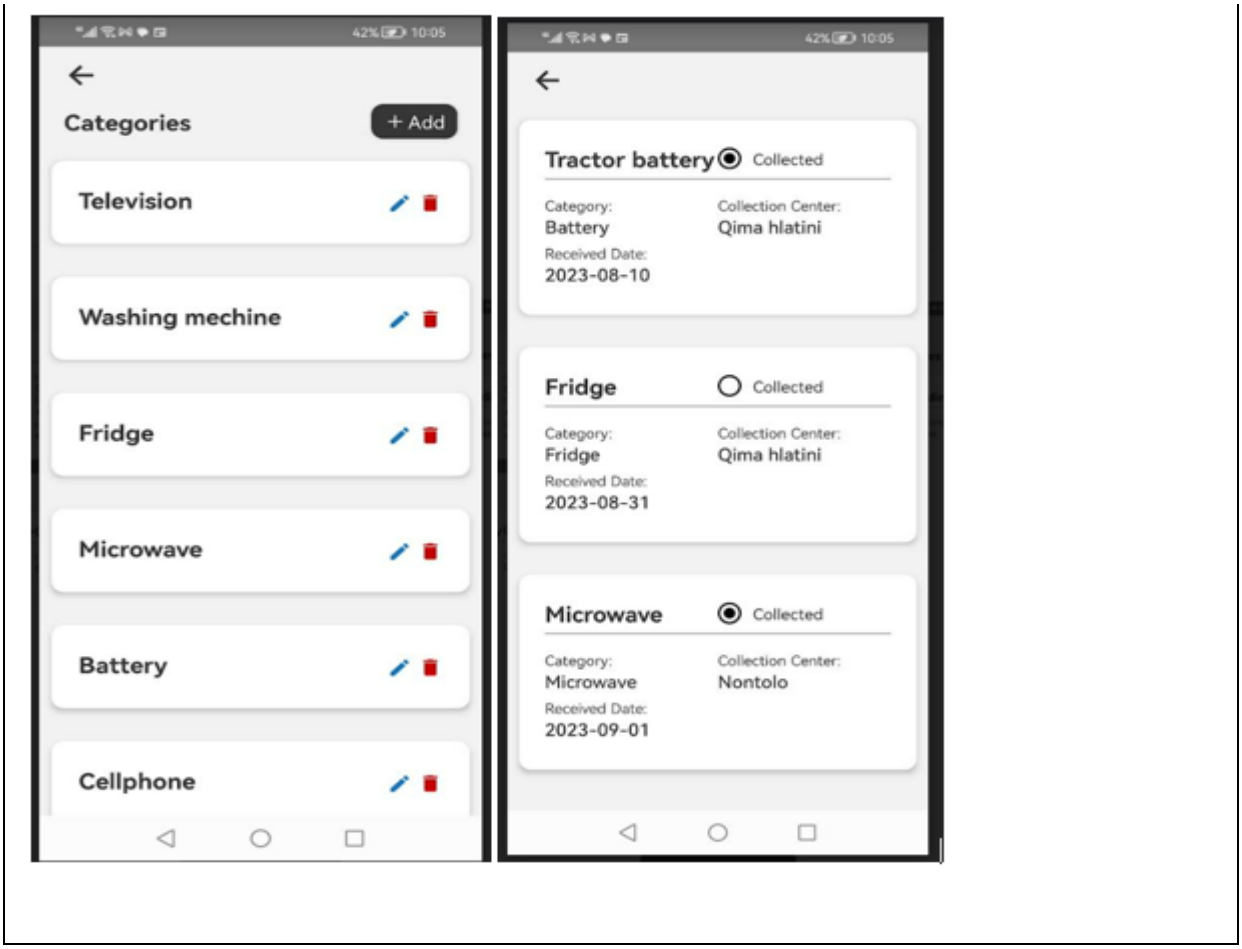
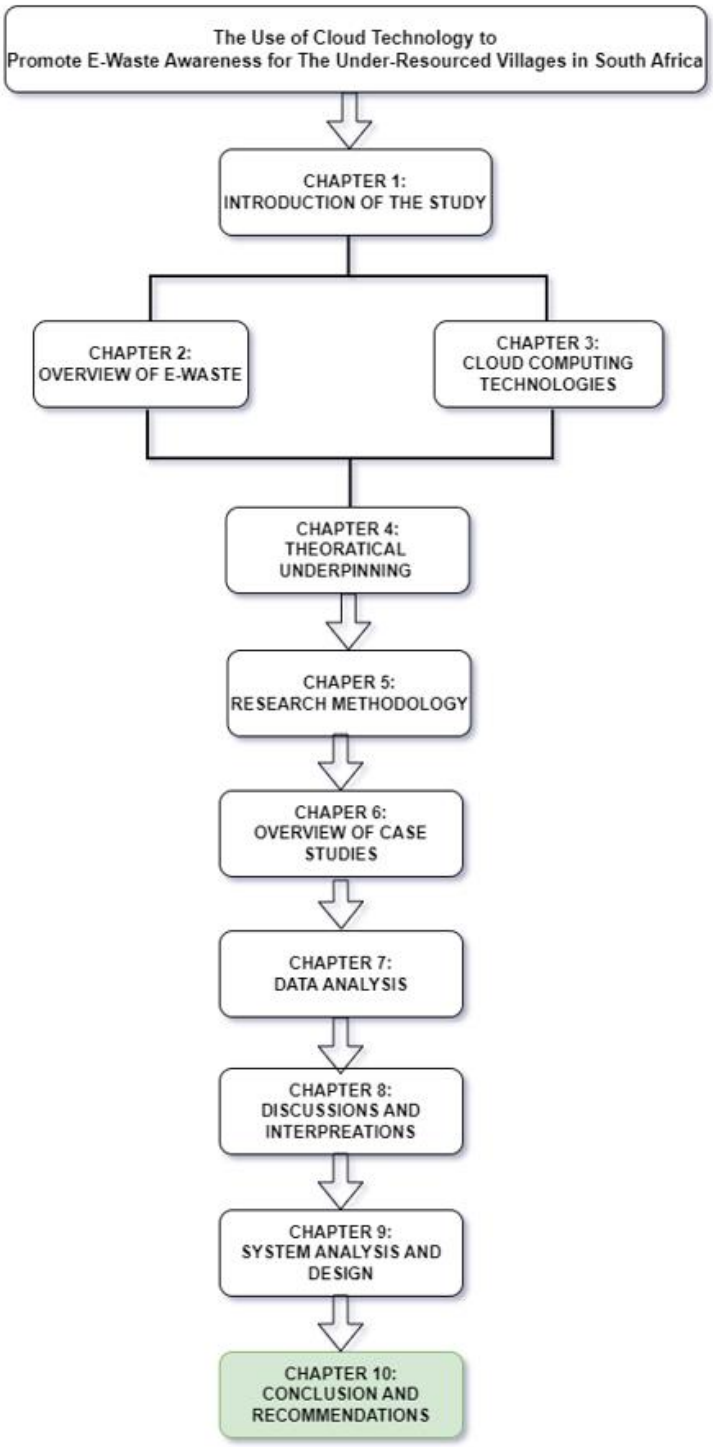


