WEEE Transform – Training of the informal sector and household participation in the e-waste sector

Technical report: Case Studies

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EXECUTIVE SUMMARY

Waste electrical and electronic equipment (WEEE or also referred to as e-waste) is the fastest-growing waste stream globally and in South Africa. E-waste presents both a threat and an opportunity – a threat to the environment and human health, but an opportunity as it contains valuable and scarce materials. Properly managed e-waste represents a valuable resource for recovery of raw materials and a market niche with new job opportunities that has barely been exploited in South Africa, while simultaneously decreasing negative environmental and human health impacts caused by non-compliant disposal of e-waste. The sustainable management of e-waste can contribute to the circularity of the South African economy.

However, data on e-waste as well as appropriate skills development to deal with e-waste at ground level is lacking. Waste reclaimers in the informal sector are a key player in the collection, repair, refurbishment and dismantling of e-waste. For a transition towards a circular economy, upskilling and training of reclaimers is crucial. It also further requires the investigation of households´ e-waste recycling behaviour to raise awareness and secure sufficient e-waste volumes.

For the waste reclaimers part of this study, an investigation was conducted to determine the profile, operations and training needs of waste reclaimers working with e-waste in the greater Johannesburg area. A structured questionnaire was used and a total number of 229 respondents were interviewed at 23 different recycling centres. This was followed with training hosted for Gauteng reclaimers to equip them with the correct knowledge, skills and tools to repair and refurbish small WEEE appliances sustainably. Twenty reclaimers operating in Gauteng were trained. The Kirkpatrick model of the evaluation was used to evaluate the training, focusing on the reaction and learning components of the reclaimers. After completion of the training, the reclaimers completed a questionnaire evaluating both the trainers and training.

The results from evaluating the trainers indicated that most participants were satisfied with the trainers as they strongly agreed that they were patient with them and facilitated their learning while also creating a safe and respectful environment. Before the training most of the participants recorded that they had no level of competence in learning areas such as, knowing the differences between good and bad practices of handling WEEE, and using the correct tools when handling WEEE. However, post training these had increased significantly.

To determine e-waste volumes in households and identify drivers of e-waste recycling behaviour in Gauteng, a mixed method approach was used. A total of 346 respondents completed the structured questionnaire. The Theory of Planned Behaviour was used as a framework for identifying the e-waste recycling behaviour of respondents. The results found that both broken and no longer needed or used electronic and electrical equipment (EEE) were stockpiled in households. Respondents were positive about participating in e-waste recycling but knowledge and know how to participate were lacking.

Different stakeholders in Gauteng participated in an Action Dialogue which was facilitated by UJ PEETS. This action dialogue was deemed successful and contributed to an e-waste management strategy for the Gauteng province.

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1 Introduction and background

E-waste needs to be attended to as a matter of urgency as it is one of the fastest growing waste streams in the world and it is regarded as a rising problem due to the challenges managing e-waste in a sustainable manner (Garlapati, 2016; Kumar et al., 2017; Forti et al., 2018; Ilankoon et al., 2018; Munsami, 2019; Bimir, 2020; Baldé et al., 2024). The South African State of Waste Report defines WEEE (waste electrical and electronic equipment), also known as e-waste, as any devices or items that were generated by electric currents or electromagnetic fields to function, including the equipment that was used for the generation, transfer, and measurements of such currents (DEA, 2018). Kumar et al. (2018) define WEEE as any electrical and electronic product that is discarded or no longer in use or devices discarded by the owner as waste without any intention to re-use it in the future.

With the arrival of an information-based society, the production and consumption of electrical and electronic equipment (EEE) have reached record levels (Cruz-Sotelo et al., 2017). The drivers behind the increased use and dependence on EEE are identified as industrialisation, economic expansion, technological advances, and luxurious lifestyles (Babu et al., 2007; Needhidasan et al., 2014; Rautela et al., 2021). The replacement of EEE before its end-of-life and the limited repair options contributes to the discarding of a large proportion of electronic devices (Forti et al., 2020; Ahirwar & Tripathi, 2021).

The increase in e-waste disposal is clearly notable in developing countries as they are often both the recipients of e-waste from developed countries and also generate their own e-waste (Forti et al., 2020). According to Perkins et al. (2014), of the estimated 8.7 million tonnes of e-waste then produced in the European Union each year, about 1.3 million tonnes of WEEE were exported mostly to Africa and Asia. Many developing countries, including South Africa, import e-waste without proper planning or strategic management (Rautela et al., 2021). E-waste contains hazardous chemical components that can potentially impact the environment and human health (Forti et al. 2020; Perkins et al., 2014) and the proper management of WEEE should be a top priority for waste managers. However, municipalities are responsible for waste management and factors such as lack of capacity and budget, urbanisation, increased complexity of waste streams, etc. make it increasingly difficult to provide reliable and sustainable waste management systems and services (Schoeman & Rampedi, 2022; Abalansa et al., 2021).

In Africa, and South Africa, WEEE is managed by both the formal and informal sector (Lydall et al., 2017) and Niyati (2014) is of the opinion that the informal sector in developing countries is playing an increasingly significant role in the processing of WEEE. They collect discarded WEEE from dustbins outside houses, landfills, outside of businesses and shopping malls and often dismantle and process this e-waste in ways that poses a threat to both their health and the environment (Schoeman & Ramutanda, 2022). It is therefore necessary to investigate the operations and role of waste reclaimers in WEEE as well as the linkages between the formal and informal sectors.

There are various factors that contribute to the development of the e-waste industry and one of the main challenges is the low volume of e-waste entering the recycling stream (Forti *et al.*, 2020). Consumers of EEE significantly influence the volume of WEEE that enters the waste stream. Currently, users of EEE hibernate their devices rather than recycle them (Gilal *et al.*, 2019). To stimulate and ensure the recovery of valuable materials from e-waste, there is a need to understand consumer behaviour and what households do with EEE that reached its end-of-life or is no longer used or needed.

1.1 Research questions

The following research questions guided the research:

1. What are the best suited practices for functionality testing, repair, refurbishment and dismantling of e-waste?
2. How should current available training material be adapted and revised to suit the South African context?
3. How effective was the training in repair, refurbishment and dismantling of e-waste?
4. What are the opportunities for the informal e-waste sector to link with the formal sector?
5. What are the e-waste awareness and recycling behaviour of households?
6. What is households' e-waste stream?
7. What measures are needed to increase their participation in recycling of e-waste?

1.2 Study area

The study was conducted with waste reclaimers and households in Gauteng – the smallest yet most populated province in South Africa (Figure 1.1) with a population of 15.1 million in 2022 (StatsSA, 2023). Gauteng is the leading economic hub that is responsible for a large portion of South Africa's waste including e-waste (DEA, 2018). Gauteng collects and process about 55% of all WEEE in South Africa (Lydall et al., 2017).

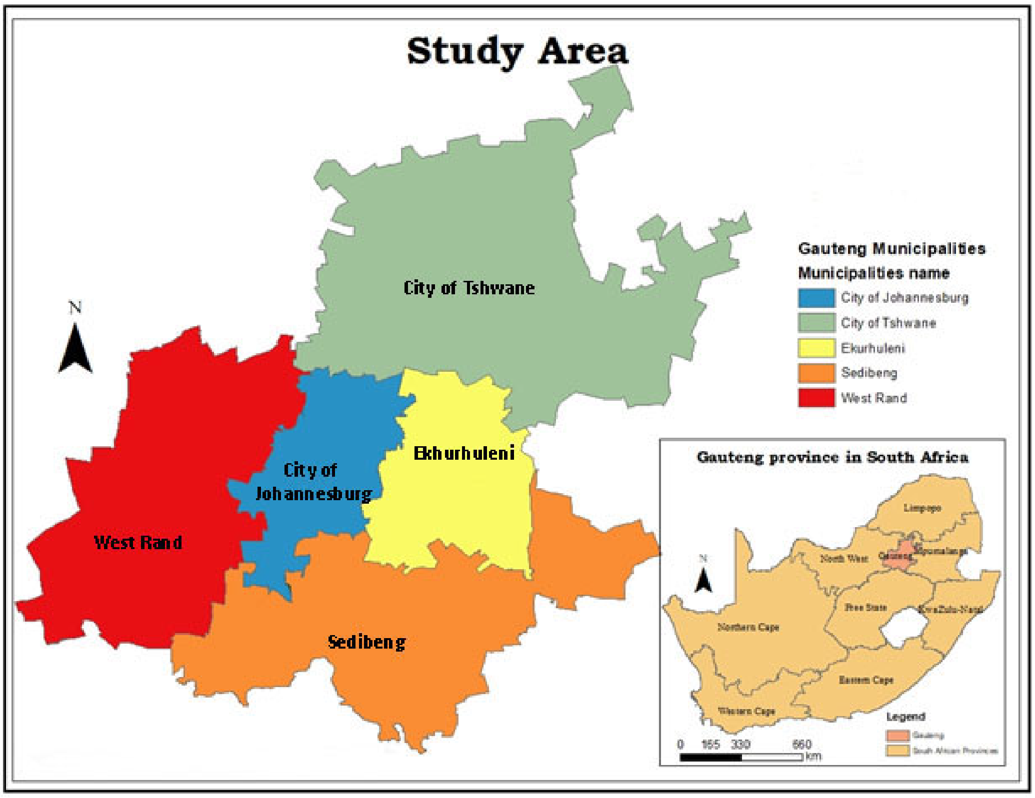

Figure 1: Study area and location of Gauteng Province in South Africa

Various studies suggest the reason Gauteng produces so much e-waste is because of the dynamics that exist within the province such as it being at least 60% urban, overpopulation and existence of many cooperate, governmental and production companies the use and discard different types of waste, e-waste included (Ichikowitz and Hattingh, 2020; DEA, 2018; Lydall et al., 2017).

This technical report presents the findings of the research conducted on the operations of waste reclaimers, the evaluation of the training that was conducted to repair small appliances, and stakeholder engagement. Furthermore, the findings of the volume of e-waste in households and the e-waste recycling behaviour of residents in Gauteng are also reported on.

2 Why research in e-waste is needed

When inappropriately disposed of, the toxic components in EEE pose a risk to the environment and human health, warranting the sustainable management of discarded EEE (WEEE). The mismanagement of WEEE hinders achieving sustainable development goals (SDGs) and results in environmental degradation, leading to health risks (Hossain et al., 2015; Anuardo et al., 2023). The sustainable management of WEEE thus ensures environmental and human protection. Additionally, WEEE that is handled sustainably (i.e., reused, refurbished and recycled) can reduce the use of natural resources. Despite several benefits associated with the sustainable management of WEEE, various barriers hinder its effective management, such as low collection rates, inadequate legislation and infrastructure, and insufficient education and awareness to ensure safe management (Anuardo et al., 2023).

This chapter reviews literature on e-waste generation and presents the numbers associated with the generation and recycling of e-waste. This is followed by a brief outline of the potential impacts of e-waste on the environment and human health. This is followed by the opportunity e-waste present in a circular economy. The role of the informal sector in e-waste ends this discussion.

2.1 E-waste generation and recycling

To understand the background of the e-waste industry, it is necessary to make enquiries into the global and local state of e-waste. The generation of e-waste and current level of recycling is important to identify and understand current practices and priorities towards waste. Additionally, the United Nations Organization emphasises the value of global e-waste with an estimated value of waste electrical and electronic equipment is at €55 billion (Shevchenko et al., 2019). The Global E-waste Monitor 2024 (Baldé et al., 2024) puts the overall economic impact of e-waste management in 20222 at $37 billion.

2.1.1 Global e-waste generation and recycling

According to Cruz-Sotelo et al. (2017) and Shittu et al. (2021), the growing rate of WEEE is usually three times faster than that of municipal solid waste (MSW), with an increased rate of about 3-5% globally. According to Ongondo et al. (2011), the rate of discarded EEE is increasing at an alarming rate, particularly in countries that are signatories to the Organisation for Economic Cooperation and Development (OECD). Markets are overwhelmed with vast quantities of new EEE yearly (Ongondo et al., 2011).

In the Global E-waste Monitor 2024 reports that in 2022 a record of 62 billion kg of e-waste was generated globally – or the equivalent of 7.8 kg per capita per year (Figure 2). This presents a significant increase from the 34 billion kg of e-waste that was generated in 2010, an annual increase of 2.3 billion kg. Europe recorded the highest amount of e-waste generated per capita in 2022 with 17.6 kg, followed by Oceania (16.1 kg) and the Americas (14.1 kg) while Africa generated only 2.5 kg per capita (Baldé et al., 2024).

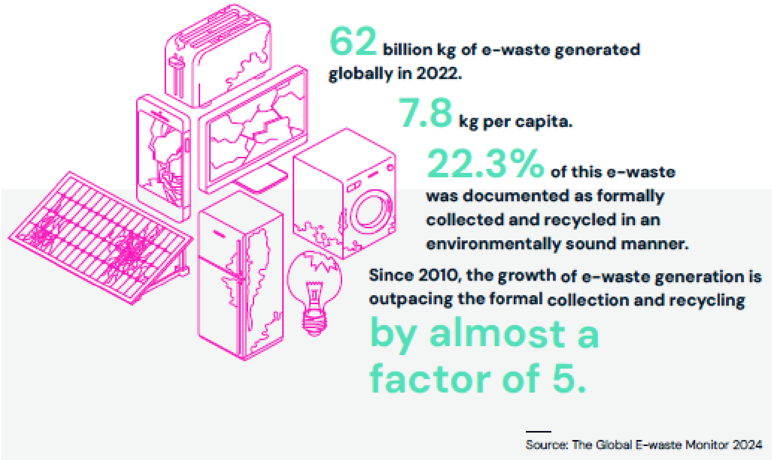

Figure 2: Global e-waste generation and recycling in 2024 (Baldé et al., 2024)

The world is undergoing digital transformation and electronification that requires devices to live, work and socialise in the modern world. Statistics reveal that in 2019 the global generation of EEE increased by 7.6% per annum from 2014 (Statista, 2020). The rise in EEE production is because these products enhance living standards and make life easy, even in the remote parts of developing areas (Osibanjo & Nnorom, 2008; Forti et al., 2020). The global market of EEE in the last two decades has grown exponentially and continues to grow in that manner (Needhidasan et al., 2014). The decrease in the effective lifespan of EEE, rapid product innovation, the miniaturisation of EEE, and the replacement of EEE before the products have reached their end of life (EoL), that is, before they are dysfunctional or fit the description of waste, are all attributed to the exponential growth of EEE (Reyes et al., 2012; Baldé et al., 2015; Needhidasan et al., 2014; Rautela et al., 2021).

In the Global E-waste Monitor 2014, Baldé et al. (2015), proposed that e-waste could land up in one of the following scenarios: in the official take-back system, in a waste bin with general waste and subsequently in landfill and disposal sites or even being traded either legally or illegally outside of the official take-back systems. The global statistics for the management of e-waste revealed that in 2019 only 17.4% (9.3 million tonnes (Mt)) of the generated e-waste was handled in a proper manner (Scenario 1) (Forti et al., 2020). The fate of 82.6% (44.3 Mt) of WEEE generated in 2019 was uncertain. The disposal of e-waste in waste bins and subsequently in landfills or through incineration was approximately eight percent (8.0%) (0.6 Mt) (Scenario 2) (Baldé et al., 2017; Forti et al., 2020). Approximately 7.0% to 20.0% (43.7 Mt) was exported (Scenario 3 and 4) illegally or under the guise of being reused or as scrap metal (Forti et al., 2020). Baldé et al. (2015) and Asante et al. (2019) state that most e-waste finds its way from the developed world into developing countries and accumulates on open dumpsites in West African countries, particularly Ghana and Nigeria. Baldé et al. (2017) state that undocumented e-waste is most likely to be treated by the informal sector and while still emitting its inherent toxins, recycled without adequate protection being provided to the workers.

