Evaluating E-waste management practices in buildings of the National Department of Public Works, South Africa

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PREFACE AND ACKNOWLEDGMENTS

The concept of sustainable solid waste management is linked to the Sustainable Development Goals (SDGs) (particularly goals 11 and 12), which aspire to improve waste management in all countries and commit to the prevention, reduction, re-use and recycling, and proper collection and disposal of waste by 2030. The National Waste Management Strategy, call from the Minister to submit and prepare Industry Waste Management Plans, and the recent Extended Producer Responsibility (EPR) regulations highlight the importance of sound electronic waste (E-waste) management. I was motivated to carry out this research because there is little analysis of how E-waste is managed in South Africa, especially by government departments.

I would like to thank Dr. Claudine Roos my supervisor for her support and assistance throughout the writing of this dissertation. Dr. Claudine Roos supported me greatly and kept on encouraging me to write my dissertation.

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I would like to thank both of my children for their support and courage. You were always there when I needed support. Let me not forget my grandchild who was there giving me support whilst I was busy with my research work. You always watched TV whilst I was busy until you slept in front of that TV.

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ABSTRACT

E-waste is a universal problem, and in 2014, approximately 41.8 million tonnes of e-waste was generated worldwide. In 2017, the Global E-waste Monitor also indicated that there was a 5% year on year increase in E-waste globally. Despite generating its own E-waste, Africa is also the recipient of E-waste from other continents, and many high-income countries deposit their waste, illegally, into poor African countries. The E-waste management problem is not only about the amount of E-waste generated, but also the failure to formulate and implement innovative ways to manage E-waste. Despite the well-known challenges of E-waste, there has been very little research on E-waste management practices in South Africa. This research, therefore, aimed to evaluate E-waste management practices in buildings of the National Department of Public Works (DPW), South Africa. Five DPW facilities located in rural and urban areas of Gauteng, the Eastern Cape and the Western Cape, were included in this research. Data was collected through a survey questionnaire with 130 respondents, supported by observations, document review and evaluation, and literature review.

The results indicate that there is a general lack of formalised arrangements and knowledge about proper E-waste management. E-waste is generally stored correctly, but inconsistent recordkeeping of collection and disposal of E-waste poses a challenges in terms of the compliance of DPW to legislation. Responses to open-ended questions highlighted seven main themes: uncertainty about E-waste management practices, need for training and awareness, need for standardisation (through procedures/policies), need for recordkeeping and need for improved transparency, the opportunity to implement the waste management hierarchy and the opportunity to generate income from E-waste.

Recommendations for improvement for E-waste management by DPW include the development of policies and procedures for E-waste managment, strengthening registries and recordkeeping, standardising E-waste management practices, enhancing knowledge transfer, training and collaboration, and improving monitoring and evaluation.

Keywords: *Electronic waste, E-waste, management practices, Department of Public Works, South Africa*

ABBREVIATIONS AND ACRONYMS

Al	Aluminium
BFRs	Brominated Flame Retardants
Cd	Cadmium
Cr(VI)	Hexavalent Chromium
Cu	Copper
DEA	Department of Environmental Affairs (now DFFE)
DEFF	Department of Environment, Forestry and Fisheries (now DFFE)
DFFE	Department of Forestry, Fisheries and Environment
DPW	Department of Public Works (South Africa)[1]
DRO	Dismantling and Recycling Office
DSI	Department of Science & Innovation
DST	Department of Science & Technology (now DSI)
DTI	Department of Trade & Industry (now DTIC)
DTIC	Department of Trade, Industry & Competition
ECA	Environment Conservation Act (Act 73 of 1989)
EEE	Electrical and Electronic Equipment
EIA	Environmental Impact Assessment
EU	European Union
EPR	Extended Producer Responsibility
E-waste	Electronic waste
eWASA	E-waste Association of South Africa (now the EPR Waste Association of South Africa)
E-WIK	E-waste Initiative Kenya
Fe	Iron

[1] Also known as the Department of Public Works and Infrastructure.

GNR	Government Notice Regulation
IndWMP	Industry Waste Management Plan
IT	Information Technology
MTSF	Medium Term Strategic Framework
NDP	National Development Plan
NEMA	National Environmental Management Act (107 of 1998)
NEMWA	National Environmental Management Waste Act (59 of 2008)
NWMS	National Waste Management Strategy
NWU	North-West University
OHSA	Occupational Health & Safety Act (Act 85 of 1993)
PCBs	Printed Circuit Boards
Pb	Lead
PRO	Producer Responsible Organisations
PVC	Polyvinyl Chloride
SANS	South African National Standards
SAWIS	South African Waste Information System
SDGs	Sustainable Development Goals
SMEs	Small and Medium-Sized Enterprises
WCMS	Waste Classification and Management Systems
WEEE	Waste of Electrical and Electronic Equipment

KEY DEFINITIONS

“Electronic waste (E-waste)” *waste electrical and electronic equipment (EEE).*

"Electrical and electronic equipment (EEE)” *equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current (Extended Producer Responsibility Regulations, Notice 1184 of 2020)*

“Recovery” *means the controlled extraction or retrieval of any substance, material or object from waste”* (National Environmental Management: Waste Act 59 of 2008 as amended).

‘‘Re-use” *means to utilise the whole, a portion of or a specific part of any substance, material or object from the waste stream for a similar or different purpose without changing the form or properties of such substance, material or object”* (National Environmental Management: Waste Act 59 of 2008 as amended).

“Waste” means –

(a) any substance, material, or object, that is unwanted, rejected, abandoned, discarded, or disposed of, or that is intended or required to be discarded or disposed of, by the holder of that substance, material, or object, whether or not such substance, material or object can be re-used, recycled or recovered and includes all wastes as defined in Schedule 3 to this Act; or

(b) any other substance, material, or object that is not included in Schedule 3 that may be defined as a waste by the Minister by notice in the Gazette, but any waste or portion of waste, referred to in paragraphs(a)and(b), ceases to be a waste—

(i) once an application for its re-use, recycling, or recovery has been approved or, after such approval, once it is, or has been re-used, recycled, or recovered.

(ii) where approval is not required, once waste is or has been re-used, recycled, or recovered.

(iii) where the Minister has, in terms of section 74, exempted any waste or a portion of waste generated by a particular process from the definition of waste; or

(iv) where the Minister has, in the prescribed manner, excluded any waste stream or a portion of a waste stream from the definition of waste (National Environmental Management: Waste Act 59 of 2008).

Note: The above definition of “waste” was in effect at the time of performing this research. Although the National Environmental Management Laws Amendment Act (NEMLA) of 2022 took effect on 3 July 2023, Section 61(k), which proposes the amendment of the definition of “waste” has not yet taken effect.

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CHAPTER 1 INTRODUCTION

1.1 Background

In 2017 the Global E-waste Monitor estimated that 41.8 million metric tonnes of electronic waste (E-waste) were produced globally in 2014, and if the 5% year-on-year increase is maintained, it was estimated that 52 million tonnes of E-waste would have been generated in 2020 (Forti *et al*., 2020). It is, however, reported that approximately 57.4 million tonnes of E-waste were generated in 2020, representing an increase of 21% over five years (Forti *et al*., 2020). It is estimated that E-waste will reach a generation rate of 74 million tonnes per annum by 2030 (Murthy & Ramakrishna, 2022). The International Telecommunications Union (2020) states that not only is the amount of E-waste a challenge, but the difficulty in developing and implementing solutions for managing it also poses challenges.

Murthy and Ramakrishna (2022) argue that governments need to keep up with current technological advancements, but the influx of new and updated electronic equipment leads to rapid obsolescence of existing electronics. Consequently, high generation rates of E-waste are an issue that need to be dealt with.

Asia, the Americas and Africa are the most significant contributors to E-waste (Wagner *et al.,* 2022). Additionally, Africa is disproportionately affected by E-waste due to increased levels of E-waste being illegally dumped in poor African countries (Wenwanne, 2019). All 54 countries in Africa are affected by the illicit import of E-waste and obsolete electrical items. Wenwanne (2019) maintains that Ghana and Nigeria are among the biggest receivers of E-waste from developed nations.

Masoabi (2020) in her dissertation focusing on *"Understanding public knowledge and awareness of e-waste management practices in Maseru, Lesotho"* found E-waste management practices are not always well-defined, leading to unsound E-waste management practices. Despite the well-known challenges of E-waste management, there has been very little research on E-waste management practices in South Africa. Even less is known about how E-waste is managed by the public sector in South Africa.

1.2 Problem statement and rationale for the study

E-waste management practices have become a global concern due to its potential for adverse environmental consequences arising from improper practices (Rajaram & Pekeur, 2014). In

South Africa, E-waste constitutes 5-8% of total municipal solid waste and is growing three times faster than other waste streams (Department of Environmental Affairs, 2018). Government institutions, including national departments, provincial departments, municipalities, and state-owned enterprises, together generate a significant amount of E-waste. Moreover, inadequate E-waste collection services and disposal practices continue to be widespread. Rajaram & Pekeur (2014) note that the growing rate of production and consumption of electrical and electronic equipment has resulted in considerable expansion of E-waste worldwide.

E-waste management has become a priority in South Africa due to the growing accumulation of this waste stream. The National Waste Management Strategy (NWMS) of 2011 recommended that research and attention should be focused on the issue of E-waste management (Department of Environmental Affairs, 2011). Heywood (2013) argues that it is the responsibility of the government to enact and execute policies to ensure the development of the state and protection of its core values. Therefore, it is necessary for South African government to formulate and implement policies for proper E-waste management. Such policies should focus on increasing awareness among citizens concerning E-waste management, encourage reducing E-waste production, and properly managing the disposal of E-waste.

E-waste has been classified as hazardous waste within South Africa. This is because of the range of materials, such as minerals, plastics, metals, and precious metals, integrated into such equipment which may vary in levels of toxicity and complexity (GreenCape, 2019; Finlay & Liechti, 2008). Evaluation of E-waste management in South Africa may elucidate the connection between institutions, policymakers, and interests and the actual E-waste management problems in South Africa. Evaluation of such practices is important as it explains the relationship between institutions, policymakers, and interests, and E-waste management challenges. This research is necessary due to rapid technological advancements, population growth, adherence to global commitments (SDGs) and the need for integrated waste management.

The National Department of Public Works (DPW) is a government department responsible for overseeing national government department infrastructure. The DPW comprises eleven regional offices and one head office, with a combined staff of approximately 7800 employees (National Department of Public Works, 2017). These offices purchase large amounts of electrical and electronic equipment, which contributes to the problem of E-waste generation and management in South Africa. E-waste management within the Department is undertaken by Movable Asset Management, IT, and Provisioning branches. Unfortunately, the National Department of Public Works does not have a means of accurately measuring and understanding the total quantity of E-waste produced. There is also a lack of formal procedures and work instructions outlining the

processes required for adequate E-waste management. Consequently, a great deal of E-waste is either stockpiled in warehouses, disposed of with general waste or burned. All these courses of action result in human health risks and environmental damage due to the hazardous materials present in E-waste (Osinbajo & Nnorom, 2007).

1.3 The research aims and objectives.

This research aims to evaluate E-waste management practices in buildings of the Department of Public Works in South Africa.

The research objectives included:

1. **Research objective 1:** *Evaluating E-waste management practices followed by the Department of Public Works in selected buildings.*

2. **Research objective 2:** *Providing recommendations for improvement of E-waste management practices based on lessons learned from other countries.*

1.4 Scope of the research

This research investigated electrical and electronic waste *(E-waste) management practices*[2] in the Department of Public Works (DPW) buildings in South Africa. No other waste types were included in the research. The scope of the research is limited to the Department of Public Work (DPW) buildings in South Africa. Five DPW facilities (buildings) located in different provinces were selected. These buildings comprise the National DPW office in Pretoria AVN Building, and CGO Building (Pretoria Regional Office) in Gauteng, Eben Donges Building (Gqeberha), and the Prd2 Building (Umtata) in the Eastern Cape, as well as the Customs House Building (Cape Town) in the Western Cape. These five buildings have been purposively selected to represent buildings located in different provinces, in both urban and rural areas. In each building, the following actions /processes were investigated: movable asset management, provisioning, IT, supply chain, workshop, facilities management, and real estate units. The research respondents included employees from these different directorates from the Department of Public Works and included a total of 130 participants.

[2] For the purposes of this research, the terms *E-waste management practices* and *E-waste management* are used interchangeably.

Data collection took place between March and August 2020, before *the Extended Producer Responsibility Regulations for the Electronic and Electric (WEEE) sectors* came into effect.

1.5 Contribution of this research

The concept of E-waste management aligns with the Sustainable Development Goals (SDGs) (particularly goals 11 and 12), which both aspire to improve waste management in all countries and commit to the prevention, reduction, re-use and recycling, and proper collection and disposal of waste by 2030. The National Waste Management Strategy, regulations for Industry Waste Management Plans, and the recent Extended Producer Responsibility (EPR) regulations highlight the importance of sound electronic waste (E-waste) management.

Therefore, this research contributes to the limited knowledge on E-waste management practice in South Africa. This research is essential as it will inform future policymakers, institutions, and private sector organisations on managing E-waste.

1.6 Structure and outline of the dissertation

This dissertation consists of five chapters.

Chapter 1 serves as the introductory chapter of this study. It provides a brief discussion on E-waste management in South Africa, and it presents the problem statement. In addition, this chapter outlines the research aim and research objectives that guide this study. Finally, this chapter also presents the motivation and significance of this study, as well as the research scope.

Chapter 2 provides the literature review and focuses on the growing E-waste problem, the negative impacts of E-waste, the potential benefits of E-waste, an overview of waste management practices, and the legal framework for E-waste management in South Africa.

Chapter 3 outlines the methodology followed and outlines the methodological design, data collection methods, data analysis method, and study limitations.

Chapter 4 provides the findings of this research, while **Chapter 5** outlines the conclusions and recommendations of the study.

1.7 Conclusion

Chapter 1 presented an overview of the research problem, aim, objectives and scope of the research. Chapter 2 will contextualise the research in terms of a literature review.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

According to McCombes (2021), a literature review refers to scholarly information on a particular topic. It provides an overview of existing information which allows the researcher to identify theories, applicable methodology, and gaps in the existing literature, allowing the researcher to develop questions and further objectives. The literature review chapter aims to contextualize the research and provide background to E-waste management and was conducted by using keywords and search terms such as "*electronic waste," "E-waste," "EEE waste," and "E-waste management"* in different combinations. The primary literature repositories used were Google Scholar, Scopus, Web of Science, and the North-West University Library dissertation and theses repository (Boloka). Although research and published literature on E-waste management on a global level could be found, literature on E-waste management in South Africa, focusing on public entity level (especially by government departments) was sparser.