Figure 9.87: Admin's user interface design

9.9 Conclusion

The chapter presented the design process of the solution from inception to the end. It also demonstrated the distinct parts of the process that were embraced to develop the proposed solution such as the system design, database design, design model, use case diagram, system functionality and test cases were presented. Lastly, the user interfaces of the developed cloud solution were presented.

CHAPTER 10: CONCLUSION AND RECOMMENDATIONS



10.1 Introduction

The chapter presents a high-level overview of the study by presenting the conclusion and proposed recommendations. The conclusions and recommendations are derived from the findings of the study and interpretations. The chapter also provides a scientific justification for the development of the proposed cloud-based solution.

The study aimed to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste. The aim was achieved by applying a two-case study design, an interpretative approach, semi-structured interviews and document analysis. Two theories were embraced for the study Social Capital Theory (SCT) and Activity Theory (AT). SCT was chosen because the theory provides means to understand vital issues of the characteristics, lived experiences and nature of individuals, their contribution and what they want to benefit. The first three objectives were addressed using SCT and their data was analysed with Thematic Analysis (TA). The last objective was analysed using AT.

10.2 Overview of the study's chapters

Ten chapters make up this thesis, each chapter contributed to the study by presenting areas of importance to justify why this study is important. Below is the summary of each chapter:

Chapter 1: Introduction of the study establishes a base for the study. The chapter presented the research problem that the study seeks to solve. The aim of the study, research objectives and research questions are also introduced in this chapter. These are derived from the research problem. A brief background of the study supported by the literature review was presented in this chapter including the high-level definition of two theories underpinning the study. The chapter also presented research design and methodology which includes research philosophy, research strategy, research approach, research methods, data collection methods, sampling, and data analysis. The remaining part of the chapter covered the delineation, ethics, significance, and contributions of the study.

Chapter 2: Overview of E-waste (Literature review) provided a more detailed literature review of the study. The chapter enabled the researcher in efforts to gain detailed knowledge of the topic studied. The chapter presented work done by other researchers on the topic. This was

to identify gaps in the literature that the study is hoping to close regarding e-waste awareness in the under-resourced villages of South Africa.

Chapter 3: Cloud Computing Technology (Literature review) aimed to evolve a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste. Cloud computing (CC) research studies had to be incorporated into the study based on its aim. This assisted the researcher in gaining more understanding of CC and choose as to which CC instance is suitable for the solution developed by the study. Different cloud computing instances were investigated to assist the researcher in having a broader view of the diverse types before deciding on the possible type that is relevant and proposed for this study. Adoption of the SCT and AT underpinning theories of the study are presented including their use in IS studies.

Chapter 4: Underpinning theories of the study, SCT and AT are presented including their use in IS studies. Also, how the study makes use of the theories is discussed in this chapter.

Chapter 5: Research Methodology discussed the research methodology applied in the study. Research philosophy, research strategy, research approach, research methods, data collection methods, sampling and data analysis are discussed in the study. The research methodology was chosen based on the objectives of the study. The study employed the qualitative research method, two case studies were selected for the study. Semi-structured interviews were used to collect data from participants. The study adopted the inductive approach as it looked to build a solution from participants' views and experiences. The study's conceptual framework is presented in this chapter which defines the integration of theories that underpinned the development of the framework.

Chapter 6: Overview of Case Studies addressed the two cases piloted in the study namely Village A and B and the municipalities servicing the two cases. The chapter presented a broader view of the state of e-waste management and how it is understood and perceived by the participants of the two cases and related municipalities. The views and future aspirations of the participants are outlined in this chapter. The chapter also presents the alignment of the study with the national mandate regarding the agenda of e-waste management through the document analysis approach that was embraced by the researcher.