In 2022, 22.3% of e-waste was documented as formally collected and recycled in an environmentally sustainable manner (Baldé et al., 2024) that presents an increase from the 17.4% reported in 2019 (Forti et al., 2020). As stated before, Europe was the region that generated the most e-waste (17.6 kg per capita), but it had the highest documented collection and recycling rate (7.5 kg per capita or 42.8%) (Figure 3). Oceania recorded recycling of 41.4% of the e-waste generated while in Africa only 0.7% of e-waste was recycled.

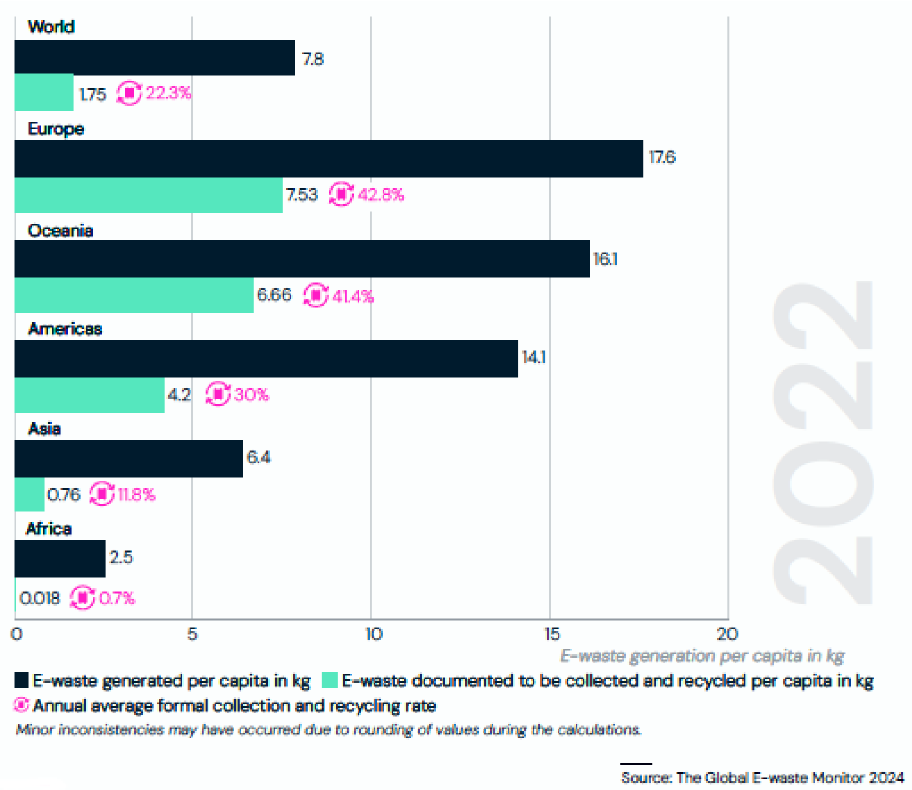

Figure 3: E-waste generated and documented as formally collected and recycled by region in 2022 (Baldé et al., 2024)

2.1.2 E-waste generation and recycling in South Africa

In South Africa, like the rest of the world, e-waste has emerged as the fastest growing stream (DEFF, 2020). Lydall et al. (2017) express the opinion that accurate data regarding e-waste is largely lacking in South Africa. Conflicting numbers are given for e-waste generation in South Africa. Lydall et al. (2017) estimated that only 74 923 tonnes of e-waste were produced in South Africa in 2015. In contrast, Forti et al. (2020) estimates that 416 000 tonnes of e-waste were generated in South Africa in 2019. The South Africa State of Waste Report (DEA, 2018) estimated that in 2017 360 000 tonnes of e-waste were generated. The Global E-waste Monitor 2024 reports a much higher number for e-waste generation in South Africa – 527 million kg or 8.8 kg per capita in 2022 (Baldé et al, 2024). Data that is not accurate and/or conflicting makes the sustainable management of e-waste a challenge.

Conflicting numbers for recycling rates are also a characteristic of the e-waste recycling landscape in South Africa. The South Africa State of Waste Report gives a recycling rate of 9.7% for 2017, 86.4% stockpiling and 3.9% disposal of e-waste. On the other hand, Lydall et al. (2017) and Ichikowitz &

Hatting (2020) state that only approximately 11% of e-waste is recycled and most of the e-waste is stockpiled in businesses and households while some ends up disposed in landfills. Baldé et al. (2024) in the Global E-waste Monitor 2024 reports that 22.9% of e-waste in South Africa is documented as formally collected and recycled. However, the recycling rate reported by Baldé et al. (2024) is significantly more than those documented by researchers and organisations in South Africa and therefore is not an accurate reflection of the state of e-waste recycling in South Africa. The EPR Waste Association of South Africa (eWASA) reported in 2023 that South African generated 6.2 kg of waste per capita in 2023 and that about 12% of this was recycled (eWASA, 2023).

The e-waste stream contains diverse and hazardous materials that require special treatment (Lundgren, 2012; Mmereki et al., 2016). In fact, the presence of hazardous material restricts e-waste from being landfilled. Furthermore, the inadequate recycling infrastructure and poorly managed disposal protocols in African countries are contributing to poor and unsustainable waste management practices (Asante et al., 2019). As a result, there are potential health and environmental issues.

2.2 Impacts of e-waste on human health and the environment

As Gangwar et al. (2019) argued, the incorrect and illegal disposal and processing of e-waste generates large amounts of pollution and adds numerous organic and non-organic pollutants such as heavy metals, acids, and greenhouse gases to the atmosphere which affect both the ecosystem and human health. This view is supported by Orisakwe et al. (2019) that state e-waste is hazardous and dangerous to people and the environment they live in.

2.2.1 Impact on the environment

Due to the toxic nature of e-waste components, when e-waste is not disposed of according to the correct procedure and delivered to appropriate recycling companies, it negatively impacts the environment. In developing countries, e-waste often ends up being burned in landfills thereby polluting the environment and releasing toxins into the atmosphere and ecosystems (Umesi & Onyia, 2008; Orisakwe et al., 2019). The practice of burning e-waste discharge hazardous materials that damage the environment (Maphosa & Maphosa, 2020). Informal processing of electrical cables is one example of open burning of e-waste. Moreover, harmful materials such as lead, mercury and some inorganic acids are being released to the environment due to poor disposal and recycling methods of e-waste (Tetteh & Lengel, 2017). These hazardous materials released pollute the soil, water and air which further impacts ecosystems. Thus, unregulated e-waste recycling and processing contribute to environmental degradation and issues like global warming (Lebbie et al., 2021). Furthermore, environmental degradation disrupts ecosystems of wild animals and loss of water quality also disrupts the habitat of aquatic animals (Machete, 2017).

Cai et al. (2021) emphasize that there are many toxic materials introduced to the environment through e-waste. Saidan et al. (2012) also share that these toxic materials include heavy metals and persistent organic pollutants. The particularly alarming component of e-waste is that the remaining toxicity of past e-waste that has been landfilled or disposed of illegally is already part of a hazardous cycle contaminating the natural environment, which emphasizes the need to prevent further e-waste contamination (Ismail & Hanafiah, 2020).

2.2.2 Impact on human health

It is undeniable that e-waste can have serious impacts on human health as it contains toxic components such as mercury, arsenic, lead and cadmium (Robinson, 2009; Gutberlet & Uddin, 2017). E-waste recycling sites built near residential areas leave communities prone to health concerns such as inhaling toxic chemicals and being exposed to radiation (Jibiri et al., 2014). A study by Machete (2017) in South Africa revealed that human exposure to toxic metals have a negative effect on their organs. Pollutants released during e-waste processing trigger respiratory infections, eye infections and asthma (Acquah et al., 2019). In studies on waste reclaimers' health, Asampong et al. (2015) found that waste reclaimers who dismantle e-waste suffer from acute respiratory infections and chest pains, while Peluola (2016) found that they suffer from skin and eye irritation and persistent coughing. Thus, it is not only processing e-waste such as burning of cables that affects human health but also e-waste dismantling. Furthermore, informal waste reclaimers that rely on stones, hammers, chisels to dismantle e-waste are at risk of musculoskeletal injuries (Maphosa & Maphosa, 2020).

E-waste does not only contain hazardous material, but also valuable material such as gold, silver and copper to name a few. Therefore, if e-waste is managed properly, it can contribute to the circular economy and create sustainable green jobs as outlined in the next section.

2.3 The value of e-waste

According to Ilankoon et al. (2018), e-waste is seen as valuable due to the value of raw materials used in individual components such as the presence of multiple precious metals (e.g., gold, platinum, palladium, ruthenium, rhodium, iridium, copper, and silver) along with other valuable materials such as iron, aluminium, cobalt, indium, germanium, bismuth, and antimony. E-waste is therefore a valuable resource for several precious and strategic metals (Herat & Agamuthu, 2012). There is a growing need for the recovery of e-waste resources due to scarcity, restricted global trade and price fluctuations for some of these metals. Noteworthy benefits of harvesting e-waste resources are substantially less energy used and significantly less greenhouse gas emissions compared to mining of these resources (Mudali et al., 2021).

The Global E-waste Monitor 2024 estimates that 19 billion kg of metals from e-waste were turned into secondary sources. The platinum-group metals and precious metals were present in lower quantities but were among the most valuable metals with an estimated 300 000 kg turned into secondary sources (Baldé et al., 2024).

Another vital consideration is the value and opportunity of functioning WEEE. Ishak et al. (2018) emphasise a significant social opportunity of e-waste as it has the potential to provide second-hand devices to less-advantaged communities (Lau et al., 2013). The Mohammadi et al. (2021) study noted that e-waste recycling is contributing to economic growth by creating jobs. In line with this, the unemployed youth and adults in developing countries often work as waste reclaimers to earn income through waste and e-waste recycling. WEEE recycling has the potential to be an important employer as 25 jobs can be created for every 1 000 tonnes of e-waste managed in South Africa (Lydall et al., 2017). Thus, the presence of job creation and skills training is vital to unlocking the potential economic benefits held by the e-waste industry. E-waste has the potential to create business opportunities in the recovery and recycling of electronic devices, which can contribute to the circular economy in South Africa. Waste reclaimers play an important role in waste management but are unfortunately often excluded (Coletto & Bissop, 2017).

2.4 E-waste in the circular economy

A circular economy plays an important role in streamlining sustainability aimed at an effective e-waste industry. When an e-waste industry is effective, it uses the refurbished materials which were an output of the production process and transfers it back into the input process of production, thereby using waste as a resource (Forti et al., 2020). In other words, sustainability is promoted as the end products of manufacturing are returned to the start of production which increases profits as less new materials are used while decreasing waste that enters landfills. As defined by Shevchenko et al. (2019:1), a circular economy is “a tool for the operationalization of the concept of sustainable development as it deals with entire life cycles and covers production, consumption, secondary raw materials, and waste management.” D’Adamo et al. (2019) also maintain that a circular economy can be seen as a framework to achieve sustainability, emphasizing the social, economic, and environmental sectors of the country. Additionally, Velenturf and Purnell (2021) share that a reverse supply chain of e-waste aligns with the needs of the characteristics of a circular economy. This is because a circular economy assumes the maximum use of raw materials in a closed-loop economy and limits the final amount of waste to enter landfills as a last resort (Awasthi et al., 2019). Second-hand and refurbished goods also play an important part in diverting EEE from entering the waste stream and landfills when directing back into use can decrease pressure on the waste stream (Lepawsky, 2018).

Thus, the potential value and economic opportunities for the e-waste industry play an important role in prioritizing the development of the e-waste system. Economic revitalisation can be streamlined by redirecting waste into a resource while it creates jobs and training opportunities. In many developing countries, and in South Africa, the informal sector plays a significant role in e-waste recycling. However, the e-waste recycling industry has a need for semi-skilled and skilled workers and skills training can contribute to unlocking the potential economic benefits held by the e-waste industry. The next sections discuss the informal sector and training of the informal sector in e-waste.

2.5 The informal sector in South Africa

In South Africa, the informal e-waste sector consists of collectors and recyclers who are unlicensed and not registered with any official entities (Lundgren, 2012). According to Lydall et al. (2017), these informal waste reclaimers collect waste from landfills, dustbins, shopping malls, industrial malls and suburbs. Furthermore, most of them practice dismantling and processing e-waste and sell their materials frequently to local recyclers via exploitative intermediaries (UJ-PEETS, 2020). However, the International Labour Organization (2014) noted that informal waste reclaimers collect, dismantle and process e-waste due to the lack of formal and public collectors, the high demand for secondary raw materials, and to allow themselves to make a living. In summation, the rising rates of unemployment and high volumes of e-waste are the main drivers of informal waste recycling.

Informal waste reclaimers in South Africa are facing numerous challenges in the collection, transport and processing of waste and e-waste for recycling. A report commissioned by the DEA (2016), confirms this view and also notes that the lack of formalisation is a challenge. In the City of Johannesburg (CoJ), the Environment, Infrastructure and Services Department launched a Waste Pickers Empowerment programme in 2011. This programme consisted of the formulation of a database for the waste reclaimers in the CoJ for which the reclaimers had to register, skills training and organizing them into co-operatives (Baker et al., 2016). Baker et al. (2016) states that more than

500 waste reclaimers have benefited in the programme. However, only South African or foreign waste reclaimers that had the necessary documentation could register for this programme. Schoeman (2018) found that 78% of trolley pushers that participated in her study were foreign nationals and the majority did not possess the necessary documentation to make their status legal in South Africa. Thus, many waste reclaimers are not able to register and participate in integration projects and therefore also do not have access to the associated skills training.

Baker et al. (2016:172) state that "The CoJ recognized the Waste Pickers form [the] integral part of waste minimization". However, it seems that the CoJ did an about-turn. Samson (2021) expresses the opinion that Pikitup, the waste management service provider in the CoJ, does not incorporate the waste reclaimers in recycling. She further states that waste reclaimers are the real recycling experts and Pikitup designs charity-style projects for them and contracted private companies to collect recyclables – which is in direct competition with the waste reclaimers and threatens their livelihoods. Pillay (2017) has a similar opinion that the CoJ has not made waste pickers part of their waste strategy. She states that the CoJ developed programmes and projects without consulting the waste pickers and the reason given is that they cannot consult waste pickers as they are not organised. This view by the CoJ is contradicted by findings of the Waste Integration in South Africa (WISA) project that found that waste reclaimers are organized (WIEGO, 2021). The lack of recognition cumulated in large-scale protest organized by the African Reclaimers Organisation (ARO) in May 2019. Waste reclaimers marched against the CoJ's refusal to recognize them, answer their demands and offer fair compensation and treatment (WIEGO, 2021).

The Waste Pickers Guideline for South Africa (DEFF & DST, 2020) notes that training is provided by municipalities and industry but does not provide detail of the training. Regarding the pilot project to integrate waste pickers in Sasolburg, the report alludes that the training provided to waste pickers was in the area of data gathering and keeping of financial records. A finding of this pilot project to integrate waste pickers states that "a training programme more specifically tailored for this type of initiative is likely required" (DEFF & DST, 2020:48).

It seems that training of waste reclaimers in South Africa is mostly in the entrepreneurial and business side of recycling. The training provided by Taking Care of Business (TCB) (previously The Appliance Bank) is an exception. Starting with a pilot project in 2015, TCB has a two-year training programme for unemployed men that not only includes the business side of WEEE, but also in repairing household appliances. Recently there has been a focus on e-waste and a recognition that it can contribute to the circular economy. At the time of writing, formal qualifications are being developed to increase skills in the WEEE sector. These are in the areas of WEEE collection, processing and managing. However, for any training programme in e-waste to work, more information is needed on who are the waste reclaimers that collect e-waste, what is done with this e-waste and if there is a need to train them in the repair of e-waste. The next chapter presents the results of the role of the informal sector in e-waste.

3 The informal sector in e-waste

In contrast to the formal e-waste recycling practices in developed countries, the informal sector contributes significantly to the recycling of e-waste. For example, many waste reclaimers in developing countries burn e-waste to recover valuable metals – that puts their health and the environment in danger. In South Africa, most recycling and waste reduction is done by informal waste reclaimers. Without personal protective equipment (PPE), waste reclaimers handle waste directly, exposing themselves to health risks (DEA, 2016). The Schoeman (2018) study on the City of Johannesburg (CoJ) trolley pushers also found that the majority of waste reclaimers need to be provided with safety equipment by the municipality.