Legislation was also reviewed to provide an overview of the requirements of E-waste management in South Africa. Reviewed legislative documents included the National Environmental Management Act, 107 of 1998 (NEMA), the White Paper on Integrated Pollution and Waste Management (2000), National Waste Management Strategy and Action Plans (1999), National Waste Management Strategy (2011, 2020), National Environmental Management Waste Act, 59 of 2008 (NEMWA), Norms and Standards for the Disposal of Waste to Landfill (GNR 636 of August 2013), the Extended Producer Responsibility Regulations (GNR 1184 of November 2020) and EPR Scheme for Electrical and Electronic Sector (GNR 1185 of November 2020) as amended.

This chapter first defines *"E-waste"* within the South African context and then presents a discussion of E-waste and its growing impact globally. It further expands on a discussion by assessing measures adopted by other countries to address the E-waste challenge. Second, it provides an overview of the South African E-waste crisis, waste data management, information, and accessibility. This chapter also focuses on policy and legal frameworks for E-waste management in South Africa. Finally, it reviews the E-waste management practices from other countries facing similar E-waste challenges, as lessons for future learning.

2.2 Defining electronic waste (E-waste)

There are many definitions of "*electronic waste or E-waste",* and it has been argued that only some of these definitions have been accepted globally (Khurrum *et al*., 2011).. Some literature suggests that E-waste is an *electrical appliance that no longer has use or satisfies the owner's desires* (Khetriwal *et al*., 2009), while others suggest that *E-waste is any electrical or technological item that no longer functions or is needed* (E-waste Africa, 2015) or *white goods and information technology that has reached its lifespan and is no longer desired by society* (Khurrum *et al*., 2011). The United Nations University (2015) defines E-waste as *"a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that the owner has discarded as waste without the intention of re-use."*

Forti *et al.* (2018:48) argue that *"a taxonomy for E-waste ought to sort products by comparable function, similar material composition, and related end-of-life features".* It can be inferred that products within the same category have a similar average weight and are likely to achieve similar life cycles of usage.

The definition for E-waste adopted for the purposes of this research is based on the South African legal definition of E-waste as outlined in the *Extended Producer Responsibility Regulations (EPR) for the Electrical & Electronic Equipment Sector* (GN. 1185 in Government Gazette 43880 of 5 November 2020 as amended, RSA 2020). The South African EPR regulations define E-wate as "*waste electrical and electronic equipment (EEE)"* and then defines *"electrical and electronic equipment"* as *equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current*.

2.3 Global E-waste management challenges

The Information and Telecommunications Technology (ICT) sector has been credited with improving the speed of technology and increasing the capacity of computers and other electronic devices (Ikhlayel, 2018). However, such growth has come with a cost, as it has caused products to lose value quickly (Boudier & Bensebaa, 2011). This, in turn, has resulted in large volumes of electrical and electronic waste being produced annually (Osibanjo & Nnorom, 2007). It is estimated that E-waste volumes generated increase by 5 to 10% each year (Ikhlayel, 2018). Households and businesses contribute significantly towards this high generation rate of E-waste, driven by the process of modernisation and rapid obsolescence (Ledwaba & Sosibo, 2017).

The global emergence of E-waste has been linked to numerous human health and environmental challenges due to the presence of toxins in the waste. E-waste disposal has been linked to effects on food production and supply, as the toxins may enter into the food chain and be ingested by humans (Kiddee *et al*., 2013). Additionally, the informal reclamation of E-waste components has been associated with a range of human health risks, such as respiratory conditions, neuropsychiatric issues, convulsions, comas, and even fatal incidents (Halluite *et al*., 2005). These health hazards also affect workers in the recycling industry.

E-waste management presents a significant challenge, particularly for developing countries (Heeks *et al*., 2015), which are also affected by the illegal transboundary movement of E-waste from developed countries. Furthermore, most of the E-waste produced locally is disposed of in uncontrolled landfill sites (Ledwaba & Sosibo, 2017). In developing countries, regulatory advances are slow, enforcement is low, and the collection and proper management of E-waste is poor. Therefore, E-waste has proven to be more challenging to manage in the Global South than in the Global North (Ledwaba & Sosibo, 2017).

Disposing of such E-waste proves to be complex as materials used in electronic products have become more difficult and expensive to recycle (Arora, 2008). Such products often contain hazardous substances such as lead, cadmium, beryllium, mercury, and arsenic, as well as toxic flame-retardants, PVC-containing plastics, printer cartridge inks, and toners (Arora, 2008). In addition, informal E-waste recycling is widely practiced, where electronic equipment is burned in open spaces to remove plastic and recover copper and other electronic components (Arora, 2008).

2.3.1 Growing volumes of E-waste generation

Several countries around the world have introduced policy goals, legislation, and guidelines for dealing with E-waste. Despite this, E-waste continues to be on an upward trajectory due to rapid global modernisation and increased consumerism (Finlay & Liechti, 2008; Ledwaba & Sosibo, 2017). E-waste generation continues to grow at a rate of three times more than municipal solid waste, and Ledwaba and Sosibo (2017:1) reports that volumes of E-waste generated are estimated to be increasing by 3 to 5% annually, since the 1990s.

Forti *et al.* (2018) showed that the European Union (EU) countries sold more than 9.3 million tonnes of electronics in 2008. According to Greenpeace International (2008), the number of electronic products being discarded is increasing by 30 to 50 million tonnes yearly. An analysis of E-waste production by Huisman *et al*. (2008) revealed that Germany was responsible for the

most E-waste generation in the EU, with 110 000 tonnes collected and recycled in 2007/2008. China also produced 2.4 million tonnes of E-waste in 2009, mainly derived from 25 million televisions, 5.4 million refrigerators, 10 million computers, 6 million printers, and 40 million cellular phones (Ongondo *et al*., 2010). In 2013/14, in the United Kingdom, an average of 21.8 kilograms of E-waste was produced per person per year, amounting to 1.4 million tonnes of E-Waste generated annually.

The Global E-waste Monitor (2017) estimates that 41.8 million metric tonnes of electronic waste (E-waste) were produced globally in 2014, and if the 5% year-on-year increase is maintained, it was estimated that 52 million tonnes of E-waste would have been generated in 2020 (Forti *et al*., 2020). It is, however, reported that approximately 57.4 million tonnes of E-waste were generated in 2020, representing an increase of 21% over five years (Forti *et al*., 2020). It is estimated that E-waste will reach a generation rate of 74 million tonnes per annum by 2030 (Forti *et al*., 2020).

2.4 Adverse impacts of E-waste mismanagement

According to Rajaram and Pekeur (2014), electronic waste (E-waste) is an increasingly serious environmental and health challenge. This is because E-waste contains hazardous substances such as lead (Pb), cadmium (Cd), hexavalent chromium (Cr(VI)), polyvinyl chloride (PVC) and brominated flame retardants (BFRs) which, if not disposed of responsibly, can cause adverse impacts to the atmosphere, soil and water, and detrimental effects to human health (Sthiannopkao & Wong, 2013). Furthermore, large amounts of E-waste are often disposed of illegally in uncontrolled or unengineered landfill sites where there is no monitoring or regulation, leading to further environmental and health risks (Rajaram & Pekeur, 2014).

2.4.1 Environmental impacts

According to Gaidajis *et al.* (2010), toxic chemicals released by electronic products during disposal in landfill can enter the environment in the form of leachate. Furthermore, informal E-waste reclamation practices involving the disassembling, shredding, burning, and acid-leaching of E-waste (Daum *et al*., 2017) magnifies the problem. Tran and Salhofer (2018) found that informal recycling facilities produce twice the amount of waste compared to formal recycling facilities due to the lack of efficient systems and technology for the storage, recycling, and pre-treatment of solid waste and wastewater prior to discharge.

Robinson (2009) suggests that the chemicals and compounds which are released from E-waste (i.e. lead, cadmium, chromium, PVCs, etc.) are non-biodegradable and can persist in the environment for prolonged periods, further increasing the risk of exposure. If these substances

reach groundwater, it can also become acidic, polluting groundwater resources. Chowrimootoo (2011) adds that such chemicals can seep into soil and be absorbed by plants, eventually entering the food chain and posing health risks to both animals and humans. Moreover, Olowu (2012) believes that E-waste mismanagement can also lead to climate change when emissions are released from the uncontrolled burning of E-waste. Damage caused by E-waste to ecosystems may be permanent and irreversable (Olowu, 2012).

2.4.2 Health impacts

According to Carlson (2016), exposure to E-waste-related toxic substances may cause a range of adverse health impacts, including cancer, kidney and liver dysfunction, hormonal imbalance, immune system suppression, musculoskeletal disease, congenital disabilities, premature births, impeded nervous and sensory system development, reproductive disorders, mental health problems, cardiovascular diseases, genitourinary disease, and dementia.

Cadmium compounds are known to accumulate in the human kidneys, and both cadmium and beryllium have been identified as potential cancer-causing agents (Chowrimootoo, 2011). Additionally, exposure to lead can damage the central nervous system and potentially disrupt normal reproductive functions (Chowrimootoo, 2011).

In addition to the toxic compounds found in E-waste, the noise exposure generated during the recycling process can lead to hearing loss (Carlson, 2016). E-waste workers also face a risk of physical injury while dismantling such products, especially under uncontrolled conditions during the informal reclamation of E-waste components (Raghupathy & Chaturvedi, 2013). Acid baths used to extract precious metals such as gold can cause chemical injuries to recyclers who lack the necessary protective clothing (Grant & Oteng-Ababio, 2013). Finally, workers dealing with E-waste may be exposed to polychlorinated biphenyls (PCBs) and other persistent organic pollutants (Grant *et al*., 2013), which may cause detrimental health effects.

2.5 Potential E-waste benefits

Mouton (2020) suggests that E-waste recycling and management can have a positive impact on social, environmental, health, and economic relief. The implementation of E-waste recycling has also enabled the generation of employment opportunities for many unskilled youth across the world (Rajaram & Pekeur, 2014).

Furthermore, the Extended Producer Responsibility (EPR) principles uphold the idea that manufacturers should be responsible for the entire lifecycle of a product (Rajaram & Pekeur,

2014). This includes components such as copper (Cu), iron (Fe), aluminum (Al), plastics, glass, and other precious metals that can be recycled. Arora (2008) argues that collected electronic products are often used for re-sale in the second-hand market, while others are dismantled and sent to Southeast China for recycling.

This E-waste trade chain also employs numerous informal workers, scrap dealers, and recyclers which allows for components to be used again. This value cycle is further emphasised by the World Economic Forum (2019), wherein they posit that the most sustainable way to use electronic products is to extend their life-cycle. This circular economic model promotes the re-use of resources, meaning that the value extracted from them does not have to be discarded (World Economic Forum, 2019). As a result, as electronic products are recycled, they are also potentially incorporated into the final product.

2.5.1 E-waste mismanagement

Finlay & Liechti (2008) noted that collection of E-waste occurs through both formal and informal means. In the informal sphere, E-waste has been salvaged from general waste for many years, notably on the roadside, at landfills and municipal collection points. Electronic cables are (illegally) burned and monitors and screens are broken to obtain copper and other metals. These metals are mostly sold to scrap metal dealers found in urban settings. In South Africa, burning and dumping of E-waste remains an issue, causing various types of pollution which threaten public health and the environment (Borthakur & Singh, 2017).

Illegal and informal recycling of E-waste remains a malpractice in many countries due to the lack of legislation, services, and practices for its management. Furthermore, dismantling E-waste has become more common due to the enabling environment created by the lack of supervision regarding the melting of circuit boards, open burning of wire piles, and discardment of metal-bearing acidic solutions (Borthakur & Singh, 2017).

E-waste management in South Africa is, therefore, primarily characterised by non-compliance with legislation and a lack of technical capacity to manage landfill sites (Uhunamure *et al*., 2021). Moreover, an absence of aggressive waste avoidance strategies leads to increasing volumes of E-waste produced (Uhunamure *et al*., 2021). In order to address this issue, it is important to know the volumes of E-waste generated in South Africa, as well as tackling the volumes of waste that are recycled, treated, landfilled, and exported (DEA, 2018).

2.5.2 Examples of E-waste mismanagement practices

The issue of E-waste mismanagement in developing countries has been prevalent for many years. The media and various environmental agencies have exposed the illegal and often clandestine dumping of E-waste, which has led to the exposure of people to hazardous toxins. This disregard for essential regulations, such as the Basel Convention, which was adopted in 1989 to regulate the transboundary movement of hazardous waste, has highlighted the need for improved E-waste management strategies in developing countries. Despite the implementation of various laws intended to counter such practices, there is still a need for improved or full functioning E-waste management legislation in many of these countries.

The sections below outline some examples of E-waste mismanagement in developing countries. The intent of the section is to be illustrative, rather than giving a full account of E-waste mismanagement within the global context.

2.5.2.1 Uganda

In Uganda, E-waste management presents numerous challenges mainly due to a lack of interest and awareness of its adverse effects on human health and the environment (Mugashe, 2009). Furthermore, similar to many developing countries, Uganda is yet to establish the required regulations for E-waste management. Consequently, there is no formal system of recycling, treating, and disposing E-waste (Nuwematsiko *et al*., 2021.). Additionally, Uganda does not have legislation that controls E-waste, nor does it have a formal collection system. The informal collection system is becoming prevalent as people are incentivised to trade it, and this means that Uganda lacks environmental health and safety measures (Maphosa & Maphosa, 2020). Moreover, E-waste in Uganda is often processed informally, which is not monitored, and poses a significant risk to human health as pollutants can be inhaled during the displacement of materials from E-waste (Nuwematsiko *et al*., 2021).

2.5.2.2 Bangladesh

In Bangladesh, the collection and management of E-waste remains largely underdeveloped and disorganised. According to Javed and Chakraborty (2018) the country does have a system of reusing and recycling E-waste. Most E-waste is discarded in landfill sites near informal settlements (Ananno *et al.,* 2021) .Many computers and mobile phones are disposed of in litter bins, while clinical E-waste is primarily disposed of in offices, with the remainder in litter bins and accumulators (Alam & Bahauddin, 2015). In addition, the population of Bangladesh largely

discards electronic products and appliances without any consideration for the potential environmental and sustainability impacts.

While Bangladesh is a signatory to the Basel Convention Prohibiting Transboundary Movement of Hazardous Waste (Alam & Bahauddin, 2015), lacking a comprehensive e-waste policy, the country only requires permission for the import of any type of E-waste and has only put forward a few basic restrictions (Ananno *et al*., 2021). It is, therefore, apparent that there is an urgent need for the government of Bangladesh to develop and organise a system for collecting and managing E-waste in order to reduce the negative implications of E-waste practices.

2.5.2.3 Brazil

Brazil has been identified as a major polluter, with the highest emissions on the South American continent (Araujo *et al.,* 2017). Commonly, disposal of E-waste has been practiced across the country, with much of the E-waste being handled as general waste and discarded in domestic landfill sites (Souza *et al*., 2016). Consequently, Brazil lacks proper E-waste recycling infrastructure, elevating the need to understand E-waste dismantling processes.