Chapter 7: Data Analysis presented data analysed from each case. The first three objectives of the study were analysed using the TA, this was to gather challenges, current methods in which e-waste is dealt with in the location and strategies to be adapted to bring about awareness to under-resourced villages. The fourth objective was analysed using AT theory which led to the development of the cloud solution. The analysis of data, discussions and interpretations of the findings followed in Chapter 7.

Chapter 8: Discussions and Interpretations of the findings summarised the discussed and interpreted findings from Chapter 7. The chapter intended to bring an overview insight of the participants' contribution to the study and the development of the proposed solution.

Chapter 9: System Analysis and Design: outlined the core of the study which is the processes embraced to develop the proposed solution. It demonstrated the technical and non-technical elements of the study such as system design, database design, design model, use case diagram, system functionality, test cases and user interface are presented in this chapter. The process flow of the development of the solution from the inception of understanding the problem to the final stage of testing the effectiveness of the solution.

Chapter 10: Conclusion and recommendations presented the high-level overview of the study by presenting the summaries of the chapters and the recommendations for this study. It submits the summaries to conclude the study. An evaluation of the study is also provided in this chapter.

10.3 Evaluation of the research study

Evaluation of a study is important in that it assesses the quality outcomes of the study. The study employed the six components of the 5W1H (what, when, where, who, why and how) approach in assessing the study. The 5W1H is a method used for qualitative study evaluations (Dane, 2017). Furthermore, the six components are adopted from Iyamu & Shaanika (2018), they employed the six components in their research to quiz and retrieve information. The table below outlines the study's evaluation.

Table 10.7: Evaluation of the research study

Component	Evaluation of the Research Study
What	E-waste awareness and its management were investigated in two under-resourced villages in South Africa. The researcher observed that e-waste is a huge burden in the two under-resourced villages, as there are no mechanisms for managing it.
When	Data was collected on separate days between the two cases. Data collection was stopped when the saturation point was reached. Data was analysed as soon as the collection was done whilst the researcher had a fresh memory of what transpired and what was said.
Where	Two under-resourced villages were used in the study. Namely, Village A and Village B. Also included was the municipality overseeing these locations. This was done to gather information on where the municipality collects e-waste in its demarcated under-resourced villages and how it manages it.
Who	Participants of the study had to meet the study's criteria. Views and experiences of villagers from both locations were collected extending to the municipality overseeing the two cases.
Why	The researcher observed that there was e-waste littering in the two locations. Also, there is a lack of cloud technology usage to help promote e-waste awareness among people living in under-resourced villages in South Africa. This is needed to assist with promoting e-waste awareness on its dangers to the environment and human health. Also, to help manage e-waste better than how it is currently managed as revealed in Chapter 5.
How	The study employed two cases, an inductive approach, an interpretative approach, semi-structured interviews, codesign sessions, a qualitative research method, and two theories underpinned the study SCT and AT. SCT was chosen because the theory provides means to understand vital issues of the characteristics, lived experiences and nature of individuals, their contribution and what they want to benefit. The first three objectives were addressed using SCT and their data analysed with Thematic Analysis (TA). The last objective was analysed using AT.

10.4 Summarising the study's findings

The study aimed to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste. To reach the aim, four sub-questions of the study were addressed relative to an associated objective as set out in Chapter 1, Table 1.2. Furthermore, the answering of the main research question (MQ) linked directly to the four sub-questions SQ1 to SQ4 (Sections 10.4.1 to 10.4.4).

10.4.1 SQ1: How do people living in under-resourced villages currently manage e-waste?

This sub-research question is intended to establish how people in under-resourced villages are currently managing their e-waste. The findings of the study confirmed that e-waste equipment is discarded in open fields such as dams, rivers, fountains and grazing fields. It was indicated that some e-waste is also stored indoors with other working electronic equipment. The kept e-waste is being re-used as glossary cupboards, storage of tools and used as decorations of households.

E-waste that is stored indoors with other equipment is not sorted and is kept with other general waste such as gas cylinders, plastic bags and containers and wooden waste. Furthermore, it was indicated that there are people in the villages who fix non-functioning electronics, but as time passes these electronics repeatedly break, leading to them being discarded in the open fields. It was further indicated that villagers are using diverse ways of managing e-waste such as burning it. E-waste is burnt to avoid it being taken back to the homes.

The current way of e-waste management was done as there are no mechanisms to manage e-waste and lack of knowledge on how villagers should manage e-waste. The lack of knowledge and lack of proper infrastructure to recycle e-waste posed risks to the environment and human health. The discarded e-waste in open fields could contaminate the environment by having e-waste elements leaching into the sand, polluting the underground water. Burning e-waste pollutes the air which could lead to sickness or lung diseases for humans.

It was confirmed that e-waste equipment such as refrigerators, would be dismantled so its parts could be used for nesting purposes and provide warmth to kraals during winter. This was done by taking parts such as doors and sides and placing them in between poles used to build

the kraals. This question addresses the objective **O1**: **To determine how people living in under-resourced villages manage e-waste currently.**

10.4.2 SQ2: What are the challenges and impacts posed by the disposal of e-waste on the ecosystem in the under-resourced villages?