The informal sector plays a huge role in the waste economy of the CoJ and South Africa. According to the DEFF & DST (2020), waste pickers/reclaimers are individuals who obtain re-usable and recyclable components from residential and commercial waste bins, landfill sites, and open areas in order to revalue them and gain an income. South Africa does not have reliable information on the dismantling, processing, repair or recycling of e-waste by informal waste pickers. Many studies have focused on the health dangers that waste pickers face with picking waste but very little is known about how they conduct dismantling and processing of e-waste (Orisakwe et al., 2019).

The main aim of this part of the research was to investigate the operations of waste reclaimers regarding e-waste and to determine their willingness for training in the repair of e-waste. The following objectives have been set out:

- profiling waste reclaimers that collect e-waste;
- document their operations regarding e-waste;
- investigate dismantling, processing and repair practices of e-waste by waste reclaimers; and
- determine the need of waste reclaimers for training in the repair of e-waste.

3.1 Methodology

The study adopted a mixed method approach involving triangulation of both qualitative and quantitative designs. The setting of the study was the greater Johannesburg area focusing on informal waste reclaimers in Johannesburg and surrounds. The data collection took place during the Covid pandemic and travel during the different lockdown periods and access to buy-back centres were extremely limited. All respondents were informal waste reclaimers. Purposive sampling refers to a non-probability sampling technique that identifies and chooses participants that have knowledge or experience about the phenomenon of interest by the researcher (Campbell et al. 2020). As this study investigated waste reclaimers that collect, transport and process e-waste, only waste reclaimers that work with e-waste were interviewed.

Interviews were conducted using a questionnaire, allowing for face-to-face interaction with informal waste reclaimers in the field, as they collected recyclables. The questionnaire was developed by the UJ, UCT and UWC South African e-waste research group. The different sections of the questionnaire included demographics, operations, dismantling, processing and training. The questionnaire consisted of questions often asked when profiling waste reclaimers and questions regarding their willingness to undergo training. Both open-ended and closed-ended questions were asked. The researcher and fieldworkers conducted interviews in the field and applied participant observation method for field observation. The observed field work involved processing and dismantling practices. A total number of 229 respondents were interviewed at 23 different recycling centers.

Thematic analysis was applied using the Nvivo software to transcribe interview conversations into coded themes. Thematic analysis is an identifying, analyzing, organizing, describing and reporting method on themes found within a set of data (Nowell et al., 2017). For quantitative data, descriptive statistical analysis was performed in Excel. This method was used because it summarizes complex numerical findings into representable tables, graphs or chats.

3.2 Demographic profile of waste reclaimers

This section presents demographic variables of the respondents and includes gender, race, education level, etc.

3.2.1 Gender

Waste picking in this survey was dominated by men (83.4%) and only 16.6% were women. This is in line with the Schoeman (2018) study that found that 80.4% male and 19.6% female waste reclaimers operated as trolley pushers in Johannesburg. Waste picking is a strenuous job, and it is expected to be dominated by men as they have greater physical strength than women (DEFF & DST, 2020).

3.2.2 Race and country of origin

The majority of the respondents were African/Black (87.3%) followed by Coloureds (11.4%). Only two respondents (0.9%) were White and one respondent (0.4%) identified as Indian/Asian (Figure 4 (a)). A total of 81.6% of the respondents were South African followed by 11.4% from Zimbabwe and 3.1% from Malawi (Figure 4 (b)). This is in contrast to the Schoeman (2018) study that had 78% foreign nationals and Sentime (2011) that only recorded 56.6% South Africans. The result is in line with the DEA (2016) report that noted that only 9.3% of waste reclaimers originated outside South Africa. Possible explanations on the difference in the country of origin with previous studies are the impact of the Covid pandemic that reduced the number of foreign nationals waste picking in Johannesburg, or that undocumented foreign nationals do not participate in surveys as they fear that they would be reported.

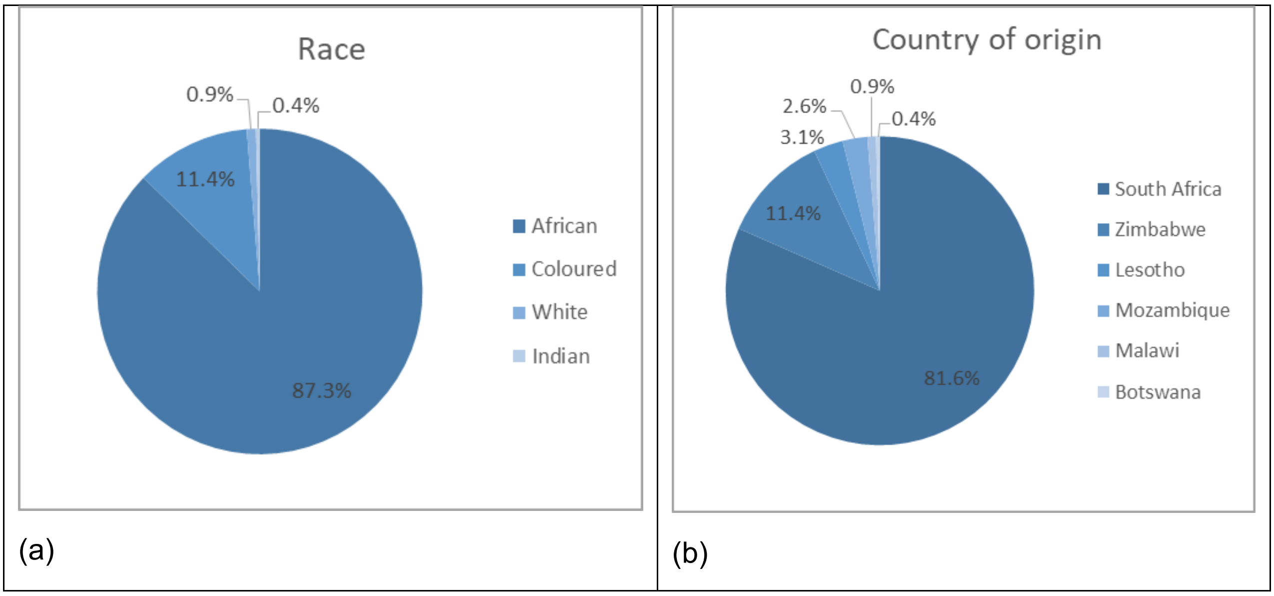

Figure 4: (a) Race and (b) Country of origin

3.2.3 Level of education

The bigger number of informal waste reclaimers completed some high school level (65.2%), while 25.9% attended or completed only primary school. The most surprising result was that there were well educated waste reclaimers, three (1.4%) waste reclaimers obtained tertiary qualifications, namely a BCom Accounting, a BA Honours Design and Technology and Nursing degree (Table 1). In contrast with the Sentime (2011) study that found that waste reclaimers in Johannesburg have very limited education, this study found that Gauteng waste reclaimers had a higher level of education. This national study (DEA, 2016) reported that 13.1% waste reclaimers in Gauteng completed matric, which is similar to the results of this study.

Table 1: Level of education

Level of education	Number of respondents	Percentage
Completed some primary school	29	12.9%
Completed primary school	15	6.7%
Complete some high school	146	65.2%
Completed Matric	31	13.8%
Post-matric qualification	3	1.4%

3.3 Operations

Operations in this study refers to the way in which waste reclaimers function on their daily basis. This section presents the types of waste they collect, their number of years working, place of e-waste collection, other recyclables they collect, the buyers they sell to, place of storage, income they made and their willingness to sell to e-waste recyclers.

3.3.1 Types of e-waste collected by waste reclaimers

Waste reclaimers collected different types of e-waste and cables (45.9%) were the most collected type of e-waste, followed by screens (43.1%) and radios (30.2%) (Table 2 and Figure 5). The least collected types of e-waste were monitors (7.0%) and washing machines (2.9%). Washing machines and monitors are bulky and heavy equipment and would therefore not be easy to transport to a collection or recycling centre.

Table 2: Types of e-waste collected

Commonly collected waste	% of collectors
Cables	45.9%
Screens	43.1%
Radios	30.2%
Microwave	23.8%
Monitors	7.0%
Washing machines	2.9%
Kettle	21.4%
Iron	18.2%
All types of electronic goods	23.6%

Figure 5: Examples of e-waste collected (Author)

3.3.2 Number of years working

A fifth of waste reclaimers (20.1%) had five to six years' experience, while 16.6% had more than ten years' experience (Figure 6). The highest number recorded was a waste picker that reported 22 years working as a waste collector, while only 0.4% was not sure of how many years they worked. There can be several reasons why more than a third (36.7%) of waste reclaimers had less than five years' working experience. One such reason is that often it is young people that dropped out from or recently completed school that work as waste reclaimers. With very high youth unemployment rates they could not find jobs in the formal sector. In the Alexandra Township, most of the young waste reclaimers indicated that they are just into waste picking/recycling because they are "tired of staying at home and doing nothing". This is in line with the Made et al. (2020) study that found that there is a growing number of 18 years old waste pickers, who just left high school and could not get jobs.

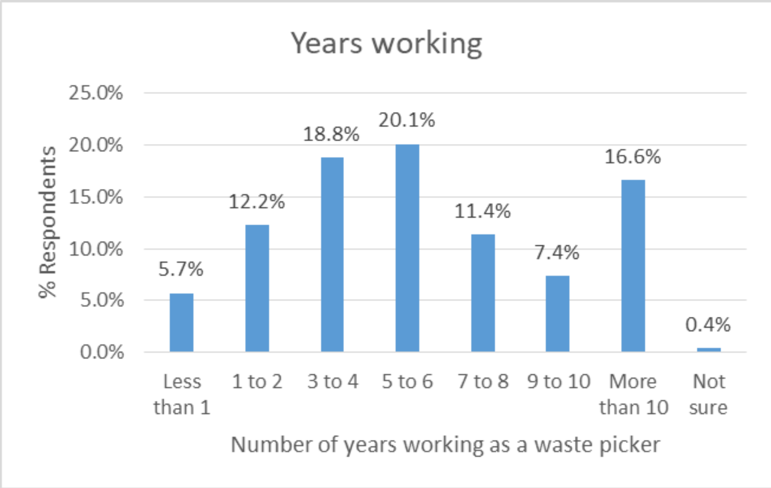

Figure 6: Number of years working as a waste picker

3.3.3 Place of e-waste collection

Waste reclaimers collected e-waste from multiple locations (Figure 7). Dustbins outside houses (74.2%) were where the most e-waste was collected, followed by shops/business (60.9%) and 56% was directly collected from residents. The lowest number of waste reclaimers (7.3%) indicated that they collected their waste from 'other', with 'other' being streets/roads and local illegal dumping areas. This is similar to the DEFF & DST (2020) guidelines that described waste pickers as people who collect both re-usable and recyclable material from residential and commercial bins, landfill and open spaces.

Figure 7: Place of collection of e-waste

3.3.4 Other recyclables collected

Waste reclaimers interviewed did not only collect one type of recyclables, but everything that was discarded and could be sold or that was perceived to have value was also collected. Of the recyclables collected, metals (79%) were the most collected, followed by plastic (77.1%) and paper (76.2%) (Figure 8). Only 16.4% of waste reclaimers collected globes and 19.2% tetra pack. The findings of this study are similar to those of Yang et al. (2018) and Kasinja & Tilley (2018) that found that metal, plastic and paper are the most collected type of recyclable by waste pickers. They can get relatively higher prices as these recyclables have the highest recycling potential.

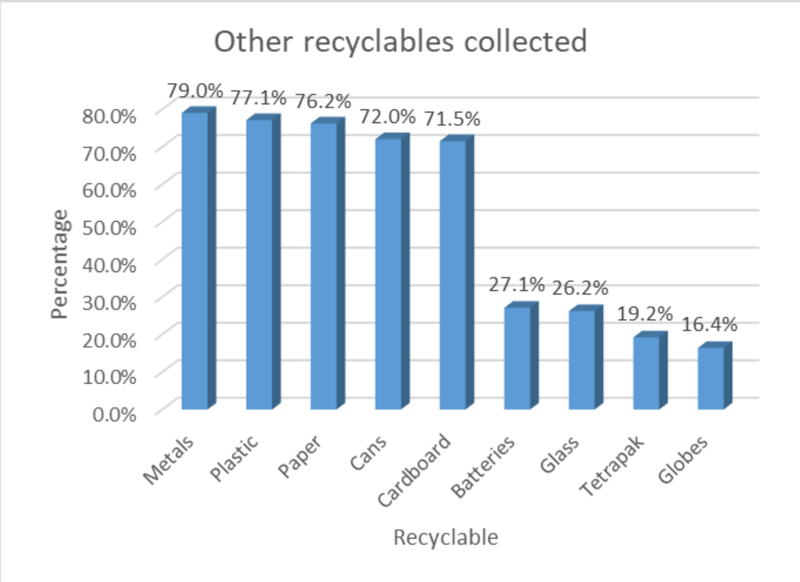

Figure 8: Other recyclables collected

3.4 E-waste buyers

The majority of waste reclaimers (76.4%) sold the e-waste they collected to scrap metal dealers, while 49.3% of them sold it to a general buy-back centre or an e-waste buy-back centre (Table 3). Only 10 respondents (4.1%) were selling to factories, other waste reclaimers or local individuals and some e-waste are repaired and then sold (represented as category 'other'). Most waste reclaimers from all sites prefer scrap metal dealers as they are of the opinion that scrap metal dealers pay higher prices than other potential buyers and have less strict requirements. The results, however, also showed that waste reclaimers sell e-waste to more than one buyer.

Table 3: E-waste buyers

Sold to	Number	Percentage
Scrap metal dealer	172	76.4%
General buy-back centre/depot	112	49.8%
E-waste buy-back centre/depot	111	49.3%
Buyer with a bakkie	111	49.3%
E-waste recycler	102	45.3%
I do not know who it is	23	10.2%
Other	10	4.1%

3.5 Willingness to sell to e-waste recyclers

There was a number of waste reclaimers (45.3%) that indicated that they do sell to e-waste recyclers (Table 3). For waste reclaimers (54.7%) that did not sell to e-waste recyclers, a question was administered to find out whether they are willing to sell to e-waste recyclers or not. For those that indicated they would sell to e-waste recyclers, a common theme was depicted from their responses, namely: better income. In support, two chosen responses from willing waste reclaimers were:

"Yes, maybe they will pay better than other dealers."

"Yes, I think they would pay better than scrap yards. I think scrap metals pay less".

In contrast, responses from waste reclaimers unwilling to sell to e-waste recyclers, three notable themes were identified, namely: location, familiarity, and reduced income. Regarding location, one respondent said:

"*No, I don't know their locations*".

Common problems identified by waste reclaimers was the fluctuation in prices for recyclables (Kasinja & Tilley, 2018) and not been paid a fair price for recyclables (Schoeman, 2018). Therefore, it was not unexpected that waste reclaimers were not willing to sell to e-waste recyclers if they get lower prices for goods. This is reflected in the following view of a waste picker:

"*No, they will give me a small amount of money compared to what I get at scrap dealers*".

Been familiar with a buyer and having a good working relationship were also important to waste reclaimers. This came to the fore in the following reason provided by a respondent:

"*No, I have a good relationship with my current buyers*".

3.6 Storing of e-waste

Just more than half (54.9%) of waste reclaimers stored their e-waste somewhere (Figure 9). The top five places of storage for those that store e-waste were: on the streets, under bridges, at home, in bins and in bulk bags. The most surprising response was finding that some waste reclaimers store their e-waste at the scrapyards they sell to. It confirmed that they have built up relationships and trust with buyers to such an extent that they stored their e-waste with the same person who bought e-waste from them. However, for those that did not store e-waste anywhere, the study found that they sold their e-waste on a daily basis.