E-waste dismantling processes in Brazil are usually conducted through five channels: partnership with other companies, private collection services, voluntary delivery by consumers, acquisition by waste pickers, and through municipal partnerships (de Oliveira *et al*., 2019). In the majority of cases, E-waste pickers use rudimentary and unsafe processes to dismantle products. Once sorting and dismantling is complete, the E-waste material is exported to other countries for recycling.

Finally, it should be noted that Brazil's model of E-waste management largely relies on independent actions and does not detail any specific stakeholders responsible for the E-waste recycling programs. As a result, the formal and informal collection rates of E-waste remain relatively low in the country (de Oliveira *et al*., 2019).

2.6 Best practices and lessons learned from developed countries

According to Sthiannopkao and Wong (2013), the management of E-waste in developed countries is regulated by international conventions, laws, and directives, primarily based upon the Extended Producer Responsibility (EPR) approach. In most developed countries, the management of E-waste includes three elements: a national registry, a collection system, and logistics (Sthiannopkao & Wong, 2013). The national registry contains a listing of producers and their associated collection responsibilities. This registry is typically kept by various governmental

agencies in order to monitor which producers are upholding their obligations. The collection systems within these nations may be either non-profit and/or non-governmental.

Typically, the government sets rules governing allocation and monitoring, as well as distributing the national registry to a coordinating body to determine producer obligations and establish e-waste collection points. Following the collection of the E-waste, dismantling, pre- and end-processing steps are then employed to ensure its safe disposal and/or recycling (Sthiannopkao & Wong, 2013).

The sub-sections below outline some best practices for E-waste gleaned from China, Japan and Switzerland. The intent of the sub-sections is not to give a full account of all best or good practices related to E-waste management, but rather to provide guidance and illustrative examples.

Section 2.7 and its sub-sections gives an account of good practices from developing countries.

2.6.1 Lessons from China

According to Wang *et al.* (2008) the E-waste collection system prevalent in China provides for the inclusion of informal waste collection, which is responsible for a high number of collectors who can access a vast majority of households. The system provides a lucrative avenue for those who wish to make money via the reuse and recycling of E-waste materials.

Additionally, the Chinese Government prohibits individuals and organisations that are not listed under the E-waste Dismantling System from conducting E-waste management activities. By way of the Regulations on the Administration of Recycling and Treatment of Waste Electric and Electronic Equipment (Decree of the State Council, No.551, effective since January 2011), it has been mandated that individuals must possess a license and qualification that would enable them to engage in proper E-waste management. This is outlined in the requirements to be registered on the E-waste Dismantling Enterprise List and to receive an E-waste license, both of which are issued by local environmental protection bureaus (Wang *et al*., 2021).

2.6.2 Lessons from Japan

In Japan, the Extended Producer Responsibility (EPR) requirements for E-waste management was established in the early 1990s through the *Law on Promotion of Effective Utilisation of Resources* and the *Law on Recycling of Specified Kinds of Home Appliances*. The emphasis of the laws was on improving recycling methods, minimising E-Waste generation from both manufacturers and consumers, and assigning responsibility (Sthiannopkao & Wong, 2013).

Consumers are liable for recycling fees while the local government is responsible for collecting the disposed E-Waste. Retailers provide collection points while manufacturers must undertake the recycling effort.

Additionally, many computer and other Information and Communication Technology (ICT) device manufacturers offer take-back programmes even in the absence of a mandated law. As a result of these initiatives, Japan has achieved a collection rate of 74%, as reported by Sthiannopkao & Wong (2013). Statistics suggest that in 2019, the E-waste sector in Japan had around 1.47 million employees (Dhir *et al*., 2021), significantly contributing to the economy in the country.

2.6.3 Lessons from Switzerland

Switzerland is widely considered a global leader in E-waste management. Khetriwal *et al.* (2009) assert that citizens and the government have a successful cooperative relationship in this regard. Moreover, the Swiss government has established a stringent system for persons who violate waste management legislation (Ali & Shirazi, 2022).

Switzerland was one of the initial EU nations to implement the extended producer responsibility (EPR) approach, which enabled the government to levy consumers with an advanced recycling fee. This fee is used for the conduction and management of all E-waste processes. Furthermore, manufacturers and importers require the equipment sold in Switzerland to be accessible on return. Because consumers pay the ARF, the end customer can return the equipment for free to the manufacturer. Switzerland achieved high recycling rates by engaging the four PROs focused on different E-waste devices (Islam & Huda, 2019.). According to the 2017 statistics, the EPR approach successfully facilitated 73% of E-waste recycling, and further improved the state's collection system (Islam & Huda, 2019). To promote international learning, the Swiss Institute for Materials Science & Technology was founded to share global knowledge on E-waste management. It was meant to extend developing countries, allowing all stakeholders to engage in mutual learning (StEP, 2008).

2.7 Best practices and lessons learned from developing countries

Many African nations are aware of the risks associated with inadequate E-waste management but often lack the necessary legal and infrastructural frameworks, as highlighted by Baldé *et al.* (2017). Moreover, only a handful of these countries possess official documents dedicated to E-waste management. While most African countries have ratified the Basel Convention, the majority have not incorporated its provisions into domestic legislation to regulate the handling of

hazardous waste streams. This section will delve into E-waste management practices in developing nations.

2.7.1 Rwanda

Kigali, Rwanda's capital, stands as one of Africa's cleanest cities due to its effective waste management system (Kabera, 2020). In Rwanda, E-waste management is primarily the responsibility of private sector organizations, while the city authorities in Kigali oversee general waste management (Twagirayezu *et al.,* 2021). Kabera (2020) emphasises that the success of Kigali's waste management is primarily governance-oriented, rather than driven by technical factors. Kigali has adopted the Umuganda model, which serves as a benchmark for urban cleanliness and its associated advantages (Rutebuka *et al.,* 2015.). E-waste management practices in Rwanda primarily revolve around the Umuganda model, which is enforced through the vigilant implementation of by-laws by community policing committees and other agencies, extensive educational and awareness campaigns, as well as waste-to-energy programs and partnership models that engage citizens and the private sector in environmental preservation efforts (Kabera, 2020).

2.7.2 Botswana

Private environmental protection firms in Botswana have undertaken initiatives to enhance the recovery rate of E-waste, including used toners. The country boasts specialised companies and non-governmental organizations actively engaged in solid waste management (Mmereki *et al.,* 2015). These activities encompass the collection, transportation, and disposal of solid waste, typically managed by municipal authorities. This arrangement entails the same organization handling administration, supervision, and operation of solid waste disposal. Generators of waste also bear responsibility for collection, transportation, and disposal, while providing reports to the government. Nevertheless, there remains a pressing need for the development of an E-waste policy framework, improved collection infrastructure, and the promotion of public awareness among government departments, private institutions, collection systems, households, and consumers of electronic products (Mauco *et al*., 2016).

2.7.3 Kenya

Present trends in E-waste management involve source segregation, where some organizations segregate waste on-site and hand it over to service providers for further treatment. In certain households, source segregation occurs, but waste mixing may happen during collection (Tocho & Waema, 2013). Currently, E-waste is not separately collected from other waste streams.

Collection centers, which are either individual, joint, or registered society entities, have been established. These centers can be owned by a designated agency, a company, or an association responsible for E-waste collection operations. The established collection centers contract or subcontract E-waste collectors, often referred to as 'scavengers,' to provide them with the waste (Bimir, 2020). Once general waste is collected at designated locations, the contracted service providers gather and transport it to disposal sites and recycling facilities for processing (Kiinga *et al*., 2022).

The E-waste Initiative Kenya (E-WIK), an NGO founded in 2015, is responsible for e-waste management in the informal sector. They provide safe disposal options across the country at different networks. E-WIK focuses strongly on stewardship, community initiatives, and incorporation of the informal sector (E-WIK, 2023)

2.8 E-waste management in South Africa

In South Africa, the E-waste industry is still developing, and several barriers continue to impede its progress. One of the major challenges delaying the development of E-waste management strategies is the lack of baseline data (Ledwaba & Sosibo, 2017). Limited research has been undertaken to gain quantitative and qualitative data on E-waste, making it difficult to accurately assess the situation in South Africa (Uhunamure *et al*., 2021). E-waste management in South Africa is still, in many instances, characterised by illegal management and disposal of E-waste, with waste reclamation practices still being mostly informal. Fortunately, the country has now recognised E-waste as one of six waste streams requiring further investigation (Ledwaba & Sosibo, 2017).

Section 2.8 and its sub-sections provide a more detailed account of E-waste management in South Africa, since it is the country in which the research for this dissertation was conducted.

2.8.1 E-waste generation in South Africa

E-waste is estimated to contribute roughly 8% to the total amount of municipal solid waste in South Africa and is expected to increase dramatically over the next few years (Andeobu *et al*., 2021). In the last 50 years, technological advancements and population growth have been significant in South Africa, with the population rising from 30 million in 1970 to 58.8 million in 2019. According to the 2018 State of Waste Report, released by then-Department of Environmental Affairs (DEA), a total of 44 million tonnes of waste was produced in South Africa in 2017 (DEA, 2018). Of this, approximately 300 000 tonnes were E-waste. Notably, just 12% of this waste was

recycled, with much of it being landfilled, recovered by waste pickers, or illegally dumped (Sadan, 2019).

Furthermore, a study published in 2020 revealed that at least 461 000 tonnes of E-waste was generated in South African in 2019 (Forti *et al*., 2020). Despite this consistently increasing rate of waste generation, E-waste recycling rates remain below 10%, a problem common across South Africa and many developing countries (Andeobu *et al*., 2021). There has been a rapid increase in the tonnages of E-waste generated in South Africa from 2016 to 2019 (DEFF, 2020a). Table 2-1 provides an overview of the major categories and types of E-waste generated in South Africa, indicating that that E-waste emanates from numerous electronic gadgets used globally in different sectors, organisations, and businesses.

Table 2-1: Major categories and types of E-waste generated in South Africa (Source Mouton, 2020: 86, Lydall *et al.,* 2017)

E-waste Category	Examples
Small household appliances	Vacuum cleaners, coffee machines, toasters, irons
Large household appliances	Washing machines, refrigerators, dryers, air conditioners
Office, information, and communication technology (ICT) equipment	PCs, laptops, mobile phones, fax machines, printers, and photocopiers
Consumer electronics and entertainmentequipment	Televisions, VCR/DVD/CD players, hi-Fi sets, radios, train sets, coin slot machines, parking ticket equipment
Lighting equipment	Fluorescent tubes and lamps, sodium lamps
Electrical and electronic tools	Drills, electric saws, sewing machines, lawnmowers, extensive stationary tools, machines
Security and healthcare equipment	Surveillance and control equipment, medical instruments, and equipment
Mixed waste electrical and electronic equipment	Various E-waste

2.8.2 E-waste management in South Africa

Rajaram and Pekeur (2014) reports that WEEE (or E-waste) remains the fastest-growing form of waste in South Africa as the general population's access to electronic goods, especially mobile phones, has increased in the last decade.

In 2008, the Government of Switzerland and the KwaZulu-Natal Department of Agriculture collaborated to initiate the Dismantling and Recycling Office (DRO) in Cedara, KwaZula-Natal as part of a pilot project concerning E-waste recycling. This endeavour led to further investigations on effective E-waste management practices. Consequently, the e-Waste Association of South Africa (eWASA) was established as an outcome of this collaboration.

eWASA (e-Waste Association of South Africa) is a non-profit organisation that works to promote the safe handling and management of E-waste in South Africa. eWASA's main aim is to reduce E-waste pollution as well as to reuse and recycle E-waste where and whenever possible. eWASA works closely with all stakeholders in the E-waste sector including recyclers, collectors, manufacturers, government, civic organisations, and media. Through its advocacy and awareness campaigns, eWASA works to increase informed decision-making among households and businesses about the disposal and handling of E-waste, as well as to educate the public about the potential harms of improper E-waste handling. eWASA also provides training programmes for stakeholders engaged in E-waste management and helps to develop strategies and best practices to ensure the safe handling of E-waste (eWASA, 2023).

In South Africa, most of the E-waste processing is done by the private sector, which responded instinctively to the profit potential of recycling discarded technology. Scrap metal recycling – including white goods such as fridges and washing machines – has been a growing concern in the country for some time, as has the refurbishment of computers for use in social projects, including in schools in disadvantaged communities (Finlay & Liechti, 2008).

The informal reclamation of E-waste, especially in rural areas, remains a concern, because mechanisms for recycling E-waste have yet to be developed in many parts of South Africa (Ledwaba & Sosibo,2017). South Africa still needs to establish the necessary collection, recycling and refurbishment infrastructure for E-waste and roll it out in the country (Rajaram & Pekeur, 2014:2). The EPR ensures that producers take responsibility for the life cycle of the products they put into the market, right through to post-consumer waste disposal. This move is transformative, because up until this EPR regulation was passed the cost of waste collection and disposal was placed squarely on the public ,citizens, and local government. With the producers now financially and/or operationally responsible for their waste, it is hoped that this waste will be increasingly diverted from landfills and more recycling and other circular economy activities will gain momentum. The amended EPR regulations for paper and packaging, E-waste and lighting were published on 5 May 2021. For the most part, the development of EPR plans has been tasked to various existing industry Producer Responsibility Organisations as allowed for in the regulations.

With the development of EPR plans underway, the focus now falls on the submissions and ability of the Producer Responsibility Organisations (PROs) to meet the legislative requirements.

2.8.3 E-waste management challenges in South Africa

In South Africa, small and medium sized enterprises (SMEs) generally focus on collection and processing of E-waste. Unfortunately, mobilising workers in the informal waste economy has proven to be a formidable task, since 92% of cooperatives fail, leading most to return to landfills as independent workers (Godfrey & Oelofse, 2017: 6). These marginalised collectors do not have a unified voice to negotiate with municipalities and other parties along the value chain. Furthermore, research reveals internal power struggles occurring over landfill access, with influence coming from both network and criminal syndicates (Lambrechts & Hector, 2016).

E-waste recycling in South Africa is currently low, with only about 11% of E-waste recycled (Lydall *et al*., 2017). Efforts have been put forth to increase this rate to 20% within the next five years (Grant, 2019). According to Mouton & Wichers (2016), the formal waste sector currently recycles approximately 20%, while 70% of South Africa's E-waste is in “storage”.

E-waste recycling is in many instances not considered a profitable activity to pursue as a stand-alone business, with many firms viewing it as a secondary activity (Lydall *et al*., 2017). In order to make a profit, many small dismantlers often combine recycling with more profitable refurbishment. The bulk of E-waste (55%) is processed by Gauteng-headquartered firms, many of which have branch offices in Cape Town (Lydall *et al*., 2017). The most valuable fractions are usually exported for further processing; PCBs to Europe, Asia, and Canada; phosphors powder to Europe; and ferrous and non-ferrous metals to Asia (Lydall *et al.,* 2017).