This question seeks to identify the challenges and impacts of disposing of e-waste in open fields by people in under-resourced villages. Challenges identified by this study included a lack of knowledge about e-waste dangers to the environment and human health. Another challenge was the contamination of food, water and air. This is attributed to a lack of knowledge of e-waste management.

People in these areas can be considered small-holding farmers as they breed their own livestock and work the land to grow their own food. The study suggests that due to a lack of knowledge of e-waste management, and the impact of e-waste illegal dumping, the villagers did not understand the impact it has on their environment, human and livestock health and their grazing fields.

The limited knowledge and understanding of the several types of chemicals contained in the e-waste equipment posed diverse health and environmental hazards due to soil and water contamination, and to air pollution from the burnt items.

The distinct types of e-waste identified in the under-resourced villages included refrigerators, electronic irons, electronic kettles, televisions, electronic stoves, washing machines, cell phones, car batteries, cell phone batteries, electronic hairdressers, radios, electronic cables, digital video discs (DVDs), electronic wall plugs and globes. All these items were not known by villagers that they are e-waste and how they should be managed in their afterlife. This question addresses the objective **O2**: **To determine different types of e-waste, challenges, and impacts on the ecosystem in under-resourced villages.**

10.4.3 SQ3: What strategies could be used to manage e-waste for the under-resourced villages?

This question seeks to identify strategies that could be applied to manage e-waste in the under-resourced villages. One of the strategies identified is that education is needed to spread the word and bring about awareness of e-waste. This should include awareness on the

dangers of e-waste on human health and the environment. Television and radio adverts were also identified as strategies that could be applied to diverse groups of people at once.

Another strategy identified was the monthly seminars were proposed as another tool for awareness, the word-of-mouth roadshows. It was also identified that e-waste management should be taught in local schools both in primary and secondary schools. This question addresses the objective **O3**: **To identify strategies that could be used to manage e-waste for the under-resourced villages.**

By adopting SCT, the three above objectives were met, which proves that SCT can be used to solve complex problems faced by communities. Prince (2024) states that SCT can be used as a catalyst to empower communities, assist people to collaborate and share ideas and resources to address common problems.

10.4.4 SQ4: What strategies could be identified and adopted in developing the cloud e-waste awareness solution?

The question looked at strategies that could be identified and adopted in developing the cloud e-waste awareness solution for under-resourced villages of South Africa. Utilising the Activity Theory (AT), the identified strategies are technical and non-technical requirements, governance and stakeholder collaborations, as follows:

- Technical requirements – technical requirements identified are internet connectivity, smartphones, and storage capabilities (databases), these are requirements needed to access the cloud e-waste awareness solution. Servers, software developers, system analysts and database administrators. These would be the requirements to build and maintain the cloud e-waste awareness solution.
- Non-technical requirements – non-technical requirements are the end users of the system and those that draft policies known as non-technical personnel. Non-technical personnel are people who provide business specifications on how the cloud solution should function.
- Governance – policies, regulations and standards are needed to ensure that e-waste littering is limited or eliminated. Policies could be drafted by the municipality in collaboration with villagers, to ensure that there is mutual understanding from both parties. According to (Blomkamp, 2018), policies, regulations and standards should

be codesigned by people who have the first experience of what needs to be addressed.

- Stakeholder collaborations – stakeholders' collaboration of municipality representatives, village representatives, retailers, recyclers and environmentalists have been identified as critical for the e-waste management. These stakeholders should collaborate for the benefit of the environment and human health. This ensures that e-waste is effectively managed.

The identification of these strategies would ensure that the proposed e-waste solution is widely adopted by those it is intended to assist. This is because each stakeholder's voice is heard and taken into consideration in assisting with the curbing of e-waste disposal to open fields. This question addresses the objective **O4**: **To identify strategies to adopt in developing the cloud e-waste awareness solution.**

This objective was met by adopting AT, strategies needed to develop the cloud-based e-waste solution were found to be effective as the strategies were used to develop the solution. This proves that AT can be used to develop IS solutions for community development.

10.5 Aim of the study

The study aimed to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste.

The cloud-based technology solution was developed based on the findings of the study. The cloud-based technology solution is documented in Chapter 9 and outlines the functionality of the solution and how it can better improve the e-waste management for under-resourced villages. The proposed solution can be adapted and adopted by different municipalities.

10.6 Contribution of the study

The section outlines the contribution of this study, the study contributed in three parts: theoretically (10.6.1), methodologically (10.6.2) and practically (10.6.3).

10.6.1 Theoretical contribution

Social Capital Theory and Activity Theory were two theories used to aid the study in achieving its aim. Both theories and the findings contributed to the development of the proposed cloud-based solution for e-waste awareness based on the lived experience of under-resourced communities.

The study also contributes theoretically in two ways, first, the study adds to the field of IS and ICT governance by introducing a new mode of how the existing theories can be expanded to address the challenges of e-waste management. In addition, the study adds to the existing body of literature on e-waste management or mismanagement in developing countries. The second contribution includes villagers' perceptions and experiences in designing the proposed technology-based solution prototype.

10.6.2 Methodological contribution

Methodological contribution is the use of the two theories that underpinned the study. The two theories are the Social Capital Theory and the Activity Theory. Social Capital Theory was used to understand the lived experiences of under-resourced villagers regarding e-waste awareness and management. Activity Theory to identify strategies that could be adopted in developing the cloud e-waste awareness solution. The two theories were used independently from each other.