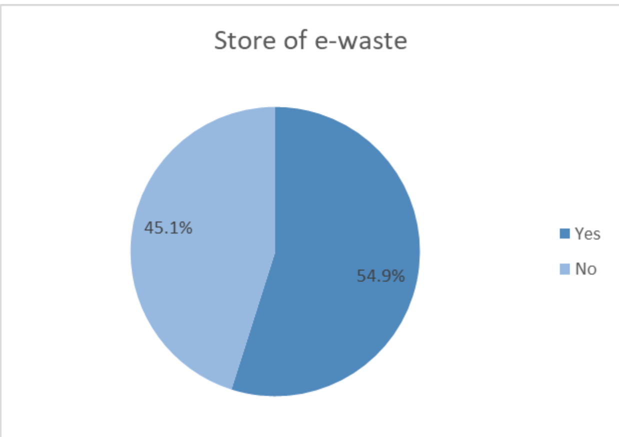

Figure 9: Store of e-waste

3.7 Income earned

Almost three-quarters (72%) of waste reclaimers earned less than and up to R600 per week for recyclables collected and sold (Figure 10). The lowest figure given for earnings per week was R100 and the highest R7 000. Only 3% earned more than R1 501 per week. The average income calculated was R580 and the median income per week R400.

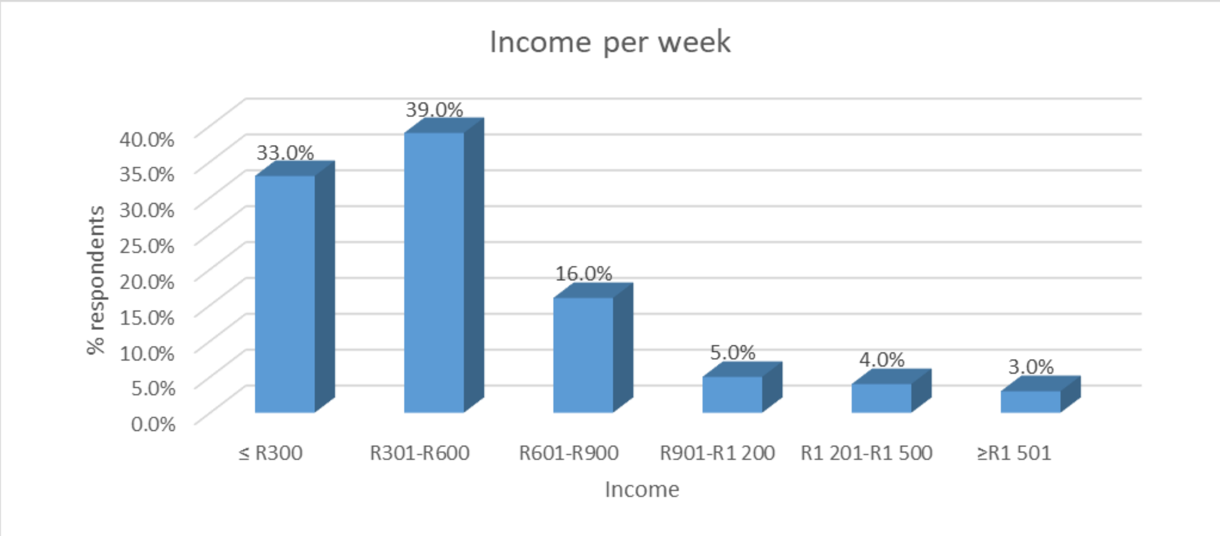

Figure 10: Average income per week

The income earnings for were very similar to the DEA (2016) report that gave R1 430 as the mean monthly income, which translates to R357 per week. Waste reclaimers that sell their recyclables were provided with a receipt (Figure 11). Unfortunately, none of the respondents kept detailed records of their earnings from e-waste. This was mainly because waste reclaimers collect more than one type of waste. Therefore, it was not possible to calculate the income that waste reclaimers earned from collecting and selling e-waste.

Figure 11: An example of a receipt (Author)

In order to earn higher income for e-waste, often dismantling and processing of e-waste take place. By dismantling e-waste, only the valuable fractions are sold, and the rest discarded. Processing involves extracting the valuable components and often includes the burning of cables to extract copper. The next sections briefly explain dismantling and processing of e-waste by respondents.

3.8 Dismantling of e-waste

E-waste dismantling involves the breaking down of discarded EEE using tools such as hammers to separate the discarded waste (Heacock et al., 2016). The majority of the respondents (68.0%) dismantled e-waste (Table 4). Out of those that conduct dismantling, only 3.3% received training and a number of them were trained by close relatives and friends and education. To attest on this, some responses:

> "*I have learnt by watching other people do it*."
>
> "*From experienced co-workers*."
>
> "*Training from friends*."
>
> "*From my father who was an electrician*."
>
> "*I did an electrical engineering course at Sedibeng College*".

Table 4: Dismantling, training and working together

Response	Dismantle e-waste	Training in dismantling	Work with other waste pickers to dismantle
Yes	68.0%	3.3%	30.4%
No	32.0%	96.7%	69.6%

However, the study found out that whether with or without training the waste pickers dismantled goods such as printed circuit boards to extract mostly valuable metals such as copper, lead, aluminium and gold (Figure 12). The least dismantled goods were washing machines and geysers. Moreover, the study also found out that 30.4% of waste reclaimers dismantled their e-waste with other waste reclaimers, whereas 69.6% prefer to work alone. Those that work with others had different reasons on how they work together, one being 'sharing responsibilities' that when the other one breaks down the goods, the other one carries the load to the buyer.

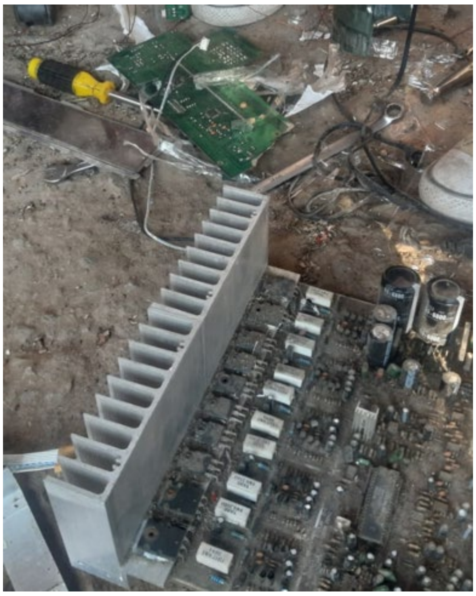

Figure 12: Dismantling of e-waste (Author)

3.9 Processing of e-waste

Processing e-waste refers to the extraction of valuable metal from discarded cables using chemical and mechanical methods (Masud et al., 2019). More than a half (60.2%) of waste reclaimers conducted e-waste processing (Table 5). Out of all waste reclaimers that conducted processing, only 1.6% received training. Similar to the findings of the previous section, waste reclaimers were trained by friends and family and the majority (66.4%) prefer to work alone.

Table 5: Processing, training and work together

Response	Process e-waste	Training in processing	Work with other waste pickers to process
Yes	60.2%	1.6%	33.6%
No	39.8%	98.4%	66.4%

The processing that was done was mostly to extract copper and aluminium from cables (Figure 13). There is thus a clear need to train and provide waste pickers with the necessary skills and tools to process e-waste in a safe manner.

Figure 13: Processing of e-waste (Author)

Another way to increase the value of e-waste is to repair and refurbish it and sell it as used goods. The next section outlines repair and refurbishment of e-waste.

3.10 Repair and refurbishment of e-waste

The majority of waste reclaimers (75%) repaired and/or refurbished e-waste collected. There were multiple purposes for repairing and refurbishing goods – some of the goods are sold but some were kept for personal use. In this study, a high number of waste reclaimers (87.4%) indicated that they resell repaired/ refurbished goods for income and 42.1% indicated that they keep the repaired/refurbished goods for personal use. Items that are kept for personal use include cellphones, kettles, irons, fans, heaters and even large household appliances such as stoves.

3.11 Training

The study found that 80.6% of waste reclaimers were willing to be trained, 5.8% of them were neutral while only 12.6% were very unwilling to be trained (Figure 14). The DEA (2016) report and the DEFF & DST (2020) guidelines both emphasised the importance of up-skill waste pickers and that municipalities should provide training for waste pickers.

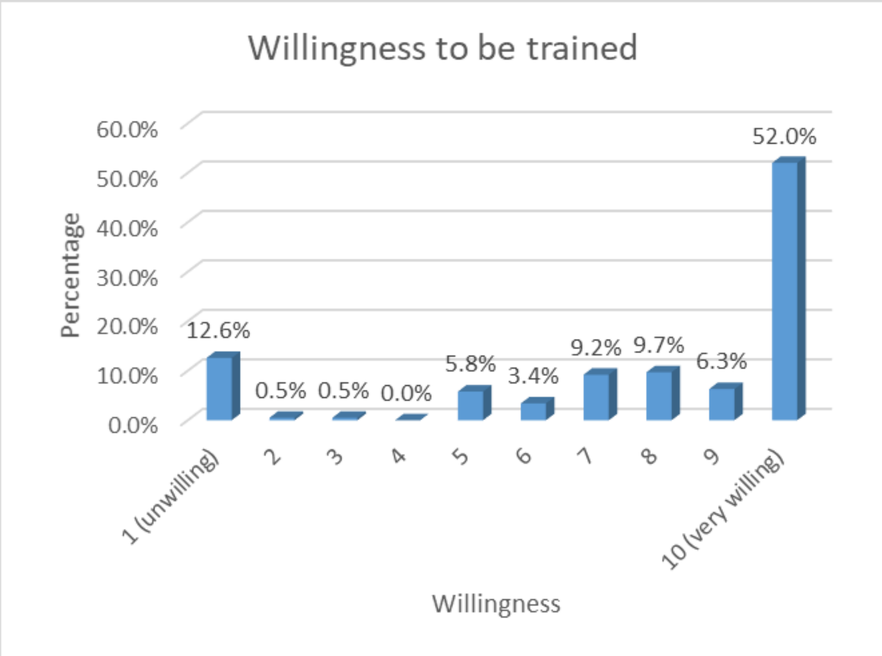

Figure 14: Willingness to be trained

Further questions in the survey were on what type of training respondents would like to undergo (Table 6 (a)) and 193 respondents completed this question. The top training need identified by waste reclaimers was training in safety (47.7%) by almost half of the respondents. This was followed by repair of household appliances (24.9%), and kettles and irons both at 12.4%. Respondents also would like to receive training on electricity and 9.8% indicated that they required this type of training. The need for safety training is expressed in the following responses of two waste reclaimers:

> *"I would like to learn how to properly break-down the appliances without hurting myself."*

> *"Learning how to dismantle goods and how to be safe while doing so would be great."*

On when the training should take place, a big variance in answers was recorded for the waste reclaimers that answered this question. Some were very specific like twice a month on a Monday morning, while other responses only indicated the time of day and not the frequency. Therefore, the answers were grouped using time of day or month and not frequency (Table 6 (b)). Just more than half of waste reclaimers (50.3%) indicated that they would prefer training to take place in the afternoon. A common reason for this choice was that they needed to collect the recyclables in the mornings. A quarter (25.4%) would prefer training to take place in the mornings and 15.2% prefer weekends. The variation in answers is illustrated in the following responses:

"Only in the afternoon so that I can collect waste in the morning."

"It should take place once a week on Monday mornings when my brain is still fresh."

"Definitely morning, as I have to go sell my waste later on during the week."

"Anytime of the day, just the opportunity to do the training would be great."

Table 6: (a) Type of training and (b) when training should take place

What to see in the training	%
Safety training	47.7
Repair of household appliances	24.9
Repair of kettles	12.4
Repair irons	12.4
Training on electricity	9.8

(a)

When training should be	%
Afternoons	50.3
Mornings	25.4
Weekends	15.2
Fulltime	6.6
Anytime	2.5

(b)

Waste picking is a physical strenuous job and a concern, doing training in the afternoon can be the lack of concentration in participants. A number of waste reclaimers also commented that they can only attend a full day or full-time training if they are paid to do so as they cannot afford to lose any income. These are all factors that should be taken into consideration in the planning of training of waste reclaimers.

The work of waste reclaimers would be made much easier if residents would separate their recyclables, including e-waste, from their domestic solid waste. Further advantages of doing this are expanding the life of landfills, creating jobs, using less resources and contributing to the circular economy. Respondents were asked for recommendations to increase participation in e-waste recycling, and this is discussed in the next section.

3.12 Recommendations to increase e-waste recycling

An open-ended question asked of waste reclaimers what municipalities can do to encourage recycling of e-waste. A total of 190 answered this question but a surprising finding was that 57 responses (30%) can be considered as negative. The negative views expressed are mainly on the corruption and the 'uselessness' of municipalities. The following responses are examples of such negative views towards municipalities:

"The Municipality must just focus on corruption, we will recycle e-waste for people."

"The Municipality is as corrupt as its leader, people like us are the ones who are supposed to inform people about e-waste recycling."

"The Municipality can't do anything because they are useless."

Some responses indicated that there is nothing the municipality can do. One respondent also commented on the independence of waste reclaimers that was also a finding of the DEA (2016) report and of broken promises. The quotes below illustrate these opinions:

"Nothing. We are now used to being independent. Many companies or firms have been coming and promising jobs or wanted us to work under them but fail to keep their promise."

"Nothing, they have already failed us a lot."

"Nothing. They are not doing anything anyway."

However, a total of 134 respondents made recommendations and municipalities should take note of these (Table 7). Too often waste reclaimers views and opinions are not taken into consideration when developing recycling programmes to integrate waste pickers. The top recommendation (43.3%) was to provide residents with the necessary information, education and awareness on how to recycle e-waste. This was followed by the provision of personal protective equipment (PPE) to waste reclaimers (11.2%), provision of jobs in e-waste recycling (8.2%), provision of bins for e-waste and more recycling facilities dedicated for e-waste with both at 7.5%. A need was also expressed by 6.7% of respondents for equipment such as trolleys and dismantling tools. Some respondents (3.7%) even suggested that residents that do not recycle should be fined.

Table 7: Recommendations from waste reclaimers

Recommendations	% responses
Information, education and awareness	43.3
Provide PPE	11.2
Provide jobs	8.2
More bins	7.5
More e-waste recycling facilities	7.5
Equipment	6.7
Fine non-recyclers	3.7

E-waste recycling and repairing are an entrepreneurial job opportunity and can lead to a reduction of unemployment and poverty and contribute to economic growth. The next chapter outlines the training of waste reclaimers in the repair of small appliances in an effort to increase their income, reduce e-waste disposed at landfill, and educate them about the save handling of e-waste.

4 Training waste reclaimers in the repair of small appliances

E-waste is managed by the informal sector in a manner associated with environmental and health concerns (Rautela et al., 2021). This includes the collection, transportation, processing, segregation, repairing, refurbishing, and dismantling of discarded EEE. However, one cannot ignore that this sector is an essential player in the fight against e-waste. The informal sector's involvement in managing e-waste operates on a dual track. On one hand, it curbs the accumulation of e-waste in disposal sites, thereby mitigating environmental impacts and offering reclaimers income opportunities. Yet, the methods they employ raise concerns regarding environmental and their health. To fully harness the sector's positive impact, it is crucial to empower reclaimers with appropriate skills for the safe handling, repairing/refurbishment and disposal of e-waste. The funding received from the Waste RDI Roadmap allowed for two training sessions to equip them with the necessary knowledge, skills and tools for the responsible management of e-waste. This part of the research, had the following objectives:

- observe and evaluate the effectiveness of the training;
- determine the effectiveness of the training by comparing the before and after results of the self-evaluation; and
- recommend actions and measures to improve the training in the repair and refurbishment of e-waste.

4.1 Methodology

A mixed-method approach was followed for this part of the research. Ashley & Boyd (2006) suggest that qualitative and quantitative approaches, operating concurrently, may be needed when addressing environmental management issues in the future.