E-waste management in South Africa, however, still remains a challenge. The most common E-waste challenges include poor public awareness of E-waste management practices; a lack of funds and investment in E-waste alternatives to landfill; and a reluctance of consumers and businesses to hand over or pay for their defunct E-waste (Nivedha & Sutha, 2020).

The South African legal framework for E-waste management has, however, progressed over time with an aim to address these E-waste management challenges.

2.8.4 Legal Framework for Managing E-waste in South Africa

Table 2-2 provides an overview of the key legal requirements for managing E-waste in South Africa. Table 2-2 focuses on generic waste management legislation, as well as legislation

specifically and explicitly applicable to the management of E-waste in the country. The overview focuses on current legislation applicable to E-waste management and does not provide a historical overview.

Table 2-2: Summary of the key legal requirements for E-waste management in South Africa

Legislation	Summary of provisions and obligations
The Republic of South Africa Constitution Bill of Rights 1996 (RSA, 1996)	It contains fundamental environmental rights, and the distribution of powers to different levels of government is given.
National Environmental Management Act, 107 of 1998 (NEMA) (RSA, 1998)	The NEMA is the framework Act for environmental management in South Africa. It provides principles for integrated environmental management in Section 2, such as "duty of care", "pollution prevention", "polluter pays", "waste management hierarchy" to name a few. These are applicable to the management of E-waste in South Africa.
National Waste Management Strategy and Action Plans (RSA, 1999) and White Paper on Integrated Pollution and Waste Management (RSA, 2000)	The National Waste Management Strategy and Action Plans of South Africa (1999) were created to develop and implement an integrated approach to managing the country's solid and hazardous waste. The strategy acknowledges that waste management is a key component of sustainable environmental management, and that the proper management of waste minimizes health risks, pollution and environmental damage The White Paper on Integrated Pollution and Waste Management (2000) of South Africa focuses on pollution and waste minimisation, resource conservation, institutional capacity building, and the development of regulatory schemes and incentive structures to support more sustainable, integrated pollution and waste management practices.
National Environmental Management Waste Act, 59 of 2008 (NEMWA) (RSA, 2008)	The NEMWA regulates the management of E-waste in South Africa by setting requirements for those activities that generate, collect, store, transport, treat, dispose, or deal in waste (including E-waste)
Norms and Standards for the Disposal of Waste to Landfill (GNR 636 of August 2013) (DEA, 2013)	GNR 636 prohibits the landfill disposal of hazardous Waste Electric and Electronic Equipment (WEEE) lamps (since 2016) and the disposal of other hazardous WEEE (since 2021).

Legislation	Summary of provisions and obligations
Call on the paper and packaging industry, electrical and electronic industry, and lighting industry to prepare and submit industry waste management plans to the Minister for approval (GN 1353 December 2017) (DEA, 2017)	GN. 1353 requires the electrical and electronic industry to prepare industry waste management plans for approval by the Minister. The contents of an industry waste management plan are outlined in GN. 1353.
Extended Producer Responsibility Regulations (GNR 1184 of November 2020) and EPR Scheme for Electrical and Electronic Sector (GNR 1185 of November 2020) as amended (DEFF, 2020b)	The regulations provide the requirements for extended producer responsibility (EPR) and for developing EPR schemes for the electrical and electronic sector. ***This research was conducted between March and August 2020, before the EPR regulations came into effect in South Africa.*

2.8.4.1 NEMWA and the National Waste Management Strategy (NWMS) and E-waste

The National Environmental Management Waste Act No. 59 of 2008 was introduced to control the illegal dumping of waste to protect public health, with a focus on waste management services, integrated waste management planning and implementing the waste management hierarchy (Finlay & Liechti, 2008). Electronic waste is not specifically mentioned in the NEMWA itself, but it is, however, addressed in the National Waste Management Strategy (NWMS) and other specific regulations mentioned below.

The main aim of the National Waste Management Strategy was to develop and set targets for waste reduction and re-use, recycling, and recovery. The 2011 NWMS mentioned that industry waste management plans (IndWMPs) will be requested for selected electronic waste streams and batteries. Under Goal 3 of the 2011 NWMS, there was also a target aimed at *"developing an Import Export Policy for waste and Near End-of-Life Electronic Equipment"* (DEA, 2011: 71).

The NWMS 2020 is a revision of the 2011 strategy. It is aligned and responsive to Sustainable Development Goals and the National Development Plan (NDP) (DEFF, 2020a) and considers priorities outlined in the Medium-Term Strategic Framework (MTSF). The 2020 NWMS promotes the circular economy concept. It is premised on the three pillars (*waste minimisation, effective*

and sustainable waste services, and compliance, enforcement, and awareness) that will promote a culture that is intolerable of illegal dumping, littering, and pollution, clean communities, financially sound and adequately managed waste services, and zero waste to landfills.

Pillar 1 of the 2020 NWMS, further, provides for the minimization of hazardous waste and makes explicit mention of “Waste, Electric and Electronic Equipment” as part of this objective (DEFF, 2020a: 39).

2.8.4.2 GNR 636 and landfilling prohibitions on E-waste

The Norms and Standards for the disposal of waste to landfill (GNR 636 of August 2013) determine the requirements for the disposal of waste to landfill and prohibits the landfill disposal of hazardous Waste Electric and Electronic Equipment (WEEE) lamps (since 2016) and the disposal of other hazardous WEEE (since 2021) (DEA, 2013).

The disposal of these E-wastes is therefore, prohibited, even if it may be included as part of permissible wastes as part of landfill site waste management licences.

2.8.4.3 Industry waste management plans for E-waste

NEMWA Section 28 provides for Industry Waste Management Plans (IndWMPs). The IndWMP is a planning instrument identifying how the industry will manage a specific waste stream. The IndWMP allows the industry to set out the additional standards it will meet for waste management activities and how it will adhere to these. The IndWMP will commit the industry to targets for waste management, which may include recycling, recovery, re-use targets, or, in some cases, waste collection targets depending on the waste stream. The industry will be required to report on these agreed targets, which will indicate the success or not of the plan (RSA, 2008).

In December 2017, the Minister published a notice (GN 1353 of December 2017) requiring the paper and packaging industry, electrical and electronic industry, and lighting industry to prepare and submit industry waste management plans for approval. The implication is that the waste generator must either prepare and submit an Industry Waste Management Plan to the Minister for approval within nine months of the publication of the notice or formally subscribe to an Industry Waste Management Plan approved by the Minister (DEA, 2017).

Following the publication of the call for IndWMPs to be developed, the Minister must have retracted this call to move away from Section 28 Industry Waste Management Plans towards Section 18 Extended Producer Responsibility (EPR) Schemes.

2.8.4.4 Extended Producer Responsibility Regulations and EPR Scheme for Electrical and Electronic Sector

In November 2020, government published the Extended Producer Responsibility Regulations (GNR 1184 of November 2020) and EPR Scheme for Electrical and Electronic Sector (GNR 1185 of November 2020) (DEFF, 2020b). These regulations were amended in May 2021.

The Regulations require an EPR scheme with related fees to be established and applied proportionally to all members by the producer responsibility organisations, or by an individual producer that establishes their fee. According to Moyo e*t al*. (2022), the new EPR regulations in terms of Sections 18 and 69 emphasise that electrical and electronic equipment must be reduced, recycled, and re-used to ensure that the aims of the National Waste Management Strategy are met.

2.9 Chapter summary

This literature review chapter has established that local and global stakeholders generate E-waste. Currently, the rate of E-waste is increasing sharply in developing countries due to urbanisation, modernisation, and increased consumer behaviour. The chapter outlined the global E-waste management challenges, the adverse impacts of E-waste mismanagement and E-waste management in South Africa. It provided a brief overview of the legal requirements applicable to E-waste management in South Africa. It also provided some lessons learned from developed countries, who have addressed E-waste management in a positive way. Chapter 3 provides the methodology followed to achieve the research aim.

CHAPTER 3 METHODOLOGY

3.1 Introduction

Chapter 3 outlines the research methodology. According to Maguire and Delahunt (2017), research methodology is a *"strategy or design by which the researcher maps out an approach to problem-finding or problem-solving"*. This chapter begins with the research design and research approach followed in the study. A discussion on data collection, sampling, and analysis then follows this.

3.2 Research design

Research design is defined as a procedure used for collecting data, analysing, and interpreting as well as reporting data in any research that is being carried out (Creswell, 2007). In addition, it is understood as an overall strategy that defines the procedure that must be followed to collect required data, analyse information, and ensure that the research question is answered (Grey, 2014).

This research aimed to evaluate E-waste management practices in buildings of the Department of Public Works in South Africa. For this purpose, a mixed methods approach, using both qualitative and quantitative approaches were employed. Creswell (2014) argues that the qualitative research approach provides the researcher with a clear understanding of individuals and groups, thus playing a critical role in the investigation of social challenges within a natural setting, focusing on aspects such as situations, processes, systems, and relationships in addition to individuals. Similarly, LaMarre and Chamberlain (2021) posit that it is particularly related to interpretation, thus facilitating the development of new concepts and a theoretical understanding of the study phenomenon. In terms of this current study, the qualitative research approach was utilised in order to gain insights into people's experience with E-waste management practices, through undertaking interviews and observing practices in the Department of Public Works.

Conversely, the quantitative research approach is used to generate a generic representation of an event or an activity, emphasizing the measure of statistical, mathematical, and numerical data collected through questionnaires, polls, and surveys (Bacon-Shone, 2022). In the case of this research, quantitative data included the reporting of E-waste quantities/volumes generated, stored, and managed.

Table 3-1 outlines the research design to address the research objectives.

Table 3-1: Research design employed to meet the objectives of this research.

Research objective	Data collection	Justification
Research objective 1: Evaluating the E-waste management practices followed by selected Department of Public Works (focusing on E-waste quantities, separation and storage practices, and final disposal practices)	**Semi-structured questionnaire** focusing on: • The existing E-waste management practices followed in the buildings of the Department of Public Works (DPW). • Volumes and types of E-waste. • The storage, separation, and final method used to dispose of E-waste. This was the main method of data collection. Surveys were supplemented by observations and document review, as far as possible. **On-site observations and verifications** were used to assess daily operations of waste management activities in DPW, using checklists (Patton, 2002) **Document review** to determine E-waste Management in practices and compliance to legislation.	Creswell *et al.* (2006) argues that questionaries can provide a qualitative and quantitative response to the researcher's questions. It is, however, advised that self-reported data should be supplemented by other sources (i.e. observations and verification of information).
Research objective 2: Providing recommendations for improvement of E-waste management practices based on lessons learned from other countries	**Literature review** Academic literature was used to gather information on E-waste practices in South Africa, Africa and globally. Lessons learned from developing countries are used to provide opportunities for improvement of E-waste management by the DPW.	Best practices from international literature were identified, focusing on E-waste storage, re-use, recycling, and disposal. These practices provided a baseline for understanding E-waste management practices in South Africa.

3.3 Selection of cases (DPW facilities/buildings)

Due to limited time and resources available to conduct this research, and the participant's willingness to be involved. Five buildings (out of a total of twelve) were purposively selected based on the following criteria:

- The buildings had to be involved in the management of E-waste.
- The buildings had to be representative of more than one province in South Africa.
- The buildings had to represent both urban and rural areas; and
- The buildings had to have sufficient participants willing to partake in the research.

The five DPW facilities included in the research are outlined in Table 3-2.

Table 3-2: DPW facilities selected for inclusion in the research.

Department of Public Works Building	Location	Province	Rural/Urban
National DPW office (AVN Building)	Pretoria	Gauteng	Urban
Gauteng Regional Office (CGO Building)	Pretoria	Gauteng	Urban
Eben Donges Building	Gqeberha (PE)	Eastern Cape	Rural
Prd2 Building	Umtata	Eastern Cape	Rural
Customs House Building	Cape Town	Western Cape	Urban

The following departments/processes were included for each of the buildings selected: movable assets, management, provisioning, IT, supply chain, workshop, and facilities and property management.

3.4 Selection of research participants

Purposive sampling was used for the purposes of this research. The participants targeted for this research were employees (preferably those involved in waste or E-waste management) working in the five selected Department of Public Works buildings included in the research.

A total of approximately 7800 employees were employed by the five DPW facilities included in the sample when conducting this research. The Andrew Fisher formula was used to calculate the representative sample size based on the total population of employees of 7800 a confidence level of 95%, and a standard deviation of 0.5. A sample size of 367 respondents was calculated.

3.5 Data collection

Data was collected between March and August 2020 through a survey questionnaire to a sample of participants (DPW employees) from different DPW facilities in South Africa to enable the researcher to determine the E-waste management practices in these buildings. The responses from the survey questionnaire were supplemented by observations (Section 3.5.2) and document review (Section 3.5.3).

3.5.1 Survey questionnaire

Surveys are employed to determine the attitudes and perceptions of respondents and to gather information on a particular topic. Survey questionnaires are usually distributed to a selected group who has sufficient knowledge and experience in a particular topic, in this case DPW employees directly or indirectly involved in E-waste management. According to Mathers *et al.* (1998) survey questionnaires are a convenient way of collecting valuable data from a large sample, but this can only be achieved if the questions are clear, precise and are asked consistently as there will be no opportunity to clarify misunderstandings after the researcher has left. Survey questionnaires also increase the reliability of responses when filled in the absence of the researcher, especially if the topic is sensitive (Bloch *et al*., 2011). In this case, the participant will be free to answer honestly. Questionnaires can be sent/returned by post or email, administered directly to participants, or completed online (Bloch *et al*., 2011). The challenge is, however, to retrieve the survey responses from the participants once distributed.

Questionnaires for this study were administered directly (face-to-face) to the chosen participants by the researcher, and collected immediate after completion. With this approach, the researcher is more likely to achieve a higher response rate than they would have had they used a postal/e-mailed survey.

3.5.1.1 Developing the survey questionnaire

For the purposes of this research, a survey questionnaire aimed at gathering information on E-waste management practices were developed. The questionnaire is appended to Annexure A, and comprised of two different sections. The first segment of the questionnaire assessed the participants' demographic information, such as gender, age, education level, and their current roles/ responsibilities in the DPW facilities. The second part posed questions related to the E-waste management practices in each building. The questionnaire posed questions in relation to the management of E-waste throughout the entire waste management life cycle – i.e., generation, storage, handling, transportation, disposal, etc.

3.5.1.2 Piloting/testing the survey questionnaire

The questionnaire was piloted to determine whether the respondents would understand the questions and their intent. As part of the piloting process, the questionnaires were administered to five employees involved in E-waste management at the Department of Public Works. One of the employees made some suggestions around the structure of the draft questionnaire and phrasing of questions, which were taken into consideration. The pilot study results were merely used to revise and modify questions that needed to be clarified to participants before officially administering the questionnaire. These responses were not included as results of this research.

3.5.1.3 Administering the survey questionnaire

Different building managers from DPW granted permission to administer the survey questionnaire to the sampled participants. The purpose and background of the research were detailed to all participants during the questionnaire/survey process. Survey participants were also required to provide informed consent (**Annexure A**). The researcher made use of a combination of electronic and hard-copy questionnaires. Responses to electronic questionnaires were captured immediately, while hard copy questionnaires were administered and collected later, which was agreed upon between the researcher and respondent(s).