Combining the two theories led to the development of a cloud-based solution for e-waste awareness and management. This is a major contribution as the proposed solution can be used by other countries to manage the e-waste for their under-resourced villages.

Furthermore, the research contributes methodologically by educating participants on what e-waste is and how it should be managed to protect the environment and health.

10.6.3 Practical contribution

Practically the proposed cloud solution can be used by other provinces in South Africa to mitigate hazardous challenges posed by the littering and mismanagement of e-waste. The solution can be adopted and used by other countries to manage the e-waste challenges of their under-resourced villages.

The proposed solution is also developed to address the national agenda on e-waste management and preservation of the environment and human and livestock health.

10.7 Benefits of the study

The research study focused on protecting the environment and human health of under-resourced villages. There is a paucity of research studies whereby a cloud-based technology solution is driven by the community for e-waste management in under-resourced villages. Such a study is significant for rural people and the municipality responsible for the areas. The participants of the study also benefited by gaining knowledge of e-waste, and its dangers to the environment and human health.

Another benefit is that the study can be used as a reference point for other areas similar to where the study was carried out. This is vital for Africa as many countries battle with the same challenges. The study also adds to the existing body of knowledge regarding e-waste management. It brings new knowledge as this is the first of its kind whereby rural people designed a cloud-based technology solution for e-waste management in under-resourced villages.

Also, academia benefits from the study as it adds to the existing body of knowledge on e-waste. From the review of literature, currently, there is no cloud solution for e-waste awareness for under-resourced villages, hence the proposed solution is a major addition. The study also adds to the field of IS studies and ICT governance.

10.8 Limitations of the study

The study did not consider all under-resourced villages in the Eastern Cape. Only two under-resourced villages were considered for the study. The study was limited to consulting one local municipality to gather data on how they manage e-waste. The study also did not consider other types of waste, it was only limited to e-waste.

10.9 Recommendations

The study aims to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste. The following recommendations (Sections 10.9.1 to 10.9.3) were identified by the study to close these gaps.

10.9.1 The municipality to have e-waste recycling infrastructure

The findings demonstrated that the municipality overseeing the two under-resourced villages had no e-waste recycling infrastructure, this is a gap that needs to be closed. The piloted villages confirmed that, currently they do not have a disposal mechanism to manage the e-waste in their environment, the provision of containers in the villages to store e-waste materials that would then be collected for recycling as suggested by this study improves the villagers' conditions and systems.

The recommendation to introduce awareness programs by the municipality is identified as part of the solution to mitigating the e-waste management challenges.

The final recommendation suggests that the municipality should introduce policy documents on e-waste management for under-resourced villages. Consideration for the municipality to partner with retailers in establishing a recycling centre for e-waste was recommended.

10.9.2 The rollout of awareness program to under-resourced villages

The study revealed that there was a general lack of awareness about e-waste in the under-resourced villages. The study recommends that an awareness program must be developed by all stakeholders and implemented in the under-resourced villages. The development of the awareness program should be initiated by the municipality. All stakeholders identified by the study should have input into the development to ensure that there is mutual understanding. The program should entail e-waste dangers on the environment and on human health and how e-waste should be managed.

There should be compensation for those who return their e-waste, this is to discourage the storing of e-waste equipment in households and the careless discarding. The study also recommends that retailers that sell electronic equipment also provide information on what the consumers should do when the device bought has reached its afterlife. Also, e-waste awareness programs should be rolled out to schools, to ensure that even children know the dangers of e-waste. This has the potential to stop them from playing with discarded e-waste.

10.9.3 The deployment of the developed cloud solution

The study achieved its aim by developing a cloud solution to assist with mitigating hazardous challenges posed by the littering and mismanagement of e-waste in under-resourced villages

of South Africa. The study recommends that this solution be piloted in under-resourced villages of South Africa and then deployed and used for its purpose. The study revealed that the designers of the solution wanted to see their work implemented and used to mitigate e-waste littering in under-resourced villages.

10.10 Recommendations for further research

This research study developed a cloud-based solution for e-waste awareness in under-resourced villages. Further research could investigate the proposed solution's effectiveness on e-waste awareness in under-resourced villages. The research could be carried out nationally to investigate e-waste awareness and knowledge among other under-resourced villages of South Africa.

10.11 Scientific justification of the development of the proposed cloud-based solution

The following section justifies how the proposed cloud-based solution was developed by linking literature to what came out of the study.

- Co-design

According to the literature, Singh *et al.* (2023), Mager (2008) and Slattery *et al.* (2020) state that co-design allows a system to be built on the users' lived experiences. Including stakeholders in system design is important to instil a sense of ownership, user satisfaction with the system, and user awareness (Dwivedi & Dwivedi, 2021; Alam, 2002 & Kujala, 2003).

The cloud proposed cloud-based solution was developed based on participants' lived experiences this was done so to promote user satisfaction with the system. As reported above involving end users from the inception phase of system design brings user satisfaction and a sense of ownership.

Burkett (2021) states that to change complex social problems, there is a need to incorporate the skills, experiences and knowledge of all people involved or impacted by the problem.

Participants and the researcher collaborated in the development of the cloud-based solution. This was done through co-design to ensure that all stakeholders are part of the development of the solution and to promote the adoption of the solution.