The first part of the questionnaire used in the study collected data on the waste reclaimers and their operations. The rest of the questionnaire was on evaluating the training by applying Kirkpatrick's evaluation model. It is a tool used to evaluate the effectiveness of training using four levels, namely, (i) gathering the reactions of the trainees at the end of the training; (ii) the learning outcomes and increase in knowledge and skills, and an improved attitude towards the attendance experience; (iii) whether the transfer of knowledge and skills into practice is happening; and (iv) the impact of training in the work environment (Rao & Kumar, 2017; Heydari et al., 2019). The study only focused on the first two levels, namely, reaction and learning.

The researcher conducted face-to-face interviews and took the study participants through the questionnaire, explaining the questions as they wrote their responses. The researcher assisted some of the participants by writing their responses in a question-and-answer style. This was done for the participants that did not know how to read and write in English as well as those that had learning disabilities.

The study made use of unstructured observations to collect qualitative data in its attempt to describe life as experienced by the research participants (McKechnie, 2008). The researcher made use of moderate participation. During the theory component the researcher was onsite making observations without engaging in the classes, whereas during the practical component, the researcher made observations whilst participating in the activities.

The research targeted reclaimers around the Gauteng province, preferably those collecting and handling e-waste. The African Reclaimers Organisation (ARO) was approached to identify reclaimers that would meet the criteria to participate in the study. Co-operatives established by reclaimers around the province and reclaimers that often sell their e-waste in Johannesburg's central business district (CBD) were also approached to participate in the study. The aim of the study was to recruit 10 participants for each training session. The total for both training sessions was determined by the availability of funding. The reclaimers had to be paid a daily stipend and provided with tools and PPE.

The quantitative data obtained from the questionnaires was captured and analysed in an Excel spreadsheet. Descriptive analysis was performed on the data, as it summarises complex data into simple and understandable formats. The second statistical analysis used in this study is inferential statistics. The study made use of a nonparametric statistical test, namely, the Wilcoxon signed rank test to compare paired data, namely the trainees' competence levels before and after the training.

Lastly, this part of the study used inductive thematic analysis on the qualitative data collected from the questionnaire survey and observations made by the researcher. The themes identified in the responses given by the respondents to the open-ended questions constitute part of the explanations of the data structure provided for in the results section of this chapter.

4.2 Demographics and operations

The first training session for the study occurred at UJ-PEETS (University of Johannesburg Process Energy and Environmental Technology Station) spanning from May 9, 2022 to May 20, 2022. Although the researcher extended invitations to ten participants, only nine attended. The subsequent training session unfolded from September 26, 2022 to October 7, 2022. As it was planned to train 20 participants, the researcher invited 11 individuals to attend the second round of training. All invitees attended the second session. By the conclusion of the training, on the final day, participants completed questionnaires after successfully repairing all the provided small appliances and the results are presented in the following sections.

4.2.1 Demographic profile

As stated before, waste reclaiming is a strenuous job expected to be dominated by males as they have greater physical strength than females. More females participated in the training, although the difference was not significantly high, with a distribution of 45.0% males against 55.0% females (Table 8). The representation of gender distribution in this study could be attributed to the nature of the training opportunity. The training did not require physical strength and very long hours of work. All the waste reclaimers were Black, the majority from South Africa (80%), and 55% completed matric or had a post-matric qualification. As the training took place during the Covid pandemic, the training required that participants be vaccinated and that they have the necessary documentation to proof they are operating legally within South Africa as required by UJ. This might account for the higher number of South African nationals participating in this study.

Table 8: Socio-demographic characteristics

Demographic	Class	First training	Second training	Percentage
Gender	Female	2	9	55.0%
	Male	7	2	45.0%
Language	English	3	1	20.0%
	Sesotho	1	1	10.0%
	IsiZulu	2	5	35.0%
	Setswana	1	0	5.0%
	IsiXhosa	1	2	15.0%
	SiSwati	0	1	5.0%
	Tshivenda	0	1	5.0%
	Shona	1	0	5.0%
Country of origin	South Africa	6	10	80.0%
	Lesotho	1	1	10.0%
	Zimbabwe	2	0	10.0%
Level of education	Completed some primary	0	0	0.0%
	Completed primary	0	1	5.0%
	Completed some high school	4	4	40.0%
	Completed matric	3	4	35.0%
	Post-matric qualification	2	2	20.0%
Municipality	City of Johannesburg	8	10	90.0%
	MidVaal	1	0	5.0%
	Ekurhuleni	0	1	5.0%

4.2.2 Operations

Similar to the results presented in Section 2 of this report, the majority (55%) of reclaimers had 5 years or less experience. One reclaimer in her thirties, indicated that she had 22 years of experience and started waste reclaiming as a child. Almost a third (30.0%) of the respondents indicated that they did not collect e-waste – all of them with under two years' experience. The respondents that did collect e-waste collected any e-waste they came across and small appliances such as kettles, irons, microwaves, heaters, and stoves, together with cables, were the most prevalent among the items collected. Half of the respondents that reclaim e-waste indicated that they also collect ICT equipment such as monitors, printers and keyboards. Other items that were widely collected include consumer electronics such as cell phones and TV sets. The reclaimers collect e-waste from various places (Figure 15). Wheelie bins outside residential areas and landfill sites were the most common places, with 42.9% and 28.6% of reclaimers collecting from these places.

Figure 15: Place of collection of e-waste

As explained in Section 2, waste reclaimers in South Africa collect more than one type of waste, and this was also the finding of this part of the study. The results indicated that the recyclables most frequently collected are cans (75.0%) and cardboard (60.0%), followed by plastic (50.0%) and paper (45.0%) (Figure 16). One of the respondents indicated that he only collected e-waste, which was very unique finding as scholars such as Finlay & Liechti (2008), Ghosh et al. (2016), Lydall et al. (2017) and Schoeman & Ramutanda (2022) have noted that many reclaimers collect e-waste together with other recyclables.

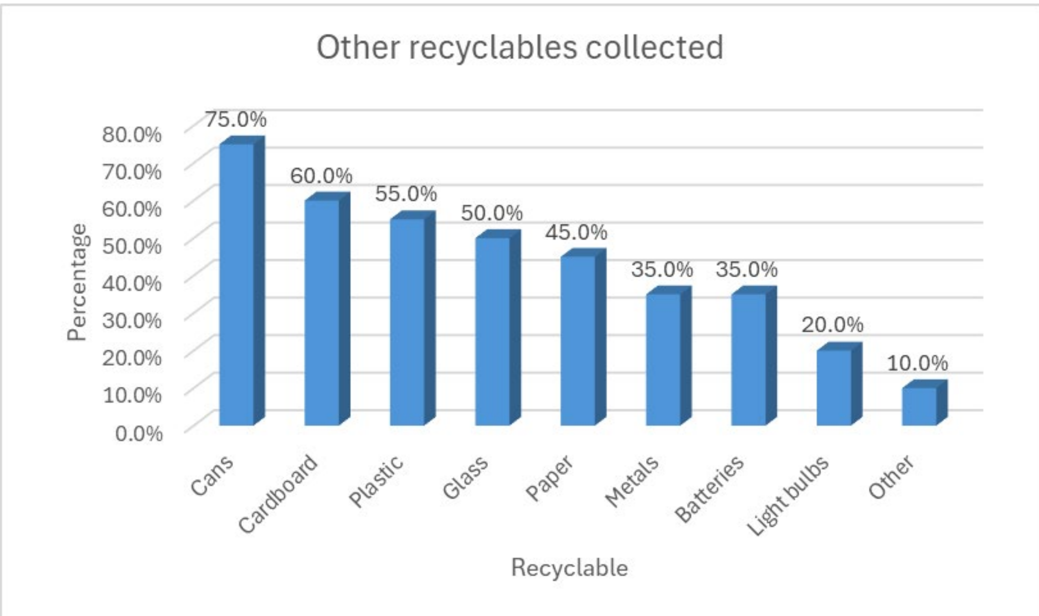

Figure 16: Other recyclables collected

The majority of the reclaimers (87.3%) stored their e-waste while the remainder sold it on the same day of collection. Respondents also sold their e-waste to various buyers – 50% to buy-back-centres, 35.7% to other buyers, 21.4% to scrap metal dealers while only 7.1% sole their collected e-waste to an e-waste recycler.

When it came to processing and dismantling of e-waste, 64.3% of respondents that worked with e-waste indicated that they dismantled and/or processed e-waste. Just more than half (55.6%) engaged in both processing and dismantling of e-waste. The results of the study also found that the those who dismantle their e-waste used their hands and tools, such as hammers and screwdrivers, to carry out the process. While the most common method to process the e-waste was by burning.

Only 25.0% of the reclaimers had previous experience in repairing e-waste. This group of reclaimers indicated that they repair various small appliances, cell phones and IT components. Only two of the reclaimers indicated that they had received training in repairing WEEE. One received training from a colleague at their previous place of employment, and the other from an educational institute. The remainder of the respondents were either self-taught or had observed the work of someone else. The respondents gave the following responses:

> *"I used to work at Cash Converters, and my colleague used to fix; so he taught me".*
>
> *"I attended a four-week course at Xtensive ICT Academy, where they taught me a lot of skills, including repairing".*
>
> *"I taught myself so that I can make money".*
>
> *"My father repaired electrical items, so I used to observe him when he was working".*

4.3 Results of the training

This part of the analysis centers on the satisfaction of the study participants regarding their training experience. It commences by assessing their satisfaction with the length and duration of the sessions, proceeds to evaluate the training content and preferred session, and culminates in an examination of overall satisfaction. Participants' satisfaction levels are gauged through sentences wherein they express their agreement or disagreement with various aspects of the training.

4.3.1 Satisfaction with duration and length of training

A five-point Likert scale was used to determine the participant's level of satisfaction with the length and duration of the training. None of the participants indicated that they were very dissatisfied, and most participants were satisfied with the length and duration of the training, followed by those that were very satisfied, with 45.0% and 35.0%, respectively. A small proportion of the respondents indicated that they were neutral in respect of the length and duration of the training, with 15.0%. Some of the responses regarding the duration and length of the training were:

> "*I would change the length and duration as WEEE covers a lot from both the theory and practical components. I would have loved to work with more WEEE appliances and know how to fix them properly"*.
>
> "*We had many appliances to work on and very little time. Increasing both length and duration would allow us to practice properly"*.

"Some of us take time to learn new skills; it took me two days to learn how to fix an iron that had an issue with its sensor. Having more time would have allowed me to learn more things without feeling like I am slow".

4.3.2 Training content

The training started with a theoretical component that covered topics on the value of e-waste, legislation, the good and bad practices in handling e-waste, and identifying different components. The practical component covered aspects such as knowing and using the correct tools, soldering and testing of equipment, and the repair of small appliances.

Only one respondent (5%) said that the training had not covered the training content that he had been expecting and stated that he had hoped it would have covered content on how to separate the precious metals found in e-waste and printed circuit boards. During observation by the researcher, the participants agreed that the repair of e-waste provided more benefits than the removal of precious metals to sell to various dealers. They also seemed to understand that activities like that were illegal and would require one to register as a recycler under the Precious Metals Act.

The practical component of the training was the part the most (85%) of participants enjoyed. Only one (5%) preferred the theory component while two (10%) of participants enjoyed both parts of the training.

4.3.3 Satisfaction with training

Only 5.0% of the respondents strongly disagreed with the assertion that the training objectives were clearly defined and achieved (Table 9). Regarding whether the training developed necessary skills for their line of work, the majority (65.0%) of participants strongly agreed, with the remainder in agreement. Similarly, for the statement regarding the effectiveness of the tools provided during training in enhancing daily operations, the majority (70.0%) strongly agreed. Figure 17 depicts one of the participants utilising the tools provided during the training.

Table 9: Satisfaction with the training

Response	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The training was effectively organised	5.0%	5.0%	10.0%	40.0%	40.0%
Training objectives were clearly defined and met	5.0%	-	-	50.0%	45.0%
Training content was relevant to my daily activities	-	5.0%	10.0%	30.0%	55.0%
Training developed skills that necessary in my line of work	-	-	-	35.0%	65.0%
Tools provided will effectively increase my daily operations	-	-	-	30.0%	70.0%

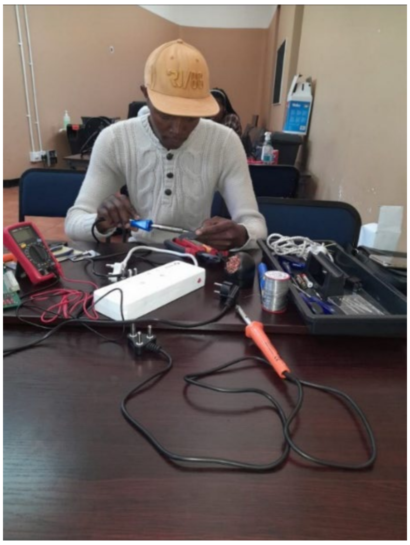

Figure 17: A participant with tools provided for the training in repair of e-waste

On evaluating whether the participants would use the skills required post training, the majority (70%) said that it would be very likely and 30% chose likely. Reclaimers were also asked if they would recommend the training to their colleagues. Some of the responses were:

> "*I work with young people looking to improve their skills and gain knowledge; having them exposed to such initiatives would benefit them greatly and hopefully develop their lives"*.
>
> "*To change how other reclaimers think about waste, particularly WEEE".*
>
> "*To allow others to learn the skills I learnt and possibly collaborate in the future to open our WEEE repair shop".*

These findings suggest that the reclaimers found the training valuable, as it enlightened them about the environmental and health consequences of mishandling e-waste. Furthermore, the training equipped the reclaimers with essential knowledge and tools, enabling some to contemplate starting their own businesses. Notably, one respondent even mentioned the prospect of opening a shop with fellow colleagues, underscoring the significance of the training's impact. Some of the responses to support this were:

> "*The trainers also incorporated lessons about how being organised helps the environment while helping me identify recyclables I can repair to make more money".*
>
> "*The training equipped me with skills and knowledge on repairing and making appliances look new after fixing them, so I can continue contributing to recycling and reusing".*
>
> "*The training improved my skills in repairing WEEE. I learnt to fix WEEE such as microwaves and blenders and how to dispose of the components I do not need without harming the environment".*
>
> "*It taught me about the circular economy and how to treat WEEE in a manner that is safe for me and the environment".*
>
> "*I was exposed to tools such as a multimeter, which I did not know and use when repairing, and how to be safe when handling WEEE".*

"I learnt that selling repaired and refurbished WEEE will increase my income rather than when I sell some parts of it".

4.4 Evaluation of the trainers

The trainers involved in this study possessed expertise in the subject matter, being integral members of the training team designated by TCB. Their role involved imparting skills training and knowledge to unemployed fathers in the repair and refurbishment of e-waste. With over three years of experience in training TVET (technical vocational education and training) college students and having conducted sessions for more than 100 individuals at a time, they had also ventured into establishing their own businesses within the repair sector. Notably, their prior experience did not include working with reclaimers. Against this backdrop, the participants of the study assessed their performance, as elaborated below.

The reclaimers that were trained by the TCB trainers were very satisfied with the trainers. Except for one neutral rating (Table 10), all other statements about the trainers were rated as agree or strongly agree. During observations, the researcher observed that the trainers showed exceptional dedication in their training as they have researched the activities of reclaimers. This effort enabled them to tailor the training content to the daily realities of the participants. The results affirm the effectiveness of this approach, with 45.0% strongly agreeing and 50.0% agreeing that the trainers successfully linked the training to their daily operations. Conversely, only 5.0% expressed neutrality on this matter.