3.5.1.4 Demographic information of survey respondents

The research targeted a minimum of 367 participants from five DPW facilities in South Africa (see Section 3.4). A total of 130 participants responded to the research (35% response rate). Considering the fact that limited research has been done in South Africa on E-waste management practices, the responses from the 130 participants were deemed to be invaluable to this research.

Table 3-3 provides the socio-demographic information of the 130 survey respondents.

Table 3-3: Socio-demographic information of research respondents (n = 130).

Demographic information	Number of participants	Percentage
Gender		
Male	48	36.9%
Female	81	62.3%
Other	1	0.8%
Age		
18 – 25	3	2.3%
26 – 35	39	30.0%
36 – 45	52	40.0%
46 – 55	33	26.1%
56 – 65	5	3.9%
> 65	0	0
Level of education		
Masters	2	1.53%
Honors	9	6.9%
Degree	30	23.07%
Diploma	66	50.76%
Completed secondary school	20	15.38%
Completed primary school	1	0.77%
No formal education	2	1.54%
Current positions		
Directors	2	1.5%
Deputy Directors	13	10%
Assistant Directors	15	11.5%
Administrators	59	45.5%
Any other	41	31.5%
Number of years employed		
Less than a year	18	13.8%
1 to 5 years	28	21.5%
6 to 10 years	34	26.3%
11 to 15 years	31	23.8%
15 to 20 years	19	14.6%
List of buildings		
Pretoria AVN Gebou Building	28	21.5%
CGO Building Pretoria Regional Office	11	8.5%
Eben Donges Building Qheberha	30	23.1%
Customs House Building Western Cape	32	24.6%
Prd2 Building Umtata	29	22.3%
Total	**130**	**100%**

3.5.1.4.1 Gender of participants

Participation in the study was dominated by female participants averaging 62.3%, while the remaining 36.9% were male respondents. Only one respondent indicated “other” (0,8%) under gender.

3.5.1.4.2 Age of participants

The majority of respondents were between 26 and 55 years old (93.8% combined), with 18- to 25-year-olds representing 2.3% and participants older than 55 representing 3.8% of respondents.

3.5.1.4.3 Level of education

Concerning education level, most of the participants either had a diploma (50%) or a 3-year degree (23%), with approximately 8% of the participants having a post-graduate degree (Hons or master’s level). The remainder of the respondents (<20%) attended high school or secondary school. Only one of the respondents had no formal schooling.

3.5.1.4.4 Position in the organisation

Most of the respondents were employed administrators (45.5%). Assistant directors (11.5%), deputy directors (10%) and directors (1.5)% also participated in the research. Approximately 31% of respondents indicated that they employed “other” positions, which included secretaries, cleaners, building managers and communications officers.

3.5.1.4.5 Number of years employed by DPW.

The participants in this research were dominated by employees who have worked for DPW for six to ten years (26.3%), whilst 23.8% were people who have worked for DPW for eleven to fifteen years. Approximately 21.5% of participants have worked for DPW for one to five years, and only 14.6% of participants worked for DPW for longer than fifteen years.

3.5.1.4.6 Representation of the five DPW facilities

All five of the facilities (except for the Prd2 Building in Umtata, which was represented by 8.5% of participants) were almost equally represented in the research. The Pretoria AVN Building was represented by 21.5% of respondents, the CGO Building Pretoria Regional Office by 24.6%, the Eben Donges Building Qheberha by 23.1% and the Customs House Building Cape Town by 22.3% of respondents, respectively.

3.5.2 Observations

Observations involve the process of examining specific aspects related to the research scope/interest (Polit & Beck, 2008). Observations were conducted to supplement the information gathered through the survey questionnaire. The researcher was granted access to all buildings, and all facilities were accessible. Observations were undertaken over a period of three non-consecutive days. A semi-structured pre-developed checklist was used to records observations made.

The following aspects were recorded during observations:

- How is/are E-waste stored? (Provide a short narrative)
- What is the condition of the facilities where E-waste are stored? (Provide a short narrative)
- Approximately how much E-waste is stored in the area? (Provide an estimate of number of items stored)
- What types of E-waste are stored in the areas? (Short summary of e-waste observed)
- Is/are E-waste types/streams separated/segregated in any way? (Provide short narrative)
- How is/are E-waste managed that are destined for disposal? (Provide a short narrative)
- Was any E-waste collected at the time of the observation? Give an explanation of the collection procedure, if applicable. (Provide a short narrative)
- Is there any evidence of illegal activities or non-compliance to legislation? (Provide a short narrative)
- **Note:** Make notes of any other observations that may be important for the purposes of this research.

The advantage of keeping a pre-developed checklist is that all vital aspects are evaluated during the observation.

3.5.3 Document review

Where available, the review of documents and records were used to supplement survey data (and observations). For the purposes of this research, the following documents were reviewed to determine to which extent they made provision for E-waste management by the Department of Public works, where applicable/available:

- Records of waste disposal, such as waste manifest documents and safe disposal certificates;
- Data bases of waste quantities and types;
- Waste collection and recycling records; and

- Waste management plans, waste management procedures, waste management policies and work instructions.

The documents were reviewed against the following criteria:

- To what extent does the document make provision for the recordkeeping of data/information on quantities and types of E-waste generated?
- To what extent does the document make provision for the recording of sources of E-waste?
- To what extent does the document make provision for the prevention of unauthorised use of E-waste?
- To what extent does the document make provision for the safe storage of E-waste?
- To what extent does the document make provision for the lawful removal/collection of E-waste?
- To what extent does the document make provision for the lawful transportation of E-waste?
- To what extent does the document make provision for the lawful re-use/recycling of E-waste components?
- To what extent does the document make provision for the lawful disposal of E-waste?
- To what extent does the document make provision for recordkeeping and reporting on E-waste?

Not all buildings included in the research could provide the documents and records listed above.

3.6 Data analysis

In this research, the researcher employed descriptive and exploratory analysis methods in describing the E-waste management practices at DPW. Descriptive analysis describes data and the patterns in a single variable in the data set (Trochim & Donnelly, 2001). In addition, the exploratory data analysis tests the relationship between different variables. These approaches become valid and relevant for this research because of the nature of the data recordings, which are primarily categorical (some measured as ordinal scale responses). Specifically, data patterns have been described under descriptive analysis by generating various descriptive measures such as the median and mode.

The qualitative data related to awareness and knowledge of E-waste management practices at the DPW) was analysed through a document review and the researcher collected data from different strands of literature to pick common topics, ideas, and patterns on E-waste management practices. After data familiarization, the text was coded, and the researcher created shorthand labels to describe their content. The patterns were then identified, and broader themes were created from

several codes. The number of times the theme appears as described and the percentage was calculated (Caulfield, 2019).

3.7 Ethical considerations

Ethical Consideration remains an essential variable in guiding the research. The researcher must also implement all considerations to avoid abusing participants in the research process, hence the need for ethical Consideration.

This research was approved by the North-West University Faculty of Natural and Agricultural Ethics Committee (NWU-01443-20-A9) and regarded as a minimal-risk application. Informed consent was obtained from all participants. Informed consent is a necessary research pre-condition for this study.

3.8 Methodological limitations

This research is mainly based on self-reported data gathered during interviews. Where possible, self-reported data was supplemented by observation and document review. Not all of the buildings included in the research, however, provided documents for review purposes. This is a limitation, since the approach of the research was to supplement self-reported data with documented evidence, as far as possible. In these cases, the findings reflect the self-reported data provided by the research participants.

Some of the identified participants were reluctant (unwilling) to participate in the research. This may be due to limited knowledge on E-waste management on the identified participants' behalf. This caused participants to be hesitant to participate in the study, which had an impact on the overall representation of DPW employees participating in the research. Of the 367 targeted participants, only 130 responded to the request to participate in the research, leading to an undesired response rate of only 35% and this means that a small sample may prevent the findings from being extrapolated, at the same time a large sample may amplify the detection of differences, emphasizing statistical differences that are not relevant. Given the limited research done on E-waste in South African government buildings, the responses received from 130 participants are, however, considered to be useful providing sufficient information to understand the E-wate management problem.

In this research, more than half of the participants (76 out of 130) could not provide or estimate the amount of electrical and electronic equipment procured by their department per year and could not respond to Question 5 of the questionnaire. Similar to the responses to Question 5 (Section 4.2.1.4),

the majority of respondents could not respond to Question 7, which required them to indicate approximate amount of E-waste generated (per month/per quarter/per year) (Figure 4-2).

3.9 Chapter summary

This chapter presented the research design, approach, sampling, data collection, and data analysis strategies. The research included five buildings of the DPW in South Africa to evaluate E-waste practices. Data was collected through semi-structured questionnaires completed by 130 participants. Results from questionnaires were supported by document review and observations. Chapter 4 outlines the results and discussions of this research.

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Introduction

This study investigated the current practices employed for E-waste management by the National Department of Public Works (DPW) in South Africa. The research included five DPW facilities located in Gauteng, the Easten Cape, and the Western Cape, representing both rural and urban areas. The main method of data collection was through a survey questionnaire, which was completed by 130 DPW employees, either directly or indirectly involved in E-waste management. The background information of the respondents is provided in Section 3.5.1.4 of this dissertation. The survey data was supplemented by observations and document review, where possible.

The results presented in this chapter relates to two research objectives:

- ***Research objective 1***: Evaluating E-waste management practices followed by the Department of Public Works in selected buildings; and
- ***Research objective 2:*** Providing recommendations for improvement of E-waste management practices based on lessons learned from other countries.

4.2 Results related to RO1: Evaluating E-waste management practices followed by the Department of Public Works in selected buildings.

Section 4.2.1 and its sub-sections report on the results of the survey questionnaire, while Section 4.2.2 reports on observation results and Section 4.2.3 on the results of the document analysis.

4.2.1 Survey questionnaire results on E-waste management practices

Section 4.2.1 discusses the results of the survey questionnaire as it relates to the different questions posed (See Annexure A).

4.2.1.1 Participants' knowledge on E-waste management requirements and legislation

Section 3.5.1.4 provides the background information on the 130 survey participants included in the research. These participants were considered to be sufficiently representative of the typical population of DPW employees directly or indirectly involved in E-waste management. The respondents were asked about their knowledge of E-waste management requirements. Responses are summarised in Table 4-1.

Table 4-1: Participants' knowledge about electronic waste (E-waste) management requirements and legislation

Level of knowledge	Number of participants	Percentage
Knowledge about E-waste management requirements		
Good	0	0%
Average	29	22.3%
Below average	46	35.4%
Poor	55	42.3%
Knowledge about E-waste legislation		
Yes	8	6.2%
No	104	80.0%
Unsure	18	13.8%
Total	130	100%

The results reported in Table 4-1 show that the participants generally considered themselves as having insufficient knowledge about the requirements for E-waste management, and E-waste management-related legislation.

None of the respondents considered themselves as having good knowledge of E-waste management practices, while only 22% considered their knowledge to be "average". The remainder of respondents (78%) considered their knowledge as being below average or average. Similarly, the majority of respondents (93%) were unaware or unsure of E-waste management legislation. Only eight of the respondents (6.2%) indicated that they had knowledge of E-waste legislation and could correctly list some of the applicable legislation. From the results, it seems as if respondents from the National DPW office (AVN Building) , Gauteng Regional Office (GCO Building) and Customs House Building generally had more/better knowledge of the requirements for E-waste management.

Similarly, research by Uhunamure *et al.* (2021) in South Africa, Azodo *et al.* (2017) in Nigeria and Nuwematsiko *et al.* (2021) in Uganda indicate that there is generally still insufficient knowledge about E-waste management in Africa and that there exists a lack of knowledge about E-waste management legislation and guidelines. This reflects the idea that lack of education and awareness on E-waste management is common in a developing country such as South Africa.

4.2.1.2 Availability of in-house policies, procedures, or work instructions on E-waste management

The respondents were prompted about the availability of any in-house policies, procedures or work instructions related to E-waste management at their buildings (Table 4-2). The majority of

participants indicated that they were unsure (53.85%) or indicated that they did not have any (40%) in-house policies, procedures or work instructions for E-waste management. Only eight of the respondents (6.15%), indicated that they had some sort of an in-house policy, procedure or work instruction on E-waste management. These respondents were from the AVN Building, CGO Building and Eben Donges Building.

Table 4-2: Availability of E-waste policy, procedure or work instruction

Availability of E-waste policy, procedure or work instruction	Number of participants	Percentage
Available	8	6.15%
Unavailable	52	40.0%
Unsure	70	53.85%

The results correspond with the findings by Borthakur and Singh (2017) who have indicated that E-waste management practices are in many instances unregulated. E-waste management in the global South is primarily characterised by non-compliance with legislation and a lack of technical capacity to manage the waste. Moreover, an absence of aggressive waste avoidance strategies leads to increasing volumes of E-waste produced (DEFF, 2020a).

4.2.1.3 Procurement of electrical and electronic equipment

The Information and Telecommunications Technology (ICT) sector has been credited with improving the speed of technology and increasing the capacity of computers and other electronic devices (Boudier & Bensebaa, 2011; Ikhlayel, 2018). However, such growth has come with a cost, as it has caused products to lose value quickly (Boudier & Bensebaa, 2011). This, in turn, has resulted in large volumes of electrical and electronic waste being produced annually (Osibanjo & Nnorom, 2007; Nnorom & Osibanjo, 2008). It is estimated that E-waste volumes generated increase by 5 to 10% each year (Ikhlayel, 2018).

In this research, more than half of the participants (76 out of 130) could not provide or estimate the amount of electrical and electronic equipment procured by their department per year and could not respond to Question 5 of the questionnaire. Thirty-eight (29.23%) of the respondents (mostly from senior management categories) could respond to the question, and responses were only from three of the five buildings included in the research (National South African DPW (AVN Building), Gauteng Regional office (CGO Building), and Eben Donges Building (Gqeberha) (Figure 4-1).

It is estimated that between 80 and 240 units of electrical or electronic equipment are purchased by each of the DPW facilities per year (Figure 4-1). This may include cellular phones, laptops,

computers, tablets, printers, scanners, fax machines and other types of office-related electrical and electronic equipment. It is important to note that the results are from only sixteen of the 130 respondents (13.31%) and based on estimated quantities purchased, since exact records were not available to the respondents at the time of conducting the survey. The results in Figure 4-1 should, therefore, be seen as an estimate of the amount of equipment purchased rather than exact quantities.