- Design Thinking

Design thinking (DT) is a process used to solve complex problems in a user-centric way (Stevens, 2020). Users are the centre of the design process, as they are the ones who understand the problem and provide lived experiences by producing workable solutions.

The communities were placed at the centre of the study. This is because participants from the communities understood the problem, it was necessary to have them at the centre of the study to lead a solution to the problem. The five stages of DT were embraced to ensure that the developed cloud-based solutions worked as intended. The solution was derived from the user's lived experiences and opinions.

- Social Capital Theory

Social Capital Theory (SCT) allows people to come together and share opinions or experiences and their common social or economic challenges or problems to find a common solution. In support, Fukuyama (2002) states that SCT is a standard for which the co-existence of people is achieved and solutions are developed based on constructive engagements.

The adoption of SCT was necessary based on the researcher's experiences whereby older men generally do not value women's and young men's views in community meetings. However, the adoption and implementation of this theory have challenged the stereotypical views and allowed different stakeholders to participate equally.

The theory was chosen because it provides ways to understand vital issues of the characteristics, lived experiences and nature of individuals, their contribution and how they want to benefit.

By adopting SCT for the study, the following objectives were achieved:

- O1: To determine how people living in under-resourced villages manage e-waste currently.
- O2: To determine different types of e-waste, challenges, and impacts on the ecosystem in the under-resourced villages.
- O3: To identify strategies that could be used to manage e-waste for the under-resourced villages.

Details of the findings of the objectives O1 – O3 are addressed in this chapter section 10.4.

- Activity Theory

Activity Theory (AT) originated from the Russian school of psychology by Vygotsky (1978) and has been widely used for social activity studies. According to Vygotsky (1978), AT is composed of components such as Activity, Subject, Object and Tools.

Hashim and Jones (2007) state that AT is a theory used to analyse and understand how humans interact using artifacts and tools, which include applications, databases or hardware. Furthermore, Häkkinen and Korpela (2007) state that AT assists in understanding user group activities in developing IS applications and provides information about the relationship between actors in a system.

The study advanced the utilisation of AT to identify strategies to adopt in developing the cloud e-waste awareness solution. Through the Activity theory, the study findings noted the importance of acquiring the technical and non-technical requirements, governance and stakeholder collaboration to ensure the effective execution of the cloud solution for the intended users. A prototype of the proposed cloud-based solution was developed. For AT to be adopted in the development phase, it was necessary to first gather information on the problem, this was done through the first theory which is SCT.

10.12Conclusion

The chapter presents an overview of the evaluation of six components adopted for this study to justify its validity as captured by Iyamu and Shaanika (2018). A summary of the findings based on the sub-questions and their associated objective was presented. The chapter also presents summaries of theoretical, methodological and practical contributions. Further, recommendations based on the identified gaps were presented. It also explains the benefits, limitations, and reasons for developing a cloud-based solution.

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APPENDICES

APPENDIX A Ethical Clearance

Cape Peninsula University of Technology
creating futures

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Office of the Research Ethics Committee
Faculty of Informatics and Design
Room 2.09
80 Roeland Street
Cape Town
Tel: 021-469 1012
Email: ndedem@cput.ac.za
Secretary: Mziyanda Ndede

06 June 2022

Mr Odwa Gazana
c/o Department of Information Technology
CPUT

Reference no: 214259684/2022/12

Project title: **USE OF TECHNOLOGY TO PROMOTE E-WASTE AWARENESS IN THE UNDER RESOURCED VILLAGES.**

Approval period: 06 June 2022 – 31 December 2023

This is to certify that the Faculty of Informatics and Design Research Ethics Committee of the Cape Peninsula University of Technology conditionally approves the methodology and ethics of Mr Odwa Gazana (214259684) for Doctor of Philosophy in Informatics.

Any amendments, extension or other modifications to the protocol must be submitted to the Research Ethics Committee for approval.

The Committee must be informed of any serious adverse event and/or termination of the study.

Dr Blessing Makwambeni
Acting Chair: Research Ethics Committee
Faculty of Informatics and Design
Cape Peninsula University of Technology

APPENDIX B Introductory Letter for the Collection of Research Data

Odwa Gazana is registered for the Doctor of Philosophy (PhD) at CPUT (214259684). The thesis is titled: The use of cloud technology to promote e-waste awareness for the under-resourced villages in South Africa and the aim of the study is to develop a cloud-based technology solution to promote e-waste awareness in the under-resourced villages of South Africa. The proposed solution is expected to mitigate hazardous dangers posed by the littering and mismanagement of e-waste.

The supervisor(s) for this research is/are:

Prof Tembisa Ngqondi (0849512688)

In order to meet the requirements of the university's Higher Degrees Committee (HDC) the student must get consent to collect data from individuals and organisations which they have identified as potential sources of data. In this case, the student uses interviews, co-design sessions, design thinking and questionnaires to gather data.

If you agree to this, you are requested to complete the attached form (an electronic version can be made available to you) and print it on your organisation's letterhead (where possible).

Please note that no data would be gathered until the researcher has received ethics clearance from CPUT.