Table 10: Evaluation of trainers

Statements	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Created a safe and respectful environment	-	-	-	35.0%	65.0%
Engaging and responded to questions	-	-	-	30.0%	70.0%
Related learning to what is relevant to trainees	-	-	5.0%	50.0%	45.0%
Enabled trainees to be fully engaged in learning	-	-	-	35.0%	65.0%
Patient with trainees and facilitated their learning	-	-	-	25.0%	75.0%
Incorporated adequate practice and repetition	-	-	-	50.0%	50.0%
Trainers used various learning methods	-	-	-	45.0%	55.0%
Allocated their time effectively	-	-	-	45.0%	55.0%

It is worth noting that throughout the training (Figure 18), especially during the theoretical component, the trainers shared their own relevant experiences with the subject matter. They adeptly utilised various South African languages, including IsiZulu, Sesotho, and English, ensuring comprehension among the diverse participants. Additionally, they employed straightforward terminology and offered thorough explanations and demonstrations. The researcher observed the trainers' commendable personal attributes, such as organisation, energy, and the integration of humour into their lessons. This fostered an environment conducive to participant expression, thereby cultivating a positive teacher-student relationship.

Figure 18: Trainees and trainers during theory sessions

Some comments on the trainers recorded in the open-ended question were:

> *"The trainers were very patient with us and ensured we understood everything we were taught during both training sessions".*
>
> *"The trainers were very nice and welcoming, made everyone comfortable to ask questions, and responded effectively".*
>
> *"The trainers were very efficient and did their utmost best to ensure that we understood the daily tasks".*
>
> *"I was very impressed with the techniques the trainers used during the training; I wish I could attend more training sessions conducted by them".*

4.5 Self-evaluation

Participants conducted a self-evaluation of their level of competence before and after the training. A five-point scale was used, and the levels of competence were as follow:

1 - No level of competence - no knowledge in the skill area

2 - Low level of competence - little knowledge and skill in the area

3 - Average level of competence - some knowledge and skill in the area

4 - Moderately high level of competence - good knowledge and skill in the area

5 - High level of competence - extensive knowledge and skill in the area

For the theory component of the course, there were some areas that were not mastered by all students. For the South African legislation regarding e-waste, 20% of respondents indicated that they had a low or average level of competence (Table 11). Areas that showed vast improvement were safety related with 95% if participants rated themselves with a high level of competence in the use and need of PPE and the good and bad practices in handling e-waste. It was interesting to note that the majority of the reclaimers had an idea of the use of and need for PPE, with only 25.0% indicating no level of competence in this area before the training. The researcher observed that on the first day of the training a couple of the reclaimers had arrived with their own PPE.

Table 11: Level of competency in the theory component before and after training

Area of the theory component	**Level of competency (%)**									
	Before the training					**After the training**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Value of e-waste	30.0	35.0	30.0	-	5.0	-	5.0	5.0	5.0	85.0
South African legislation on e-waste	55.0	20.0	15.0	10.0	-	-	5.0	15.0	20.0	60.0
The use and need of PPE	25.0	5.0	15.0	15.0	40.0	-	-		5.0	95.0
Good and bad practices in handling e-waste	55.0	20.0	15.0	5.0	5.0	-	-	5.0	0.0	95.0
Identify different electrical components	40.0	20.0	35.0	5.0	10.0	-	5.0	0.0	10.0	85.0

The training also successfully equipped reclaimers with the necessary practical skills to repair e-waste as across all areas there were significant improvements in reclaimers' levels of competence (Table 12). Knowing and using the correct tools for repairing and dismantling received the highest level of competence, with 90% of reclaimers rating themselves with a high level of competence. Only one participant (5%) recorded an average level of competence in repairing and refurbishing a blender, which was the lowest rating for practical skills.

Table 12: Level of competency in the practical component before and after training

Area of the practical component	**Level of competency (%)**									
	Before the training					**After the training**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Knowing and using the correct tools for dismantling/repairing	40.0	20.0	25.0	10.0	5.0	-	-	-	10.0	90.0
Soldering and testing equipment	80.0	15.0	5.0	-	-	-	-	-	20.0	80.0
Repairing and refurbishing a kettle	60.0	15.0	15.0	5.0	5.0	-	-	-	15.0	85.0
Repairing and refurbishing a blender	85.0	10.0	-	5.0	-	-	-	5.0	15.0	80.0
Repairing and refurbishing a toaster	85.0	5.0	5.0	5.0	-	-	-	-	25.0	75.0

Repairing and refurbishing a heater/microwave	75.0	15.0	5.0	5.0	-	-	-	-	20.0	80.0

The variances in competence levels documented by the participants pre- and post-training suggest that the training effectively imparted the requisite knowledge and skills for repairing and refurbishing e-waste. These findings underscore the effectiveness of the training program. Descriptive analysis revealed overall satisfaction among participants, with noticeable improvements in their e-waste handling knowledge and skills post-training. To test if there was a statistically significant increase in skills levels, the following hypotheses were tested:

H_0: There is no difference between the before and after training scores

H_1: There is a difference between the before and after training scores

The Wilcoxon signed rank test performed on the data resulted in a p-value <0.01 at an $\alpha=0.05$ level. The null hypothesis was therefore rejected, and the results of the study showed that there was a statistically significant increase in the skills of the reclaimers before and after training. Based on the p-value obtained from the statistical test, there is a less than one percent (1.0%) chance that the results of the study were due to a random occurrence. Therefore, if the training was to be conducted using a different group of reclaimers there is a high probability that the results would be like those recorded in the study.

4.6 Recommendations for training

The reclaimers had an opportunity to provide additional comments and recommendations about the training they had received. The responses were positive and many related to the researcher that they have gained valuable skills. There were overwhelming requests to also be trained in the repair and refurbishment of large appliances such as fridges, washing machines, dishwashers, etc.

On the question on how the training could be improved, the training in large appliances' repair and refurbishment also came to the fore in responses such as:

> *"[I] Learned about large appliances and how to proceed if I come across an appliance I cannot fix".*

> *"The practical component is to include more appliances for us to repair, such as large appliances and computers".*

4.7 Outcomes

Due to the success of the training program to train waste reclaimers in the repair of small appliances, a UJ accredited short learning programme (SLP) was developed.

More information on the SLP can be found at: https://www.uj.ac.za/wp-content/uploads/2021/11/ewaste_management_slp_mar_2024_.pdf

To ensure that future training of reclaimers is done in a safe manner, an occupational health and safety manual was developed.

This manual is available at: https://wasteroadmap.co.za/wp-content/uploads/2024/01/38-UJ-Final_OHS-Manual.pdf

However, for waste reclaimers to be able to repair and refurbish e-waste, they must have access to e-waste stock. With very low recycling rates recorded for e-waste recycling in South Africa, this study also determined the volume of e-waste in Gauteng households as well as the recycling behaviour of residents that are discussed in the next chapter.

5 Volume of e-waste and e-waste recycling behaviour

E-waste is a waste management problem that is being experienced at an international level. Global cities and African cities are finding waste management of e-waste challenging in the 21st Century characterised by mass consumerism (Ogunseitan, 2013). Electronic items become obsolete as newer versions are released, increasing the number of electronic items being disposed of (Labuschagne, 2020). Most of the time, these electronic items are disposed of informally, illegally, or incorrectly, such as through informal incineration of devices (Ádám et al., 2021).

One of the main challenges preventing the e-waste industry from developing is the low volume of e-waste entering the recycling stream (Forti et al., 2020). The volume of e-waste that enters the waste stream is significantly based on the consumers of electrical and electronic equipment who currently hibernate their devices rather than recycle them (Gilal et al., 2019). The need to understand consumer behaviour in Gauteng households provides the rationale for this part of the research project and to try and determine the volume of e-waste stockpiled in households. The main aim of this part of the study was to determine e-waste volumes in households and identify drivers of e-waste recycling behaviour of Gauteng households using the Theory of Planned Behaviour (TPB) as a framework. The objectives of the study were:

- to determine the type and volumes of e-waste and methods of disposal of e-waste in households;
- to investigate the drivers of e-waste recycling behaviour in households; and
- to identify the variables that have the biggest influence on e-waste recycling behaviour.

5.1 Methodology

This primary data phase of the study was conducted in four stages to answer the research aim and objectives. In the first stage of the study, a survey approach was adopted, and an online questionnaire was developed to collect primary data about recycling behaviour and volumes of e-waste in households. The second stage of the study involved a pilot study with a limited group of participants to complete the online questionnaire to identify how it may be improved by identifying and addressing any problems of the questionnaire. In the third stage of the study, the survey method was used to collect data from a larger sample of residents of the Gauteng. The fourth stage of the study focused on selecting data analysis techniques and then analysing the results of the data collected.

A mixed-methods approach was used through the different survey sections by blending open and fixed-response questioning, which streamlined quantitative and qualitative research. This provided qualitative and quantitative answers and reflections on the e-waste streams and the e-waste recycling behaviour of residents in Gauteng.

A non-probability-based sample technique, specifically convenience sampling, has been used for data collection using the questionnaires. Convenience sampling is a standard method of non-probability sampling whereby individuals are available and have access to participate in the research (Etikan et al., 2016; Baxter et al., 2015). This sampling technique was also selected as there were limitations on in-person communication due to the Covid pandemic during the data collection phase of the research.

Both quantitative and qualitative data were gathered through an online questionnaire designed using the Google Forms platform. Invitations to participate in the study were disseminated via various social media channels including Facebook groups, WhatsApp, and Telegram groups. To ensure comprehensive coverage, questionnaires were distributed across all regions of Gauteng province. The online survey remained accessible for three months, after which an assessment was conducted to evaluate the number of valid responses received. Given the insufficient response rate at the initial assessment, a second round of data collection was initiated. The questionnaire remained open for an additional three months, resulting in a total of 346 respondents. With this increased sample size, the dataset reached a significant level of approximately 95% confidence when considering the Gauteng population, estimated at about 15.8 million in 2022. This confidence level accounts for the fair distribution of the questionnaire across the various demographic segments within Gauteng province.

Once the data was collected, quantitative and qualitative analysis of the results was conducted. The responses from the completed questionnaires were exported into SPSS. This statistical analysis has been carried out using SPSS as it provides a range of analysis functions that need to be applied to the data collected (Valeri & VanderWeele, 2013). Statistical analysis was selected for both descriptive and inferential statistics. For the questions using a Likert scale of agreement, descriptive statistics were used to determine an average response. For open-ended question results yielding qualitative data, content analysis, more specifically, thematic analysis, was used to identify the frequency of common keywords and themes present in the data collected.

A chi-square test for independence was conducted to identify if there was a significant relationship between demographic variables and prior e-waste recycling behaviour. To further enhance the analysis and understanding of what drives e-waste recycling participation, exploratory factor analysis (EFA) was conducted. EFA examines the inter-correlations that exist between many units and reduces these items into smaller segments known as factors. The model for data analyses for this part of the study is illustrated in Figure 19.

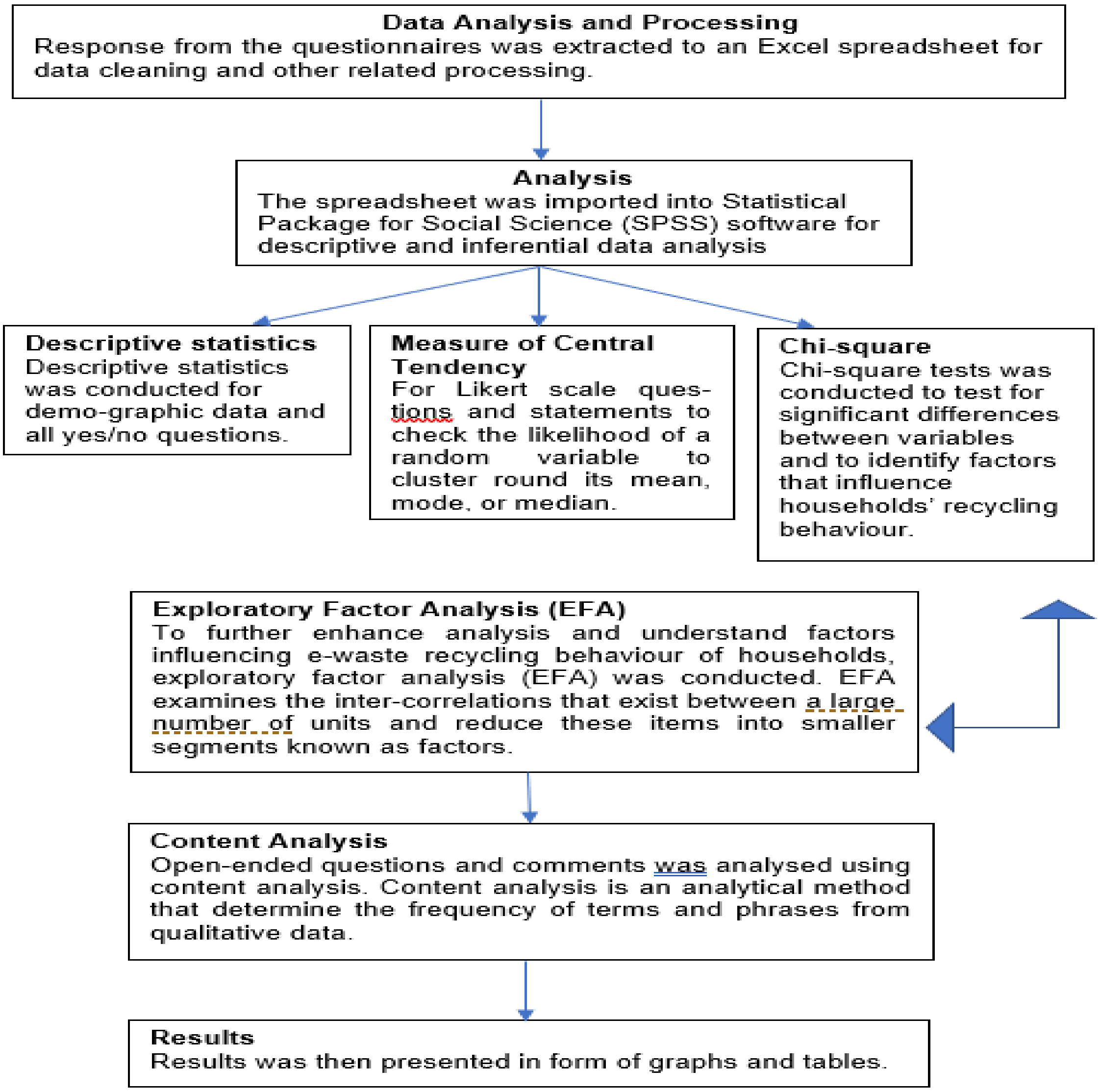

Figure 19: The different data analyses processes used to analyse data

5.2 Demographic variables

The study investigated different demographic variables such as gender, income levels, level of education and other socio-economic factors. This section breaks down different demographic aspects and their impact on the e-waste recycling behaviour of Gauteng households.

5.2.1 Gender, age and race

The majority of respondents were female (70.3%) and White (81.8%) (Table 13). Results from other studies have shown that women are more likely to participate than men (Curtin et al., 2000; Singer et al., 2000; Moore & Tarnai, 2002). The age range of respondents that participated in the study was between the ages of 18 to 81 years, with an average of 48.6 years and a median age of 50 years.

Table 13: Gender and race of participants

Demographic	Class	Percentage
Gender	Female	70.3%
	Male	28.5%
	LGBTQAI++	1.2%
Race	White	81.8%
	Black	10.6%
	Asian/Indian	5.0%
	Coloured	2.6%

5.2.2 Employment status, monthly income and education level

Regarding participants' household monthly income, approximately 52.3% reported being employed, 12.5% indicated part-time employment, and only 3.8% reported being unemployed. Other categories such as self-employment, pension, and student status comprised 4.9%, 9.6%, and 6.7% of the respondents, respectively.

The findings show that 2.4% of participants stated their household income was below R3 500 per month, while 36.1% reported it to be over R75 000 per month. Notably, nearly two-thirds (64.1%) of respondents fall into the upper-middle and affluent income brackets. This demographic characteristic was advantageous for the research, as these individuals were more likely to afford purchasing EEE and are likely the primary contributors to e-waste generation.