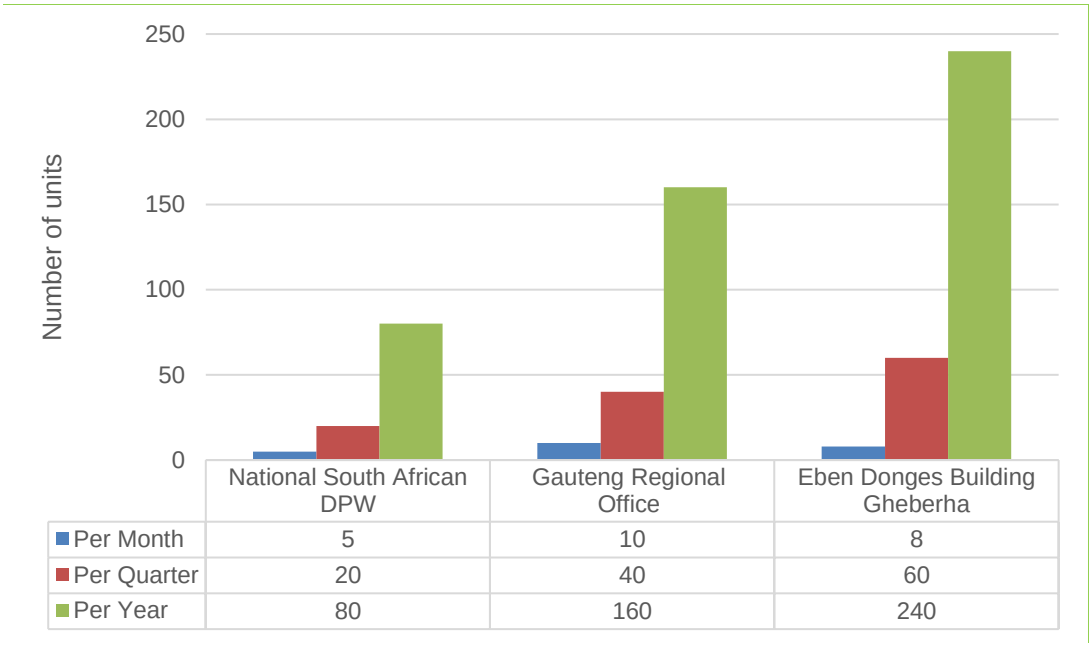

Figure 4-1: Estimated amount (units) of electrical and electronic equipment procured by DPW offices.

What is noteworthy from the responses to the question about electrical and electronic equipment procured, is that the majority of respondents did not have knowledge of the number of units purchased. Ayodele *et al.* (2017) who published on *"Green awareness and consumer purchase intention of environmentally friendly electrical products in Nigeria"*, correspondingly indicates that knowledge on procurement of the quantities and types of electrical and electronic equipment is generally limited.

4.2.1.4 Keeping of an asset register for electrical and electronic equipment

According to Islam and Huda (2018), keeping of records on inventory of electrical and electronic equipment is an integral part of the holistic E-waste management process.

Question 6 of the survey questionnaire requested respondents to indicate whether or not electrical and electronic equipment are registered on an asset register (Table 4-3). All of the respondents answered the question, with 70% of participants indicating that electronic equipment was registered on an asset register. Only two of the respondents (1.5%) indicated that electrical and electronic equipment are not registered in an asset register, while 28.5% of respondents were unsure.

Table 4-3: Keeping of an asset register for electrical and electronic equipment.

Registration of electronic equipment in the asset register	Number of participants	Percentage
Yes	91	70.0%
No	2	1.5%
Not sure	37	28.5%
Total	**130**	**100%**

Respondents who answered that an asset register is not kept were requested to motivate why it was not kept. The two respondents who answered "no", indicated that an asset register was not kept because there was lack of effective implementation of legislation and mentioned that there are no formal penalties on government departments that do not provide accountability on their E-waste. Bob (2015) in her research on *"Starting the conversation on management of E-waste in municipalities in South Africa: Preliminary survey results"* indicated that asset registers are generally not effectively used and leads to problems with E-waste quantity estimations.

4.2.1.5 Estimated quantities of E-waste generated.

Similar to the responses to Question 5 (Section 4.2.1.4), the majority of respondents could not respond to Question 7, which required them to indicate approximate amount of E-waste generated (per month/per quarter/per year) (Figure 4-2).

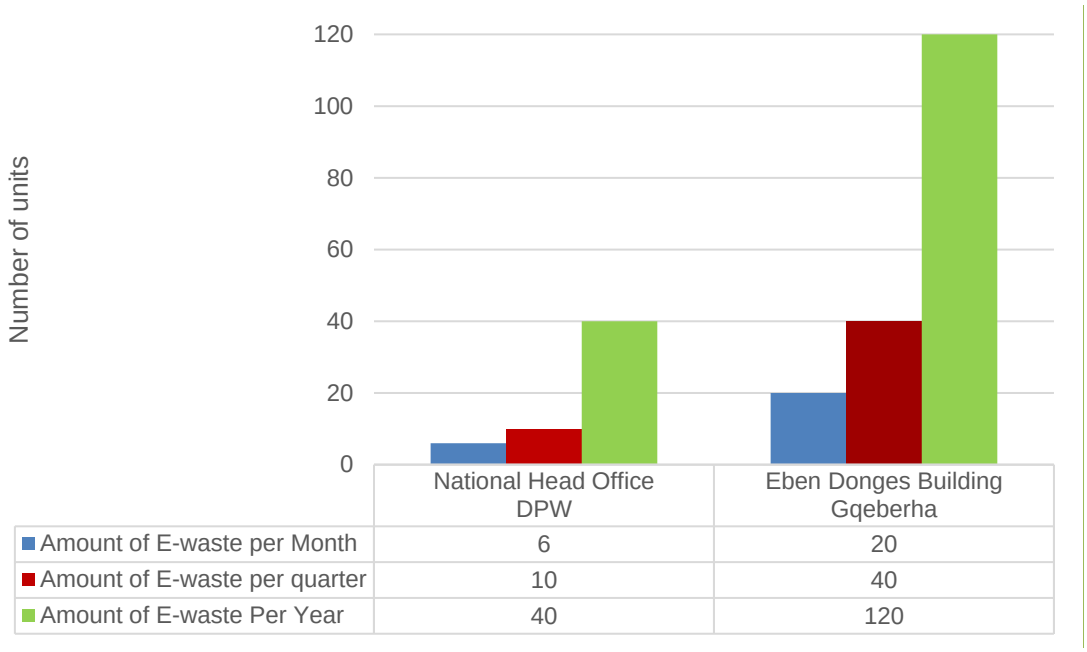

Figure 4-2: Estimated amount (units) of E-waste generated by DPW offices.

Only twelve (9.23%) of the 130 participants responded to the question. These included senior management from the National DPW Head Office (AVN Building) and The Eben Donges Building in Gqeberha. From these limited responses, it is estimated that between 40 and 120 units of E-waste are generated per year. Again, similar to the responses to Question 5, these responses should be regarded as a rough estimation and not as the actual amount of E-waste units generated. Respondents could not provide the researcher with any evidence of registers/data sheets of E-waste generated.

4.2.1.6 Storage of E-waste

Askari *et al*. (2014) highlights the importance of regulating the storage of E-waste. Controlled storage is important to prevent the unlawful use, reclamation, and storage of E-waste. According to their research conducted amongst Malaysian businesses, over 75% of the participants interviewed did not have knowledge about the proper storage practices for E-waste.

Question 8 of the survey asked (a*) "Is there any E-waste storage taking place in your facility?"* and (b) *"If yes, how much E-waste can be stored and (c) for how long?"* Table 4-4 provides the responses to Question 8 (a).

Table 4-4: Storage of E-waste at DPW facilities

Storage of E-waste at DPW facilities	Number of participants	Percentage
Yes	42	32.3%
No	16	12.3%
Not sure	72	55.4%
Total	**130**	**100%**

The majority of respondents (55.4%) were unsure whether there was any E-waste storage taking place in their buildings. Approximately 32% of participants indicated that E-waste storage was taking place, while approximately 12% indicated that no E-waste was stored in their building. The majority that indicated yes were mainly from the National DPW Head Office AVN Building, and the Prd2 Building (Umtata) in the Eastern Cape, as well as the Customs House Building (Cape Town). Based on observations done during site visits, the presence of dedicated E-waste storage facilities (store rooms or warehouses) were confirmed at all of the DPW facilities included in the research.

Respondents were generally unsure about the capacity (i.e., how much E-waste can be stored), and for how long it can be stored. These questions were either left unanswered or the respondents indicated that they were uncertain.

4.2.1.7 Awareness of quantities of E-waste disposal

Question 10 of the survey requested participants to indicate whether they are aware of the quantities of E-waste disposed by their department/facility (Table 4-5).

Table 4-5: Awareness of tonnages of E-waste disposed of

Awareness of tonnages of E-waste disposed	Number of participants	Percentage
Yes	18	13.85%
No	108	83.07%
Unsure	4	3.07%
Total	**130**	**100%**

Again, the majority of respondents (83.07%) indicated that they did not know how much E-waste was disposed of per year. Approximately 13.85% of the participants indicated that they were aware of the amount of E-waste disposed of per year. These were largely respondents in senior positions from the National DPW office (AVN Building), Gauteng Regional office (CGO Building) and Eben Donges Building (Gqeberha), with access to such data. Four of the participants (3.07%) indicated that they were unsure.

These results correspond with the findings of Masoabi (2020) and Askari *et al.* (2014) who have indicated relatively low levels of awareness about E-waste generation, management and disposal. The researcher was not provided with access to records about E-waste quantities and the tonnages of E-waste generated could not be confirmed (as mentioned above).

4.2.1.8 Frequency of E-waste disposal

According to Rawat *et al*. (2019), many businesses nowadays recognise the importance of responsible E-waste disposal and have established regular schedules for the proper disposal of outdated equipment and devices, typically on a quarterly or annual basis. The frequency of electronic waste disposal by businesses, however, varies depending on factors such as the size of the company and its technology turnover rate, with some smaller businesses opting for bi-annual disposal while larger corporations often have monthly E-waste collection routines in place.

The eleventh question asked participants about the frequency of E-waste disposal (Table 4-6).

Table 4-6: Frequency of E-waste disposal

Frequency of E-waste disposal	Number of participants	Percentage
Monthly	12	9.23%
Quarterly	7	5.38%
Once storage capacity has been reached (full)	68	52.31%
After disposal committee approval	15	11.54%
Unsure	28	21.54%
Total	**130**	**100%**

The majority of respondents (52.31%) indicated that E-waste is disposed of once the storage capacity has been reached, which indicates *ad hoc* disposal, rather than sticking to a set schedule. Nineteen of the respondents indicated that E-waste is disposed of monthly (9.23%) or quarterly (5.38%). Fifteen of the participants (11.54%) indicated that E-waste is disposed of after approval by the disposal committee. All of these participants were from the Prd2 building in Mthatha. This indicates that the DPW building in Mthatha has implemented a specific process where E-waste is only disposed of after approval by a specific "disposal committee". Twenty-eight (21.54%) of the participants were unsure about the frequency of E-waste disposal.

4.2.1.9 Means of disposing/discarding of E-waste

Organisations commonly dispose of E-waste through established recycling programmes or by partnering with certified E-waste disposal companies, ensuring that electronic devices and

equipment are properly recycled or refurbished to minimize environmental impact (Rawat *et al*., 2019). According to Lawhon (2013), in many African countries, open and closed tenders have emerged as popular methods for E-waste disposal, where governmental bodies or organizations invite bids from qualified companies to either openly compete or submit confidential proposals for managing the safe and sustainable disposal of electronic waste. Open and closed tenders have gained popularity in South Africa as a transparent and accountable approach to E-waste management, allowing businesses and recycling firms to demonstrate their commitment to environmentally responsible practices while also providing opportunities for local economic development. Donations of E-waste to charitable organisations, schools, and community initiatives have also become a prevalent means of disposal.

Question 12 asked respondents *"How is your E-waste disposed of"?* (Table 4-7).

Table 4-7: E-waste disposal/discard practices of DPW facilities

E-waste disposal/discard practices	Number of participants	Percentage
Open tender	6	4.6%
Close Tender	3	2.3%
Donated	54	41.5%
Re-use	6	4.6%
Informal Recyclers	2	1.5%
Other	20	15.3%
Open and closed tender	4	3.0%
Open tender and donate	1	0.8%
Donate and re-use	3	2.3%
Donate and informal recyclers	3	2.3%
Donate and others	6	4.6%
Not sure	22	16.9%
Total	**130**	**100%**

Fifty-four (41.5%) of the respondents indicated that E-waste is donated to charity organisations, while nine of the respondents indicated that open- (4.6%) or closed tenders (2.3%) are used to dispose of E-waste. Six of the respondents (4.6%) indicated that E-waste is re-used, and only two of the respondents (1.5%) indicated that informal recyclers are involved in E-waste disposal. Twenty of the respondents (15.3%) indicated that they used "other" means of disposal, which mostly indicated combinations of the disposal methods mentioned in the questionnaire. Twenty-two of the respondents (16.9%) were unsure of how E-waste is disposed of.

Forti *et al.* (2020) reports that E-waste management in developing countries is dominated by the informal sector and recyclers that use rudimentary techniques, without appropriate technology, and lacking the capacity to control and manage E-waste.

4.2.1.10 Records of dismantling and disposal certificates

Dismantling and disposal certificates play a crucial role in ensuring that electronic waste is managed in a way that is environmentally sustainable, legally compliant, and secure, while also promoting resource conservation and transparency in the disposal process. These certifications enable one to pass risk and prove your own compliance to the various legislations. The disposal certificate is used to provide summarised verification of the assets disposed of by an organisation and compliantly processed by Dispose-IT (including environmental disposal).

Table 4-8 indicates the responses to Question 13, which requested respondents to indicate whether or not dismantling and disposal certificates are kept for E-waste at their buildings.

Table 4-8: Records of dismantling and disposal certificates of DPW facilities

Records of -	Number of participants	Percentage
Dismantling certificates		
Yes	6	4.62%
No	6	4.62%
Unsure	118	90.77%
Disposal certificates		
Yes	33	25.38%
No	4	3.07%
Unsure	93	71.54%
Total	130	100%

Most participants were uncertain whether dismantling certificates (90.77%) or disposal certificates (71.54%) are kept for E-waste. As far as dismantling certificates are concerned, only six of the participants (4.62%) from the National DPW office (AVN Building) indicated that it is kept, while another six participants (4.62%) from Gauteng Regional office (CGO Building) indicated that it is not kept. Regarding disposal certificates – approximately one quarter of the participants (25.38%) indicated that it is kept for E-waste, while four (3.07%) stated that disposal certificates are not kept. From these responses, it is clear that the majority of participants were uncertain about the status of disposal and dismantling certificates.

Evidence of disposal and dismantling records could be provided for the E-waste disposed off by all of the buildings included in the research. This is probably because it is legal requirement and the

South African waste sector in general is operating in a transient legislative environment to promote the responsible development of a circular E-waste economy.

4.2.1.11 Training on E-waste management practices

Masoabi (2020) highlights the importance on information sharing and training on E-waste management practices. Question 14 aimed to determine whether any training is presented on E-waste management at the selected DPW facilities (Table 4-9).