For further clarification on this matter, please contact either the supervisor(s) identified above, or the Faculty Research Ethics Committee secretary (Mziyanda Ndede) at 021 469 1014 or ndedem@cput.ac.za

Yours sincerely

Prof Tembisa Ngqondi

23/02/2023

APPENDIX C: Signed Data Collection Permission from Chiefs (Village A and Village B)

Letterhead or Stamp

I Sonwabo Mpeta, in my capacity as the Chief at Mpeta location give consent in principle to allow 214259684 a student at the Cape Peninsula University of Technology, to collect data in this company/from me as part of their Doctor of Philosophy (PhD) research. The student has explained to me the nature of their research and the nature of the data to be collected.

This consent in no way commits any individual person to participate in the research, and it is expected that the student will get individual consent from any participants. I reserve the right to withdraw this permission at any time.

In addition, the company's/my name may or may not be used as indicated below (tick as appropriate):

	Thesis	Conference paper	Journal article	Research poster
Yes	✓	✓	✓	✓
No				

Insert name and signature

27/09/2023

Date

TYEKANA TRAD LEADER
Nqamakwe, Mantunzeleni A/A
Date: 12/06/2021
Sign: .....

Stamp

I Thandikile , in my capacity as Chief at Mantunzeleni location give consent in principle to allow Odwa Gazana a student at the Cape Peninsula University of Technology, to collect data in this company/from me as part of their PhD research. The student has explained to me the nature of their research and the nature of the data to be collected.

This consent in no way commits any individual person to participate in the research, and it is expected that the student will get individual consent from any participants. I reserve the right to withdraw this permission at any time.

In addition, the company's/my name may or may not be used as indicated below (tick as appropriate):

	Thesis	Conference paper	Journal article	Research poster
Yes	X	X	X	X
No				

Thandikile

Insert name and signature

<<date> 12/06/2021

APPENDIX D: Municipality Data Collection Permission Letter

Letterhead or Stamp

I----------, in my capacity as an employee of the municipality give consent in principle to allow 214259684 a student at the Cape Peninsula University of Technology, to collect data in this company/from me as part of their Doctor of Philosophy (PhD) research. The student has explained to me the nature of their research and the nature of the data to be collected.

This consent in no way commits any individual person to participate in the research, and it is expected that the student gets individual consent from any participants. I reserve the right to withdraw this permission at any time.

In addition, the company's/my name may or may not be used as indicated below (tick as appropriate):

	Thesis	**Conference paper**	**Journal article**	**Research poster**
Yes				
No				

_____

Insert name and signature

Date

APPENDIX E Data Collection Instrument

The questionnaire is divided based on the research questions and objectives of the study.

Interview questions associated with sub-research questions SQ1 to SQ4, linked to objectives O1 to O4 are to be posed to the village participants. However, interview questions aligned to SQ3 and SQ4 and thus objectives O3 and O4 were posed to municipality participants.

SQ1: How do people living in under-resourced villages currently manage e-waste?	**O1:** To determine how people living in under-resourced villages manage e-waste currently.

1. Do you know what is e-waste?
2. Can you define e-waste in your own words?
3. Do you know what is e-waste recycling?
4. How do you recycle your e-waste?
5. Where do you recycle your e-waste?
6. Can you give other ways of recycling that you have?
7. are there any dedicated places for the village people to throw e-waste?
8. If yes, how often is the e-waste collected?
9. If no, where do you throw it?
10. Anything else to add.

SQ2: What are the challenges and impacts posed by the disposal of e-waste on the ecosystem in the under-resourced villages?	**O2:** To determine different types of e-waste, challenges, and impacts on the ecosystem in the under-resourced villages**.**

1. List the different categories of e-waste you have at home.
2. How does e-waste affect your livestock?
3. How does it affect your health?
4. How does it affect children's health?
5. How does it affect the environment (river flows, vegetation, grazing land)?
6. What other e-waste challenges do you experience which are not listed above?

SQ3: What strategies could be used to manage e-waste for the under-resourced villages?	**O3:** To identify strategies that could be used to manage e-waste for the under-resourced villages.

1. What do you think should be done to help with e-waste handling?
2. If the municipality provided means for you to handle e-waste. Would you make use of them?
3. What role as the owner of the e-waste can you play in handling e-waste in an environmentally friendly manner?
4. Are you aware of any legislation that deals with e-waste disposal?
5. Do you know of any e-waste awareness methods in your villages?
6. If yes, do you use them?
7. How do these methods contribute to e-waste management?

An additional six interview questions are listed below, They apply to the municipality authorities and village participants that demarcate the under-resourced villages.