In terms of education level, the data revealed that 1.5% of respondents had some high school education, 13.4% possessed a matric certificate, 23.5% held a post-matric diploma or certificate, 21.2% had obtained a bachelor's degree, and 40.4% had achieved a post-graduate degree. Typically, individuals with higher levels of education and greater financial resources are more inclined to participate in surveys (Singer et al., 2000; Curtin et al., 2000; Goyder et al., 2002) as was the case for this study.

5.3 The type and volume of EEE in households

The research collected data on the volumes and types of e-waste in Gauteng households. The EEE were grouped into four categories, namely large appliances, small appliances, consumer electronics and information and communication technology (ICT) equipment. Respondents were asked to indicate what EEE they owed, but also EEE no longer needed/not used or not in working order that were in their household.

5.3.1 Ownership of EEE

Generally large appliances involve but are not limited to large equipment varying in size such as washing machines, clothes dryers, electric stoves, large printing machines, copy machines and photovoltaic panels. The most owed large appliance was a fridge (99.4%), followed by a washing machine with 96.5% and a stove (89.3%) (Table 14). An electric griller (21.1%) and a steam oven (5.5%) recorded the lowest numbers.

Small appliances are kettles, vacuum cleaners, toasters, microwaves, blow dryers, electric shavers, fans, friers, etc. The study found that 96.8% of the respondents had a kettle in their household which was the highest compared to other appliances (Table 14), followed by an iron (96.5%), microwave (95.4%) and extension cables (93.9%) while an electric hot plate was lowest at 28.3%.

Table 14: Ownership of EEE

Large appliances		**Small appliances**		**Consumer electronics**		**ICT equipment**	
Fridge	99.4%	Kettle	96.8%	TV (flat panel)	88.2%	Mobile phone	98.6%
Washing machine	96.5%	Iron	96.5%	Calculator	71.5%	Laptop	94.2%
Electric/gas stove	89.3%	Microwave	95.4%	Camera	69.1%	Router	84.4%
Electric/gas oven	86.7%	Extension cable	93.9%	DVD player	54.7%	Printer	77.7%
Dishwasher	74.0%	Toaster	92.8%	Radio	46.5%	Tablet	68.2%
Freezer	69.7%	Vacuum cleaner	87.3%	Stereo	37.9%	Cable	56.9%
Electric heater	67.9%	Hair dryer	87.0%	Game console	35.6%	LCD monitor	50.9%
Tumble dryer	52.9%	Blender	83.8%	GPS	28.5%	Modem	48.3%
Air conditioner	24.6%	Power tools	79.8%	VCR player	18.5%	PC	45.1%
Electric griller	21.1%	Fan	73.4%	MP3 player	17.6%	Scanner	38.7%
Steam oven	5.5%	Mixer	70.2%	TV (CRT)	15.9%	UPS	35.8%
		Electric lawnmower	56.6%	E-smoking device	13.2%	Phone (dial)	30.1%
		Electric toothbrush	51.7%			Copy machine	28.6%
		Slow cooker	44.8%			Notebook	20.8%
		Alarm clock	39.0%			CRT monitor	7.8%
		Fryer	34.4%			Fax machine	5.5%
		Electric hot plate	28.3%				

Electronic devices such as televisions (TVs), cameras, radios and e-smoking devices were grouped as consumer electronics in this study. The most owed consumer electronics were TVs, calculators, cameras and DVDs player with 88.2%, 71.5%, 69.1% and 54.7% respectively (Table 14). The least used consumer electronics were e-smoking devices (13.2%).

ICT equipment is commonly laptops, routers, UPS, mobile and dial phones as well as copy and scanner machines. Mobile phones scored the highest percentage (98.6%) of availability within Gauteng households, while only 5.5% of respondents confirmed that they had fax machines in their households (Table 14). Other equipment that most households had were laptops (94.2%), routers (84.2%) and printers (77.7%).

5.3.2 EEE no longer needed

From the responses received, it is clear that there were EEE that were no longer needed or used in households. For large appliances, electric heaters were the appliance that recorded the highest number with 19.2% households indicating they had at least one or more heaters not needed/not used, followed by tumble driers (12.2%) (Table 15).

Table 15: Large appliances no longer needed or not used

Type of appliance	None	1 needed/not used	2 or more needed/not used
Fridge	93.8%	5.6%	0.6%
Air conditioner	88.8%	8.8%	2.5%
Washing machine	96.5%	3.5%	-
Freezer	97.8%	2.2%	-
Tumble dryer	87.9%	11.6%	0.6%
Electric heater	80.7%	12.8%	6.4%
Dishwasher	95.4%	4.6%	-
Electric griller	92.8%	7.2%	-
Electric/gas stove	96.9%	2.8%	0.3%
Electric/gas oven	98.2%	1.8%	-
Steam oven	87.5%	12.5%	-

When comparing small appliances that were not needed/used within the household, all households had at least one small appliance that was not needed or not used. A total of 17.3% of households had at least one or more electric plates not needed or used, followed by electric toothbrushes (16.9%) and hair dryers (14.9%) (Table 16).

Table 16: Small appliances no longer needed or not used

Type of appliance	None	1 not needed/ not used	2 or more needed/not used
Iron	88.1%	9.7%	2.2%
Kettle	89.8%	8.9%	1.3%
Blender	93.8%	6.2%	-
Microwave	96.8%	3.2%	-
Hair dryer	88.7%	9.5%	1.8%
Mixer	96.2%	3.8%	
Fan	90.0%	8.7%	1.2%
Vacuum cleaner	90.9%	8.7%	0.3%
Toaster	95.7%	4.3%	
Slow cooker	92.6%	6.8%	0.7%
Fryer	96.3%	3.7%	-
Electric toothbrush	83.1%	12.8%	4.1%
Extension cable	91.7%	5.3%	3.0%
Power tools	91.6%	4.2%	4.1%
Electric lawnmower	91.5%	8.0%	0.5%
Alarm clock	89.8%	10.2%	-
Electric plate	82.8%	15.1%	2.2%

The results for consumer electronics no longer needed or not used in households, clearly demonstrated how advancement in technology make certain EEE obsolete. VCR players can be considered 'old' technology and more than half (50.9%) of households had one or more VCR player not needed/not used (Table 17). This was followed by another older technology, GPS devices, with 44.2%. Clearly stockpiling took place in households and it also included equipment that has been obsolete for a number of years.

Table 17: Consumer electronics no longer needed or not used

Type of appliance	None	1 not needed/used	2 or more needed/not used
TV (CRT)	85.7%	12.2%	2.0%
TV (flat panel)	89.7%	9.2%	1.1%
Radio	81.6%	16.3%	2.0%
Stereo	77.7%	22.3%	
DVD player	68.0%	28.7%	3.4%
VCR player	49.2%	49.2%	1.7%
MP3 player	61.0%	32.2%	6.8%
Camera	64.2%	24.8%	11.1%
Game console	74.3%	22.1%	3.5%
GPS	55.8%	37.9%	6.3%
Calculator	78.8%	12.6%	8.7%
E-smoking devices	65.1%	14.0%	20.9%

ICT equipment often is seen as to have re-sell value and people stockpile such equipment with the intention to sell it at one stage. Another issue is the data and privacy of the data found on some ICT equipment. Again, stockpiling of even working ICT equipment was recorded in this study with almost a third of respondents (31.3%) who had one or more mobile phone no longer needed or used (Table 18). Obsolete ICT equipment, such as a fax machine (31.6%), was also kept in households.

Table 18: ICT equipment no longer needed or not used

Type of appliance	None	1 not needed/used	2 or more needed/not used
PC	80.8%	17.9%	1.3%
Laptop	83.0%	12.2%	4.8%
Tablet	81.7%	13.4%	4.0%
Notebook	89.9%	8.7%	1.4%
CRT monitor	73.9%	17.4%	8.6%
LCD Monitor	88.1%	9.5%	2.4%
Mobile phone	68.7%	12.9%	18.4%
Phone (dial)	80.8%	9.1%	10.1%
Printer	87.8%	10.2%	2.0%
Copy machine	95.7%	4.3%	-
Scanner	93.7%	5.5%	0.8%
Fax machine	68.4%	31.6%	-
Router	86.9%	9.1%	4.1%
Modem	85.8%	9.0%	5.1%
Cable	75.8%	3.8%	20.5%
UPS	90.7%	7.6%	1.6%

5.3.3 EEE no longer in working condition

Again, some stockpiling of non-working large appliances is evident as 13.9% had one or more non-working electric heaters, 10.3% air conditioners and 7.6% tumble dryers (Table 19). The only large appliance that was not kept in non-working condition was a steam oven, which also recorded a very low number of ownerships. The results showed there was less stockpiling of broken appliance and those no longer needed or used.

Table 19: Large appliances no longer in working condition

Type of appliance	None	1 not working	2 or more not working
Fridge	95.3%	4.7%	-
Air conditioner	89.7%	9.0%	1.3%
Washing machine	97.7%	2.3%	-
Freezer	96.9%	2.7%	0.4%
Tumble dryer	92.4%	7.6%	-
Electric heater	86.2%	10.1%	3.8%
Dishwasher	96.6%	2.6%	0.9%
Electric griller	95.5%	3.0%	1.5%
Electric/gas stove	96.9%	2.8%	0.3%
Electric/gas oven	98.2%	1.8%	-
Steam oven	-	-	-

Similar to large appliances, households had numerous small appliances that could either be repaired or recycled. The results showed that 12.1% of households had at least one iron not working, 10.7% had extension cables, and 9.0% had vacuum cleaners no longer in working condition (Table 20).

Table 20: Small appliances no longer in working condition

Type of appliance	None	1 not working	2 or more not working
Iron	87.8%	8.1%	4.0%
Kettle	92.8%	6.9%	0.3%
Blender	94.5%	5.5%	-
Microwave	96.1%	3.9%	-
Hair dryer	94.0%	5.3%	0.8%
Mixer	97.9%	2.1%	-
Fan	92.5%	5.8%	1.6%
Vacuum cleaner	91.0%	8.7%	0.3%
Toaster	96.7%	3.3%	-
Slow cooker	100.0%		-
Fryer	99.1%	0.9%	-
Electric toothbrush	89.0%	6.9%	4.1%
Extension cable	89.3%	6.5%	4.2%
Power tools	91.2%	5.0%	3.9%
Electric lawnmower	94.7%	4.8%	0.5%
Alarm clock	93.0%	6.2%	-
Electric plate	91.3%	8.7%	-

Similar to keeping obsolete consumer electronics no longer needed or used, the results observed the same trend for equipment no longer in working condition. DVD players (15.9%), VCR players (19.6%) and GPS devices (19.4%) that were no longer working were kept by households (Table 21).

Table 21: Consumer electronics no longer in working condition

Type of appliance	None	1 not working	2 or more not working
TV (CRT)	94.1%	5.9%	-
TV (flat panel)	91.8%	8.2%	-
Radio	89.9%	8.1%	2.0%
Stereo	88.6%	9.8%	1.6%
DVD player	84.1%	15.3%	0.6%
VCR player	80.3%	18.0%	1.6%
MP3 player	83.1%	15.3%	1.7%
Camera	84.0%	8.9%	7.1%
Game console	91.0%	8.1%	0.9%
GPS	80.6%	19.4%	-
Calculator	91.2%	7.0%	1.8%
E-smoking devices	72.1%	18.6%	9.3%

Again, all households had ICT equipment that was not in working condition. Mobile phones were the highest with 28.7% of households indicating that they had at least one or more mobile phones not working, followed by fax machines (26.4%), dial phones (22.0%) and tablets with 20.1% (Table 22).

Table 22: ICT equipment no longer in working condition

Type of appliance	None	1 not working	2 or more not working
PC	80.0%	17.3%	2.6%
Laptop	80.5%	12.3%	7.1%
Tablet	79.9%	13.4%	6.7%
Notebook	87.9%	7.6%	4.5%
CRT monitor	82.6%	8.7%	8.6%
LCD Monitor	89.9%	7.7%	2.4%
Mobile phone	71.4%	11.4%	17.3%
Phone (dial)	78.0%	11.0%	11.0%
Printer	86.7%	9.8%	3.5%
Copy machine	92.5%	5.4%	2.2%
Scanner	91.2%	7.2%	1.6%
Fax machine	73.7%	21.1%	5.3
Router	89.0%	7.7%	3.3%
Modem	87.8%	8.3%	3.8%
Cable	81.1%	4.9%	14.1%
UPS	89.9%	8.4%	1.6%

Stockpiling of EEE no longer needed/not used and those that were no longer working was a characteristic of the results. Therefore, there were large amounts of e-waste kept in households in Gauteng or EEE that can be collected and sold or refurbished. It is thus necessary to investigate the e-waste recycling behaviour and drivers for participation in recycling of WEEE.

5.4 Knowledge of and participation in e-waste recycling

On the question if respondents knew of and e-waste recycling project or programme, just under half of respondents (49.7%) agreed that the knew or have heard of an e-waste recycling project. Regarding past behaviour, 54.0% of respondents indicated that they did recycle e-waste before. A positive finding was that 80.1% indicated that they planned to recycle their e-waste in the future, 19.4% was unsure and only 0.6% said that they would not participate in future e-waste recycling.

5.5 The influence of demographic variables on e-waste recycling behaviour

The study also investigated the relationship between e-waste recycling behaviour and demographic variables. The analysis looked at a few demographic variables such as respondents' income level, and education level.

5.5.1 Income level

The null hypothesis selected for the demographic variable of income level was 'E-waste recycling behaviour is not dependent on consumer income level'. To determine behaviour, respondents' recycling of e-waste in the past was used. Through chi-square analysis, the obtained p-value was compared with the threshold value proposed by Neuman (2013) after cross-tabulating income level and respondents' history of e-waste recycling. With a Pearson chi-square p-value of 0.221 exceeding the significance level of 0.05, the null hypothesis was upheld. The majority of respondents was from the higher-middle to affluent income groups, but the results showed to income was not a significant demographic variable in participation in e-waste recycling.

5.5.2 Age

Chi-square analysis was used to determine whether age is a determinant of e-waste recycling behaviour. The following null hypothesis was set to test the relationship between age and e-waste recycling behaviour: 'E-waste recycling behaviour does not depend on the age of consumers'. The p-value was 0.002, which was less than the value of 0.05. As a result, the null hypothesis was rejected. Age did have an influence on e-waste recycling participation, with a higher proportion of middle-aged participants recycling their e-waste previously.

5.5.3 Education level

The final analysis utilised chi-square testing, revealing no discernible positive correlation between education levels and recycling participation. The calculated chi-square significance value of 0.025 falls below the accepted threshold of 0.05. Thus, there is no significant statistical relationship between the highest level of education attained and recycling behaviour.

However, the analysis did establish a relationship with one demographic variable: age. While household income, gender, employment status, and level of education did not exhibit significant links with e-waste recycling behaviour, age demonstrated a noteworthy correlation.

5.6 Factors that influence e-waste recycling

Factor analysis was used in this study to identify the underlying factors that influence recycling perceptions and ultimately participation or not in e-waste recycling. Exploratory factor analysis used in this study is the kind of analysis that is used to research or gather and explore information about the interrelationships among a set or variables (Pallant, 2013). Principal component analysis (PCA) was performed for 28 statements that were then reduced into seven main factors based on similarity, and it showed the dataset was suitable for factor analysis. The results of the PCA divided the 28 statements into seven factors or components (Table 23).