Table 4-9: E-waste training provided by DPW

E-waste training provided	Number of participants	Percentage
Yes	0	0
No	122	93,8%
Unsure	8	6,2%
Total	**130**	**100%**

Table 4-9 indicates that majority of 122 (93.8%) respondents said “no”, which imply that they have not been trained or briefed on E-waste management. While only 8 (6.2%) respondents are not sure. The researcher was not provided with training records.

The research corresponds with findings from literature, which indicates that most people do not have detailed knowledge and education on the proper handling and management of E-waste (Miner *et al*., 2020). Lack of education and awareness on E-waste handling and management in developing countries is a common challenge, that is influenced by the lack of resources and institutional support (Masoabi, 2020).

4.2.1.12 E-waste management practices of DPW facilities

The last question of the survey questionnaire, Question 15, asked an open-ended question: *“Is there anything you would like to share about the E-waste management practices of your department?”.* The intention of the question was to invite all of the participants to mention any aspects of E-waste management that they wanted to bring under the researcher’s attention. The section was completed by 55 of the 130 participants (42.31%). Table 4-10 includes a summary of the responses provided by the participants in accordance with an intuitive thematic analysis.

Table 4-10: Responses on open-ended question regarding E-waste management practices (n = 55)

Themes	Example of phrases mentioned	Frequency	Percentage
Uncertainty about E-waste management practices	*"unsure", "do not know how E-waste is managed", "uncertainty", "no knowledge", "doubtful", "confused", "hesitant"*	40	72.72%
Need for training and awareness	*"training", "information-sharing", "awareness", "workshop", "improve knowledge", "course", "posters", "e-mails"*	38	69.09%
Need for standardisation	*"standard way of managing E-waste", "standardize", "find the same way", "not doing things differently", "procedure", "standard operating procedure", "policy", "SOP", "work instruction"*	21	38.18%
Need for record-keeping on E-waste	*"asset register", "waste disposal certificates", "data base", "records", "documents", "evidence", "record-keeping", "register", "Excel sheet"*	20	36.36%
Opportunity to implement the waste management hierarchy	*"circular economy", "waste management hierarchy", "recycle", "recover components", "divert from landfill sites"*	18	32.73%
Opportunity for income generation	*"income stream", "sell", "make money", "income generation"*	6	10.91%
Need for improved transparency	*"unsure about what happens to E-waste", "transparency", "communication", "honesty"*	5	9.09%

The responses provided by the participants ended up being a combination of gaps and opportunities for improvement. Seven themes (Table 4-10) emerged from the responses. These themes are discussed in the sub-sections below.

4.2.1.12.1 Uncertainty about E-waste management practices

The most frequently mentioned theme related to uncertainty about E-waste management practices. Forty of the 55 respondents (72.72%) mentioned that they were unsure about how E-waste is being managed by their department and also indicated that they were unsure about the correct, legal requirements for the management of E-waste. One respondent specifically mentioned that: "*I have*

been working at DPW for more than 12 years. I must be honest; I have no idea about how E-waste is being managed and how it should be managed correctly." Another respondent mentioned that *"I think only a few people at the Department know how to properly manage E-waste"*. The lack of knowledge or uncertainty of E-waste management practices were also evident from responses on the structured part of the questionnaire (See "unsure" responses in Sections 4.2.1.1 to 4.1.1.11).

The lack of knowledge and/or awareness of E-waste management has been highlighted by many authors as a concern for E-waste management (Masoabi, 2020; Lawhon, 2013; Rawat *et al*., 2019), both at a household and an organisational level. Linking to this gap, many respondents also mentioned the need for training and awareness on E-waste management (see Section 4.2.1.11).

4.2.1.12.2 Need for training and awareness.

Linking to the first theme discussed above about the uncertainty around E-waste management requirements, 38 of the 55 respondents (69.09%) mentioned the need for training and awareness on E-waste management. Some of the respondents suggested "training" and "regular workshops", while others made mention of more passive ways of awareness raising through "information-sharing" through "posters" and "e-mails".

Masoabi (2020) suggested active interventions towards improving awareness and knowledge about E-waste management in Lesotho. She suggested that training should include examples of E-waste types and typical requirements for the storage and disposal thereof. Similarly, Lawhon (2013) suggests communication and information-sharing to improve the management and prevent the unlawful disposal of E-waste.

4.2.1.12.3 Need for standardisation.

Standardisation of E-waste management practices through policies, standards and/or work instructions ensure that businesses and organisations comply with local, national, and international regulations regarding E-waste management and disposal. This minimizes the risk of legal repercussions and associated fines. Standardisation further enhances transparency in the E-waste management process, while it provides a clear framework for tracking and reporting on the disposal and recycling of electronic waste, fostering accountability among stakeholders.

Twenty-one of the 55 respondents (38.18%) mentioned the need for standardisation of E-waste management requirements. A respondent from the National DPW Head Office stated that: *"I believe there is a need to develop written procedures or instructions to standardise the way in which we separate, store and dispose of E-waste"*. A second participant added that: *"Most people are unsure*

about how E-waste needs to be managed. I think it will help a lot if we can have a standardised way in which we manage E-waste for the entire building".

Respondents generally made mention of "standardisation" through "written procedure", "standard operating procedure" (or "SOPs"), "policies" and "work instruction". One of the participants specifically mentioned that awareness raising on existing policies and procedures which might address aspects of E-waste management is required (link to Section 4.2.1.12 above).

4.2.1.12.4 Need for record-keeping

The National Waste Information Regulations (2012) highlights the importance of recordkeeping of waste types, quantities and management practices. Record-keeping on E-waste is important to (1) demonstrate regulatory compliance; (2) demonstrate accountability and transparency; (3) allow for information-driven decision-making; and (4) allow for long-term planning, whilst enabling organisations to anticipate future trends, needs and potential challenges.

Twenty of the 55 participants (36.36%) who responded to question 15 mentioned the need for improved record-keeping on E-waste. The statements mentioned referred to record-keeping on electronic equipment purchased, E-waste generated, E-waste stored, E-waste collected, and E-waste disposed of. The responses indicated the need "close the loop" from "cradle to grave" through appropriate records of the entire waste management life cycle.

The current lack of basic record-keeping of electronic equipment procured in an asset register (See Section 4.2.1.4) and of records of disposal and dismantling (See Section 4.2.1.10) by DPW is evident from responses to the structured part of the questionnaire.

Participants suggested the need for improvement of record-keeping with specific mention of "registers", "inventories", "data bases" and "Excel sheets" as evidence of compliance to E-waste management requirements. One of the participants noted that "*If we have records of how much E-waste we generate, and evidence of how we re-use, recycle, recover or dispose of the waste, it will put us in a position to report on legal requirements and the implementation of the waste management hierarchy".* The implementation of the waste management hierarchy was also highlighted as a specific theme (see Section 4.2.1.12.5).

4.2.1.12.5 Opportunity to implement the waste management hierarchy.

The circular economy, which focuses on "waste to worth" and the implementation of the waste management hierarchy forms the foundation of the 2020 National Waste Management Strategy.

The waste management hierarchy advocates that waste has value, and that waste needs to be re-used, recycled, recovered or treated, rather than being disposed of.

Eighteen of the 55 respondents (32.73%) indicate that E-waste presents an opportunity to implement the waste management hierarchy. Participant 22 mentioned that *"E-waste has components that are very valuable and that can be recycled, instead of mining for virgin materials".* Similarly, Participant 102 mentioned that *"E-waste presents an opportunity to implement the waste management hierarchy"*. Phrases mentioned by participants included: "circular economy", "waste management hierarchy", "recycle", "recover components" and "diversion from landfill sites".

Although the regulations did not yet take effect at the time of performing the survey questionnaire, the *Extended Producer Responsibility Regulations for Electrical and Electronic Equipment* specifically provides for the implementation of a circular economy through the re-use, recycling and recovery of E-waste components. The circular economy operates on the premise that income can be earned from waste and that it has "financial value". Section 4.2.1.14.6 focuses on the opportunities to generate income, mentioned by research participants.

4.2.1.12.6 Opportunity to generate income.

Six of the 55 participants (10.91%) mentioned that DPW has the opportunity to generate income from E-waste. Phrases mentioned by participants included: "income stream", "sell", "make money", "income generation".

Responses to Question 12 (Section 4.2.1.9) indicate that some of the DPW facilities already generate some income from E-waste through selling of electronic equipment, through tender. One of the participants mentioned that *"I believe that E-waste presents an opportunity to DPW to earn some income. Assets that have been written off may be sold to staff, for instance. This money can then be used by DPW to properly dispose of E-waste that could not be sold".* Another participant highlighted that *"E-waste is like gold! You can make a lot of money from it".*

E-waste recycling, refurbishing and reselling and component salvation are well-documented ways of generating income from E-waste.

4.2.1.12.7 Need for improved transparency

The last theme mentioned by respondents was the "need for improved transparency". Transparent practices hold businesses, organisations, and governments accountable for their E-waste management responsibilities. It helps identify the parties responsible for waste generation and disposal, ensuring that they adhere to legal and environmental obligations. Transparency, further,

fosters awareness and employee engagement in E-waste issues. When employees are informed about the environmental and social impacts of E-waste, they are more likely to support responsible disposal practices and demand accountability from businesses and governments (Masoabi, 2020).

Lastly, five of the 55 participants (9.09%) reported that there is a need for increased transparency around E-waste management practices. Respondents mentioned that they are "unsure about what happens to E-waste" and called from improved "transparency", "communication", "honesty" about E-waste management.

As mentioned in Chapter 3, survey results were supported by observations and document review. Section 4.2.2 and 4.2.3 elaborate on the findings of observations and document review.

4.2.2 Observation results on E-waste management practices

Based on site visits to selected Department of Public Works buildings in South Africa, the following observations were made:

- E-waste was generally stored in a dedicated area (storeroom or warehouse) with archived records or on its own. Storage conditions were generally suitable, with low risks of fire. Not all E-waste storage areas were access controlled. This makes the theft and unauthorised sale of E-waste a possible concern.
- It was difficult to estimate the number of E-waste units stored per building. E-waste stored typically ranged between 15 to 35 units stored.
- The types of E-waste stored in the DPW facilities mainly consisted of old computers, laptops and printers (including printer cartridges). On a few occasions, old cellular phones and scanners were also observed. The types of E-waste stored was in line with what would typically be expected from an office environment (Masoabi, 2020).
- In most instances, E-waste was segregated from other general waste streams. In two of the buildings, E-waste was stored with archived records (papers and files).
- E-waste was typically kept within the storage area until it was collected for disposal (monthly, quarterly, annually or bi-annually).
- The collection and transportation procedure for E-waste was not observed at the time of the site visits, since no of the visits coincided with the E-waste collection schedule.
- Although there was generally a lack of clear policy/procedures on the management of E-waste, no illegal activities involving E-waste was observed at the time of the site visits.

4.2.3 Document review results on E-waste management practices

Different from what was expected, not many documents and records explicitly addressing E-waste management were made available by the DPW facilities. Table 4-11 provides an overview of the results of document analysis against specific criteria considering the E-waste management life cycle.

Table 4-11: Results of document analysis

Criteria	DPW Waste Management Procedure	DPW Procedure for Monitoring and Reporting	DPW Procedure for the Management of Assets and Infrastructure
To what extent does the document make provision for the **recordkeeping of data/information** on quantities and types of E-waste generated?	No	Partially	Yes
To what extent does the document make provision for the **recording of sources of E-waste**?	No	Partially	Partially
To what extent does the document make provision for the **safe storage of E-waste**?	No	NA	NA
To what extent does the document make provision for the **lawful removal/collection of E-waste**?	No	NA	NA
To what extent does the document make provision for the lawful **transportation of E-waste?**	No	NA	NA
To what extent does the document make provision for the lawful **re-use/recycling of E-waste components?**	No	NA	NA
To what extent does the document make provision for the **lawful disposal of E-waste?**	No	NA	NA

No procedure exists which explicitly addresses E-waste management by DPW. Three documents were made available to the researcher for review:

- DPW Waste Management Procedure;
- DPW Procedure for Monitoring and Reporting; and
- DPW Procedure for the Management of Assets and Infrastructure.

The DPW Waste Management Procedure did not mention E-waste as one of the waste streams provided for in the procedure. No explicit mention was made of the storage, handling, transportation or disposal of E-waste in this procedure. The Procedure for Monitoring and Reporting mentions that waste generated should be monitored, measured and reported on. Although E-waste is not explicitly provided for in this procedure, it is deemed to be included as part of the definition of "waste" as defined in this procedure. Lastly, the DPW Procedure for the Management of Assets and Infrastructure specifically mentions (in the asset management part of the procedure) that waste from electronic devices should be recorded and records of assets that have been written off or broken must be kept. This is the only one of the three procedures where electrical and electronic devices are explicitly mentioned. Apart from recording and recordkeeping, no other requirements related to the management of electrical and electronic devices are provided.

4.3 Results related to RO2: Providing recommendations for improvement of E-waste management practices based on lessons learned from other countries.

Chapter 2 of this dissertation provides an overview of best practices and lessons for E-waste management from China, Japan and Switzerland (See Section 2.8.1 to 2.8.3). In developed countries, the management of electronic waste (E-waste) is governed by international conventions, laws, and directives, primarily utilising the Extended Producer Responsibility (EPR) approach (Sthiannopkao & Wong, 2013). Conversely, in most developing nations, E-waste management comprises three essential components: a national registry, a collection system, and logistics (Sthiannopkao & Wong, 2013). The national registry maintains a record of producers and their corresponding collection responsibilities, overseen by various governmental bodies to ensure compliance. Collection systems, often non-profit or non-governmental, are subject to government regulations, including allocation, monitoring, and the distribution of the national registry to a coordinating body for determining producer obligations and establishing E-waste collection points. Subsequently, E-waste undergoes dismantling, pre-processing, and end-processing steps to facilitate safe disposal or recycling (Sthiannopkao & Wong, 2013).

In summary, the E-waste management landscape varies between developed and developing countries, with distinct regulatory frameworks. While developed nations rely on international standards and the EPR approach, developing countries employ a multifaceted approach involving national registries, collection systems, and logistical measures to ensure proper E-waste management. The following sections outline select best practices from China, Japan, and Switzerland, serving as instructive examples rather than an exhaustive compilation of all commendable practices in E-waste management.