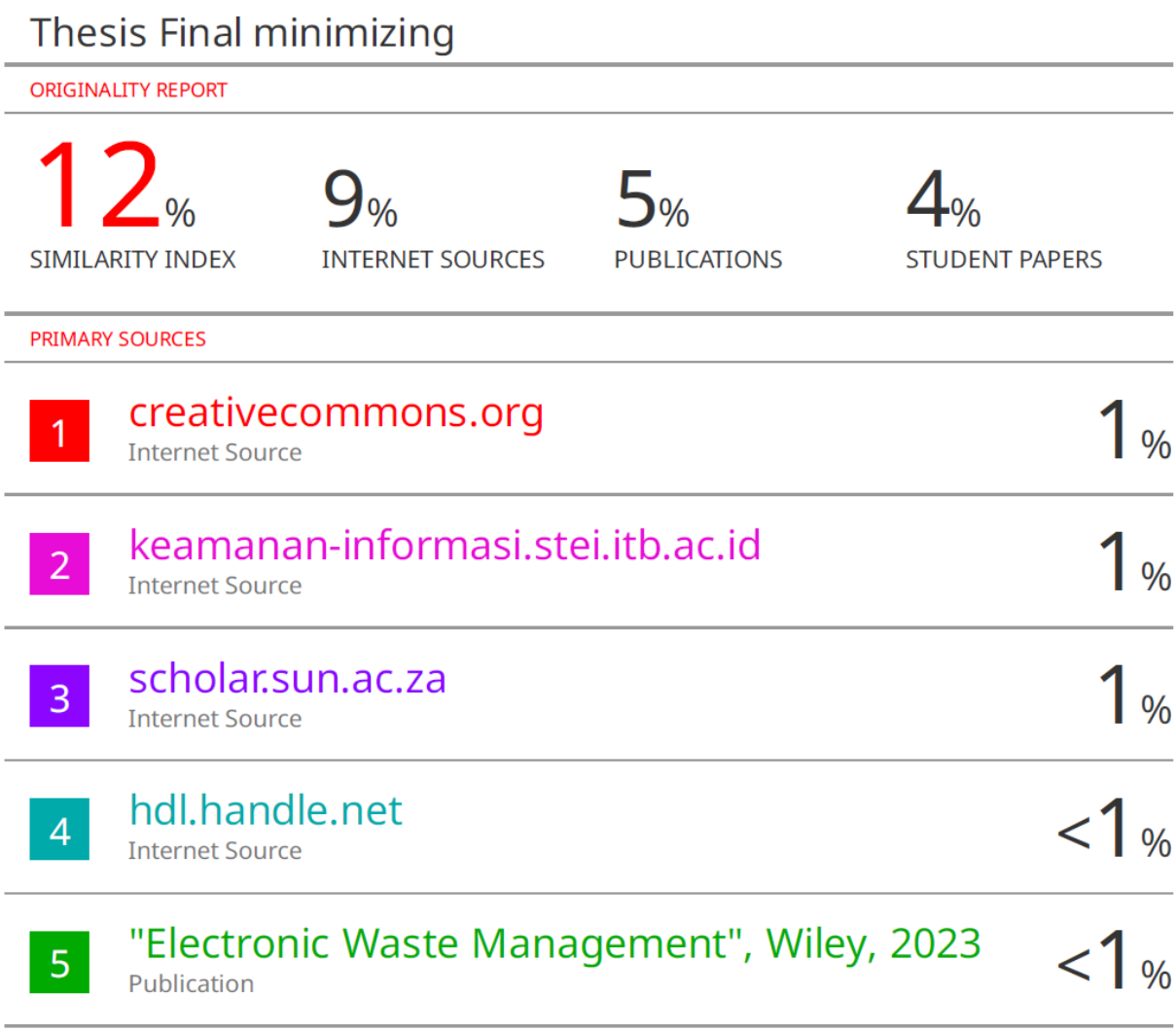
1. Do you know what e-waste is?
2. How do you dispose your e-waste?
3. Is there documentation or guidelines on dealing with e-waste in the municipality?
4. Do you have any means of transporting e-waste to recycling sites?
5. Do you collect e-waste from under-resourced villages, if yes how?
6. What do you think should be done to help with e-waste handling for under resourced villages?

SQ4: What strategies could be adopted in developing the cloud e-waste awareness solution?	**O4:** To adopt strategies in developing the cloud e-waste awareness solution.

1. Do you own a smartphone or computer/laptop?
2. Do you know what is meant by the term Internet?
3. Do you connect to the internet using your smartphone/ computer/laptop?
4. What elements of the internet can be used to help create the solution?

Anything else to add on the topic?

APPENDIX F Turnitin Report



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5	"Electronic Waste Management", Wiley, 2023 Publication	<1%

APPENDIX G Editing Certificate

DR PATRICIA HARPUR

B.Sc Information Systems Software Engineering, B.Sc Information Systems (Hons)
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To Whom It May Concern

This document certifies I have copy-edited the following thesis by Odwa Gazaba:

The Use of Cloud Technology to Promote E-Waste Awareness for Under-Resourced Villages in South Africa

Please note this does not cover any content, conceptual organisation, or textual changes made after the editing process.

Best regards

Dr Patricia Harpur

25 June 2024

APPENDIX H Generated themes and categories

Themes	Categories	Village A Sub-categories	Village B Sub-categories
Knowledge of e-waste	Lack of awareness	First time hearing of e-waste, has no knowledge of e-waste	No idea of what e-waste is, never heard of such type of waste
Environmental pollution	Soil and air pollution	No knowledge of dangers caused by carelessly disposing e-waste in landfills, no knowledge of the impact of e-waste on the environment, pullulated air by burning e-waste	Land is not safe to live on, endangers human lives and livestock, lack of access to clean water as e-waste is disposed in fountains and revers
Disposal Compensation	Monetary value	There should be incentives for handing in e-waste, ownership of e-waste items warrants incentives when handed in, the municipality should pay when collecting e-waste items.	
Education	Increase awareness	more awareness sessions, municipality should do the roadshows, use radio and television adverts to spread e-waste awareness, community to have monthly meetings	municipality to teach communities about the e-waste, make use of different platform to spread e-waste awareness, government to send out people to educate communities, integrate e-waste topic to schools
Health hazards	Danger to human health		had no knowledge of health complications caused by disposal of e-waste, the dangers of e-waste may harm lives, food poising