The following best practices were learned from other countries. Chapter 5 provides recommendations for improvement based on these best practices:

- **Enhancement of regulatory frameworks (policies and procedures for E-waste):**
  Best Practice: Developed countries leverage international conventions and the Extended Producer Responsibility (EPR) approach for E-waste management.
  Recommendation for E-waste management by DPW: DPW should consider developing standards and procedures for E-waste which are aligned with established international standards, fostering a comprehensive and standardized approach to E-waste management.
- **Strengthening national registries:**
  Best Practice: National registries, containing producer details and collection responsibilities, are actively monitored in developed nations.
  Recommendation for E-waste management by DPW: DPW should invest in developing robust national registries, where the quantities of E-waste generated, re-used/recycled and disposed of are recorded and monitored, thus fostering accountability.
- **Optimising collection systems:**
  Best Practice: Non-profit and non-governmental collection systems are prevalent in developing countries.
  Recommendation for E-waste management by DPW: The collection systems implemented by DPW should be coordinated and optimsed, ensuring compliance with legislation and best practices.
- **Knowledge transfer and collaboration:**
  Best Practice: Knowledge transfer and collaboration happens through partnerships that benefit all parties involved.
  Recommendation for E-waste management by DPW: DPW should foster knowledge transfer and collaboration, possibly through partnerships with academia and the private sector. DPW should invest in educational initiatives to raise awareness among their staff, promoting responsible E-waste disposal practices.

- **Policy flexibility and adaptability:**
  Best Practice: Developed countries often have policies that adapt to evolving technological landscapes.
  Recommendation for E-waste management by DPW: DPW should implement flexible policies/procedures for E-waste management that can adapt to technological changes, ensuring the continued relevance and effectiveness of E-waste management strategies.
- **Continuous monitoring and evaluation:** *Best Practice:* Developed nations routinely evaluate and adjust their E-waste management strategies.
  Recommendation for E-waste management by DPW: DPW should establish mechanisms for continuous monitoring and evaluation of E-waste management practices, allowing for timely adjustments and improvements based on evolving needs and challenges.

4.4 Chapter summary

Chapter 4 reported on the findings related to the two research objectives: (1) Evaluating E-waste management practices followed by selected DPW facilities. Data related to this research objective was gathered through survey questionnaires completed by 130 respondents, which was supported on-site observations and document review. The results related to the objective generally indicate that there is a general lack of formalised arrangements and knowledge about proper E-waste management. E-waste is generally stored correctly, but inconsistent recordkeeping of collection and disposal of E-waste poses a risk. Responses to open-ended questions highlighted seven main themes. Five of the themes mentioned highlighted the concerns of participants regarding E-waste management: uncertainty about E-waste management practices, need for training and awareness, need for standardisation (through procedures/policies), need for recordkeeping and need for improved transparency. Two of the themes mentioned highlighted perceived opportunities identified by respondents, namely – the opportunity to implement the waste management hierarchy and the opportunity to generate income from E-waste.

Document review revealed that E-waste management requirements are not explicitly addressed in existing procedures, while observations, surprisingly, revealed that no observed legal non-compliances regarding E-waste storage and handling exists (despite the lack of guidance).

Research objective 2 aimed to provide recommendations for improved E-waste management practices based on lessons learned from other countries. The main literature reviewed were from China, Japan and Switzerland and provided recommendations aimed at enhancement of regulatory frameworks, strengthening registries and recordkeeping, optimising collection systems,

standardising E-waste management practices, enhancing knowledge transfer and collaboration, and improving monitoring and evaluation.

Chapter 5 concludes on the research findings and provides recommendations for improving E-waste management and recommendations for future research.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

Chapter 5 provides the conclusions and recommendations which relate to the two research objectives:

- *Research objective 1: Evaluating E-waste management practices followed by the Department of Public Works in selected buildings.*
- *Research objective 2: Providing recommendations for improvement of E-waste management practices based on lessons learned from other countries.*

Section 5.2 provides the conclusions, while Section 5.3 outlines the recommendations.

5.2 Conclusions

Results related to RO1 was gathered through a survey questionnaire which 130 participants responded to. The survey results were supported by on-site observations and review of three DPW procedures.

The study concludes that there is a general lack of formalised E-waste management practices in DPW buildings/facilities across the country. The document review of three DPW procedures, where E-waste management is not explicitly addressed, support this finding. Policies, procedures and work instructions which specifically provide guidance and requirements for E-waste management were absent, which concurs with the findings of Borthakur and Singh (2017) who have indicated an absence of formalised procedures for E-waste Management in businesses in developing countries.

Although asset registers for electrical and electronic equipment were generally kept by the DPW facilities, the exact number of units of E-waste generated could not be established, since record-keeping on E-waste generation was largely sporadic and inconsistent.

Based on the number of respondents indicating that they were “unsure” in response to questions posed, it was clear that there was uncertainty about how much E-waste was generated, how it should be handled/stored, and how much/where/how it is collected and disposed of. The researcher found that the majority of respondents were able to relate with the concept of E-waste, but they lacked knowledge on the processes and legislation guiding E-waste management in South Africa. Similarly, research by Uhunamure *et al.* (2021) in South Africa, Azodo *et al.* (2017) in Nigeria, and Nuwematsiko *et al.* (2021) in Uganda indicate that there is generally still insufficient

knowledge about E-waste management in Africa and that there exists a lack of knowledge about E-waste management legislation and guidelines. Responses to the survey questionnaire also highlights the fact that no E-waste training has been provided by any of the DPW buildings/departments, with 94% indicating that they have not received training, and 6% of respondents indicating that they were uncertain. The research corresponds with findings from Miner *et al.* (2020) which indicates that most people do not have detailed knowledge and education on the proper handling and management of E-waste, and that training on E-waste management practices is generally lacking.

On a positive note, all of the buildings included in the research had a dedicated storage facility (storeroom, warehouse, office) where E-waste was kept until collected. E-waste was also largely separated from other waste streams. It was, however, difficult to determine how much (storage capacity/ storage volumes) of E-waste was stored within the storage areas, since record-keeping was inconsistent. The majority of participants (83%) also indicated that they were unaware of the amount of E-waste generated and disposed of.

There was mixed feedback from participants on the frequency of E-waste collection, however, the majority of respondents (52%) indicated that E-waste is collected once the capacity of the storage areas has been reached (full), giving an indication of *ad hoc* collection arrangements.

Again, respondents provided divergent feedback on how E-waste is disposed of. The majority of respondents indicated that E-waste is donated (41.5%) to schools or other organisations, while other responses included removal through open- and closed tenders, re-use of E-waste and collection by informal recyclers. Inconsistent recordkeeping of disposal and dismantling certificates also makes it nearly impossible to track the final destination of the E-waste that was generated.

Responses to the open-ended question - *"Is there anything you would like to share about the E-waste management practices of your department?"* highlighted seven main themes. Five of the themes highlighted the concerns of participants regarding E-waste management: uncertainty about E-waste management practices, need for training and awareness, need for standardisation (through procedures/policies), need for recordkeeping and need for improved transparency. These are typical challenges regarding E-waste management in the developing country context mentioned by Masoabi (2020), Lawhon (2013) and Rawat *et al.* (2019).

Two of the themes mentioned highlighted perceived opportunities identified by respondents, namely – the opportunity to implement the waste management hierarchy and the opportunity to

generate income from E-waste. These opportunities are clearly highlighted in the 2020 National Waste Management Strategy (DEFF, 2020a) as part of the circular economy and extended producer responsibility concepts, and also mentioned as opportunities for improved E-waste management by Forti *et al.* (2020) and Baldé *et al.* (2017).

5.3 Recommendations

The study was conducted with the aim of providing recommendations for improvement of E-waste management practices based on lessons from other countries. Best practices and lessons learned from other coutnires were discussed in Section 4.3 of this dissertation. In the conclusion to this dissertation, it is suggested that the following three recommendations should be prioritised for the improvement of E-waste management practices.

5.3.1 Development of E-waste management policies and procedures

In order to bolster E-waste management practices within the Department of Public Works (DPW) in South Africa, it is imperative to embark on a multifaceted approach rooted in contemporary strategies employed by developed nations. The initial recommendation underscores the necessity for management and DPW officials to concentrate on devising novel E-waste management policies and procedures that are in tandem with global best practices, existing E-waste legislation and extended producer responsibility (EPR) regulations. This alignment fosters a comprehensive and standardised approach to E-waste management, promoting efficiency and consistency.

Concurrently, DPW should institute mechanisms for continuous monitoring and evaluation of its E-waste management practices, as recommended below in Section 5.3.2.

5.3.2 Improved monitoring and evaluation of E-waste

In pursuit of heightened efficacy in E-waste management, the Department of Public Works (DPW) must undertake a comprehensive overhaul of its monitoring and evaluation requirements. This may entail an expansion of human resources to facilitate short-term and long-term recordkeeping and reporting on E-waste.

Drawing inspiration from the practices of developed nations, DPW should invest in robust E-waste registries that intricately detail quantities generated, quantities re-used/recycled, and final destination of E-waste. Where possible, these registries should align with the existing South African Waste Information System (SAWIS).

5.3.3 Improved training and awareness on E-waste

To elevate E-waste management practices within the Department of Public Works (DPW) in South Africa, a strategic focus on enhanced training and awareness initiatives is imperative. The Department should proactively identify key awareness programmes and implement comprehensive training across its facilities throughout the country. This approach aims to effectively disseminate knowledge on E-waste management practices, fostering a culture of responsibility and sustainability.

Expanding on the initial recommendation, it is essential for DPW to conduct a comprehensive analysis of the specific needs and challenges within different sectors and buildings. Tailoring awareness programmes to address the unique contexts of diverse environments ensures a more impactful and sustainable outreach. Moreover, the department should establish partnerships with industry stakeholders, non-governmental organizations (such as eWASA), and educational institutions to create a network of support for ongoing training initiatives. This collaborative approach enhances the reach and effectiveness of E-waste awareness programmes.

In conclusion, by adopting a multifaceted approach inspired by global best practices, the Department of Public Works in South Africa can significantly enhance E-waste training and awareness. This strategic investment in knowledge dissemination will contribute to the development of a well-informed and proactive staff members committed to sustainable E-waste management practices.

5.3.4 Recommendations for future research on E-waste management practices

This section proposes critical areas for future research aimed at advancing our understanding of E-waste management practices, particularly within government departments in South Africa.

To address persistent challenges on a national scale, it is imperative to delve into the underlying factors influencing E-waste management. An investigation into the reasons why developing countries continue to grapple with these practices is essential for informing effective policy interventions and strategies.

Moreover, a comprehensive evaluation of the implementation of policies and legislation pertaining to E-waste by South African government departments is warranted. This research should scrutinise the extent to which these regulations have been put into practice and identify potential barriers to successful implementation.

A crucial research gap exists in understanding E-waste dynamics within the informal recycling sector. More in-depth research is needed to gather nuanced data on the informal sector's role, challenges, and contributions to E-waste management. This investigation can shed light on effective strategies for integrating informal recyclers into formalised waste management systems.

Additionally, exploring the phenomenon where certain departments and households attribute sentimental value to E-waste requires careful examination. Understanding the underlying reasons for this perception is crucial for designing targeted awareness campaigns and educational initiatives to alter attitudes towards E-waste.

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ANNEXURE A: SURVEY QUESTIONNAIRE

RESEARCH TOPIC: Evaluating E-waste management practices in buildings of the National Department of Public Works, South Africa

Name of the interviewee/interviewee identifier: ……..

Date:……. **Time of the Interview……**

Name of the DPW building:……

Location of the DPW building: ……

This questionnaire aims to evaluate E-waste management current practices in buildings of Public Works in South Africa.

Instructions

1. This questionnaire has two sections. Please complete both sections of the questionnaire.
2. This research was approved by the North-West University Faculty of Natural and Agricultural Ethics Committee (NWU-01443-20-A9) and regarded as a minimal-risk application.
3. Confidentiality is ensured and your details will not be disclosed.
4. Your answer should be genuine and honest, and based on your experiences.
5. You are welcome to withdraw from this research at any time.
6. Please provide informed consent to participate in this research.

SECTION A. BIOGRAPHIC DATA OF THE RESPONDENT

Please provide your background information. This information will not be linked to your name in any way. It is only to indicate the representative nature of the respondents.

1. Age?

<18	1	
18 - 25	2	
26 - 35	3	
36 - 45	4	
46 - 55	5	
56 - 65	6	
66 & above	7	

2. Gender?

Male	1	
Female	2	

3. Highest educational qualification

No formal education	1	
Primary:		
Attempted	2	
Completed	3	
Secondary:		
Attempted	4	
Completed	5	
Tertiary:		
Diploma	6	
Junior degree	7	
Honours	8	
Masters	9	
PhD	10	

4. What is your position within the DPW?

DDG	1	

Chief Director	2	
Director	3	
Deputy Director	4	
Assistant Director	5	
Admin	6	
Any other (specify)	7	

5. Are you a permanent /contract employee?

Permanent	1	
Contract	2	

6. How long have you been working in DPW?

Less than 1 year	1	
1 – 5 years	2	
6 – 10 years	3	
11 – 15 years	4	
16 years and more	5	

7. In which unit/department are you employed?

IT	1	
Provisioning	2	
Movable Asset Management	3	
Procurement	4	
Workshop	5	
Cleaner	6	
Other	7	

8. In what capacity are you answering this questionnaire?

Head of the unit	1	
E-waste management Professional	2	
Manager	3	
PA	4	
Secretary	5	
Admin	6	
Other	7	

SECTION B. SURVEY

Please complete the following questions about your/your department's E-waste management practices.

1. What is your current knowledge of E-waste management practices/requirements?

Good	
Average	
Below average	
Poor	

2. a) Are you aware of any E-waste management legislation? YES/NO
   b) If yes, please elaborate
   .....
   .....

3. Do you have an in-house policy/procedure/work instruction on E-waste management? YES/NO

4. What is the DPW policy on the following electronic equipment after it has been used?

a) Laptops …….
b) Cell phones ……...
c) Tablets ……..

5. Approximately how much electrical and electronic equipment is procured per year (please indicate number of units)?

6. a) Are all electric/electronic equipment registered in an asset register? YES/NO

   b) If no, why not?

   .....……
   ……..……
   …….

7. Approximately how much E-waste is generated by your department?

Per month	
Per Quarter	
Per Year	

8. a) Is there any e-waste storage taking place in your facility? YES/NO

   b) If yes, how much E-waste can be stored and (c) for how long?

   ……..……
   ……
   ……..

9. Do you separate your E-waste at source? YES/NO

   b) If yes, where is it done? .....

   c) If yes, why do you separate E-waste?

   .....
   .....

10. Are you aware of the quantities of E-waste disposed of by your department/building per year?

Yes	1	
No	2	
Unsure	3	

11. How often do you dispose of E-waste?

Monthly	1	
Quarterly	2	
When storage full	3	
After disposal committee approval	4	

12. How is your E-waste disposed of?

Open tender	1	
Close Tender	2	
Donate to schools/hospitals	3	
Re-use	4	
Informal Recyclers	5	
Other	6	

13. Do you keep records of the following (a) dismantling certificates and (b) disposal certificates?

a. Dismantling certificates

Yes	1	
No	2	
Unsure	3	

b. Disposal certificates

Yes	1	
No	2	
Unsure	3	

14. Does your department provide any training on the management of E-waste? YES/NO

15. Is there anything you would like to share about the E-waste management practices of your department?

……
……
……
……
……
……
……

Thank you for your time.