Table 23: Seven factors that influence e-waste recycling

Component	Factor	Statement
1	Benefits of e-waste recycling	E-waste recycling is beneficial to the environment
		E-waste recycling reduces damage to the environment
		E-waste recycling reduces health hazards
		E-waste recycling is good
		E-waste recycling is the responsible thing to do
		There are very toxic materials in e-waste that can harm people and the environment
		It would be wrong of me not to recycle my e-waste
		E-waste items include valuable materials
		Recycling my e-waste creates jobs
2	Perceived control and situational variables	E- waste recycling is easy
		I have plenty of opportunities to recycle my e-waste
		Recycling e-waste is too complicated
		I know how to recycle my e-waste
		Recycling e-waste takes up too much time
		Recycling e-waste takes up too much space
3	E-waste recycling incentives	I would recycle my e waste if there is a bonus card system where recycled e-waste earn me points to use for shopping discounts
		I would recycle my e waste if I get cashback and/or discount coupons on new items when returning old items
		I would recycle my e waste if I am able to trade old-for-new electronic items as discounted prices
		I would recycle my e waste if a donation is made on my behalf to an environmental cause (e.g. planting a tree)
4	Willingness to pay for e-waste recycling	I would be willing to pay a recycling fee when purchasing an EEE product to assist the producer in correctly recycling the item
		I would be willing to pay a deposit when purchasing an EEE item that would be refunded to me when I return the item
		I would be willing to pay an additional fee to my municipality for separate collection of e-waste on set dates
5	Willingness to make use of drop off facilities	I would be willing to drop off my e-waste at a recycling facility
		I would be willing to drop off my e-waste at a convenient location such as a shopping centre
6	Community benefits of e-waste recycling	I would hand over my e-waste to NGOs and institutions to train the unemployed or e-waste entrepreneurs on how to repair and dismantle ewaste properly
		I would recycle my e waste if a donation is made on my behalf to a community charity (e.g. Meals on Wheels)
7	Privacy and security	Concerns about access of stored data (e.g. contact details, photos, etc.) on old devices hinders me to hand over such devices for recycling
		I would hand over my e-waste to a private recycling company that collects from my residence

The general benefits of e-waste recycling were grouped into one factor and those perceived to have benefits to the community as a separate factor. The incentives for participating in e-waste recycling and the willingness to pay also grouped into two different factors. Respondents' concern about privacy and security also came to the fore – about the data stored on devices and collecting from private households.

5.7 Barriers to e-waste recycling and recommendations

Respondents were also asked to identify barriers to participation in e-waste recycling. A general challenge mentioned by respondents was a lack of education and accessibility, as information on what e-waste recycling is, how and why it should be done, and where it can be done should be shared. These views were supported by 37.9% of respondents that agreed or strongly agreed that e-waste recycling is too complicated. Some of the responses that reflected this were:

> "*More education (to households directly? Flyers etc?). More convenient locations, or just knowing what locations there are. Knowing what items could be refurbished, and how it can benefit those doing the refurbishing (jobs, income etc).*"
>
> *"Need information available online in an SA context."*

Other barriers to e-waste recycling were accessible e-waste drop-off facilities and community e-waste recycling initiatives. Some respondents wrote that drop-off facilities used by them in the past were closed down and information on websites on recycling of WEEE were either outdated or non-existent.

In response to how to improve e-waste recycling, the common keywords that arose during thematic analysis were 'accessibility,' 'organization,' 'education' and 'awareness,' 'incentives,' 'training,' and 'drop-off sites. Education at both school and community levels were proposed to understand what WEEE is made of, why it should be disposed of correctly, and how it should be disposed of with statements such as:

> *"They could educate people on the issues because some of us don't know the dangers nor are aware e-waste could be recycled."*

Accessibility to convenient drop-off points or facilities were mentioned by 29% of respondents. A Suggestion for such a drop-off point was popular shopping malls – but then only for smaller e-waste that could easily be carried by a person. Incentives were frequently mentioned to encourage consumers to recycle their e-waste. Rebates on purchased EEE and discounts on devices returned for recycling are examples of positive reinforcement. It was interesting to note that direct financial benefits were not one of the most preferred incentives. This could be the case as most respondents were from higher-income groups. A loyalty or bonus reward card system was the most preferred incentive with 33.9% of respondents agreeing that such a system would encourage them to recycle their e-waste.

Waste management is a function of local government, but most municipalities in South Africa, and in Gauteng, are under severe strain to deliver services. There are various reasons for this, but the infrastructure and programmes for solid waste recycling are not a feature of municipalities. If municipalities cannot provide these sustainable options for solid waste, it will be even a bigger challenge to do so for e-waste. It is becoming a critical requirement to recycle e-waste as it contains valuable and perilous scarce materials. Furthermore, recycling or repairing of e-waste will definitely contribute to the circular economy. It is therefore of utmost importance that the various stakeholders of e-waste form partnerships to increase the safe and responsible recycling, repair and refurbishment of e-waste.

6 Stakeholder engagement and e-waste management strategy

The previous chapters provided evidence of the operations and involvement of the informal sector in the collection, transportation, dismantling and processing of e-waste. It also showcased that training the waste reclaimers in the repair of e-waste is feasible and needed in the South African context. There is limited participation in e-waste recycling by households in Gauteng and both working and non-working EEE are stockpiled in households.

Appropriate e-waste management strategies need to be developed for South Africa and the Gauteng province. Not only because if the exponential increase in the amount of e-waste generated, but also to make a meaningful contribution to the circular economy, job creation and protection of human health and the environment. This necessitated that as much as possible stakeholders in Gauteng come together to provide inputs and possible solutions to address e-waste management in the province.

6.1 Action dialogue

UJ PEETS therefore facilitated an Action Dialogue between government, waste management experts and research groups that discussed the following key topics:

- legislation that governs e-waste in South Africa;
- an overview of the e-waste landscape in South Africa;
- best and wors practices in e-waste management; and
- sustaining the value of metals through e-waste circularity.

The Gauteng Department of e-Government)e-Gov) was a key role-player in the Action Dialogue. The Department is the first provincial department of its kind in South Africa and was established to realise ICT-enable public service delivery. The Department was also mandated to come up with an e-waste management policy and strategy for the province.

UJ PEETS's primary mandate is to contribute towards improving operations and functions of industry and small and medium enterprises (SMEs) through the application of specialised knowledge, technology development and facilitating the interaction between industry, government and academia. The Technology Innovation Agency, which is an agency of the Department of Science and Innovation, funds UJ PEETS to enable innovation and technology transfer to grow the green economy in South Africa.

The main objective of the Sustainable Recycling Industries (SRI) programme is the sustainable integration and participation of SMEs from developing and transition countries in the global recycling of secondary resources. This is done by supporting national initiatives in partner countries. The programme that stretches over five countries, including South Africa, was focusing on governance, operational and technology aspects that would allow for the recovery of secondary raw materials. SRI is funded by the Swiss State Secretariat of Economic Affairs and is jointly implemented by the Swiss Federal Laboratories for Materials Science and Technology and the World Resources Forum.

The Action Dialogue was facilitated by the Director: Operations at Samsung Electronics South Africa. Ms Nomantu Nkoma-Ralehoko, was the Member of the Executive Council (MEC): Finance and e-Government at the time of the Action Dialogue and set the scene for the action dialogue talks. She indicated that the e-Gov department is mandated to innovate and digitise the services of the Gauteng province and harnessing ICT would prompt the need to engage with e-waste. As a result, e-Gov had to develop an e-waste management policy and strategy to guide the e-waste management in Gauteng. To quote the MEC:

> *"We do not take lightly the risk impacts that come with e-waste such as improper waste recycling which can affect our environment and as a consequence impose threats to the environment and the lives of our people. On the same breath, a comprehensive e-waste management strategy should consider economic opportunities that arises from recycling processes, especially with the current economic climate. Multiple new industries can be borne and created from a well thought out strategy, to the benefit of our SMMEs."*

Professor Linda Godfrey is a Principal Scientists at the Council for Scientific and Industrial Research (CSIR) and an Extraordinary Professor at North-West University. She also manages the Waste RDI Roadmap Implementation Unit. She gave an overview of the e-waste landscape in South Africa, referring to studies conducted such the Lydall et al. (2017) report which mapped e-waste dismantling and processing in South Africa. She highlighted two crucial issues for a policy strategy, namely the lack of data on e-waste and the stockpiling of WEEE that acts as a barrier in the recycling of e-waste as it limits the available feedstock.

Ms Sharon Mogomotsi, Director: Hazardous Waste Management in the national Department of Forestry, Fisheries and Environment, referred to Section 24 of the Constitution of South Africa that states everyone has the right to an environmental that is not harmful to their health or well-being. She further elaborated on the National Waste Management Strategy and that the waste hierarchy is used in South Africa for waste management. She acknowledged that a barrier to the growing the e-waste recycling sector is the expensive and time consuming mandatory environmental authorisations required through an environmental impact assessment. The Director also indicated that SRI was busy developing a national e-waste policy, and that an EPR scheme for e-waste will come into effect.

Ms Susanne Karcher, the South African co-ordinator for the SRI programme, explained that worst practices in e-waste are known and that these unsound practices occur globally due to a lack of control mechanisms, operational aspects, legal loopholes and the secondary metal recovery from e-waste. She also highlighted that these worst practices were not only limited to the informal sector. Good practices in e-waste needed to be supported by an e-waste policy with the associated norms and standards that are linked to activities and associated risks. She referred to the technical guidelines published under the Basel Convention on how to recycle and reclaim metals in an environmentally sound manner.

Ms Aysha Lotter, a PhD candidate from the University of Cape Town, discussed the potential market value of WEEE in South Africa. As e-waste is currently classified as hazardous waste, she highlighted how e-waste recycling was impacted by various legislative provisions, different authorisations and licences that are required for waste activities that can have a significant impact on the environment. She presented that the different spheres of stakeholders at both national and local levels overlap, and that collaboration needs to be fostered across all levels and spheres and that circular principles should be implemented at the design stage of any e-waste recycling or recovery.

The Action Dialogue Report was compiled by Ms Katharina Gihring, a project manager of UJ PEETS.

6.2 E-waste landscape and proposed strategy for Gauteng

An e-waste strategy was developed in consultation with the Gauteng Department of e-Government in collaboration with various stakeholders of the e-waste sector. The members of the steering committee were Prof Linda Godfrey (CSIR), Susanne Karcher (SRI Programme South Africa: National Coordinator), Aysha Lotter (UCT) and the University of Johannesburg's Process Energy and Environmental Technology Station (UJ-PEETS) team represented by Dr Takunda Chitaka, Katharina Gihring and Nickey Janse van Rensburg.

The strategy aimed to provide a strategic framework for the management of e-waste in Gauteng. At the same time to guide the management of e-waste to ensure that environmentally sustainable development is promoted, and waste minimisation becomes a priority.

The e-waste management strategy is available at:

https://wasteroadmap.co.za/

7 Summary, conclusion and recommendations

The funding received from the Waste RDI Roadmap supported research conducted on part of the value chain of e-waste in Gauteng – starting with the informal sector, training of the informal sector to e-waste recycling behaviour of households and stakeholder interaction. This part of the report briefly summarises the main findings and make recommendations for further research.

7.1 The informal sector

A typical waste reclaimer that collects e-waste was male (83.4%), from the Black population group (87.3%) and a South African (81.6%). The most collected type of e-waste was cables (45.9%), and e-waste was collected from multiple locations, but mostly from dustbins outside houses (74.2%). The majority of waste reclaimers (76.3%) sold e-waste to scrap metal dealers and earned an average income of R580 per week from selling e-waste.

Amongst reclaimers that collected e-waste for recycling, 68% conducted dismantling and 60.2% processing. These practices are profit driven and income from processed cables was higher than those who only conduct dismantling. However, informal reclaimers were found to have mostly no safety equipment for the procedures they perform. It was observed that they used tools such as hammers and stones to break down the electrical equipment and appliances for metal extraction. Those who conducted processing used fire to burn cables in open land. Thus, these risky activities threaten their health and the environment they live in.

In 2010 a program for waste reclaimer empowerment was initiated to register and integrate the informal waste pickers into the formal sector. It seems that once again waste picker integration failed, and no support is given to waste pickers. Even though waste pickers are considered to be the main recyclers in South Africa and it is estimated that they have saved municipalities up to R748 million per annum (Godfrey et al., 2016), local government keeps on ignoring their contributions and experience.

The latest regulatory requirement is the EPR regulations that came into effect on 5 November 2021 and the success of these regulations are uncertain. Instead of making use of the informal sector to increase the recycling, repair and refurbishment of WEEE, the government keeps on formulating legislation and regulations. As stated by Godfrey & Oelofse (2017), waste management is overregulated in South Africa and makes it extremely difficult for recyclers to comply with.

For future research in this field, the following recommendations are made:

- Research to investigate the capacity and willingness of recycling facilities and buy-back-centres to train waste pickers in certain aspects such as safety.
- Comparative studies in metropolitan and secondary cities in South Africa.

Research to investigate the volume of e-waste in households and businesses and to determine what measures would increase participation in e-waste recycling.

7.2 Training of the informal sector

This part of the project evaluated the training of reclaimers in repairing and refurbishing small WEEE appliances. The first two levels of the Kirkpatrick evaluation model as tools to evaluate the training. These include the reaction and learning level and have been identified as essential components when evaluating training.

All feedback from participants unanimously affirmed the value of the training they received. The majority (45%), expressed satisfaction with the training, followed closely by 35.0% who reported being very satisfied. Among those dissatisfied with the duration, the consensus was to extend both the length and frequency of sessions to allow for thorough theory coverage and so they could fix the appliances until they are confident with themselves.

The content of the training emerged as a pivotal factor in its effectiveness. Participants were asked to assess the relevance of the content, with 95.0% confirming it met their expectations. Moreover, when asked about their preferred session, 85.0% favoured the practical component, confirming their request for time devoted to repairing and refurbishing e-waste appliances, as expressed in their comments. The participants also indicated that they were very satisfied with the trainers.

Significant improvements were noted in participants' competency levels across various learning areas post-training. Initially, a substantial portion reported a lack of competence in distinguishing between good and bad practices in handling e-waste (55.0%), and in using the appropriate tools (40.0%). However, after the training, competence levels surged, with 95.0% and 90.0% respectively indicating high levels of proficiency in these areas.

Participants, including those with prior repair experience, highlighted newfound skills acquired during the training, such as using a multimeter for equipment testing. This indicates the training's benefits, catering to both experienced and novice reclaimers. An encouraging outcome was participants' heightened awareness of the importance of sustainable e-waste handling to safeguard the environment and personal health. Some trainees even noted that they were happy contributing to the circular economy, which shows that both components of the training were essential and well received by the trainees.

The following research is recommended:

- The Kirkpatrick model of training evaluation has four levels to measure the effectiveness of training programmes. The study evaluated the training using Levels 1 & 2 of the model, thus not providing a complete evaluation of the training. Follow-up research that evaluates the training on Levels 3 & 4 is recommended. This will provide a complete evaluation of the training process.
- There is no information on the environmental impact of the work done by reclaimers. A study investigating the effects of recyclables collected by reclaimers in preserving the environment is recommended. An analysis of this nature will help show the significance of reclaimers in waste management and resource conservation.
- There is a lack of data on the tonnages of recyclables that reclaimers handle. This is even more so for the e-waste collected by reclaimers. A study that investigates the weight of the different types of recyclables handled by reclaimers is recommended.
- The participants of this study commented on conducting training that includes large e-waste appliances as they come across them when collecting waste. Therefore, a recommendation

is made for a study that develops and evaluates training on repairing and refurbishing large WEEE appliances.

- The study made use of a self-evaluation to determine the effectiveness of the training. There are however several mediums that could be used to measure training effectiveness. Therefore, a study that requires the study participants to take a written assessment, examination or a quiz to determine the effectiveness of the training is recommended.

7.3 E-waste volumes and recycling behaviour

As there is a lack of data on e-waste generation and e-waste recycling behaviour, this part of the project determined the volume of potential e-waste in households in Gauteng and what residents' recycling behaviour was. The research found that ownership of EEE was high under respondents. At the same time, clear evidence was presented on the stockpiling of both goods in working condition, obsolete equipment as well as EEE no longer working. To contribute to circularity in e-waste, it is important to find ways to get households in Gauteng to dispose of their WEEE in a responsible manner so that secondary materials can be recovered.

The study found that 43.5% of respondents know how to recycle their e-waste correctly, while 40% do not feel confident in their e-recycling knowledge. Furthermore, only 18.7% of respondents have heard about e-waste recycling opportunities which shows a considerable lack of knowledge and recycling options. Thus, the main challenges identified were a lack of knowledge, lack of time, accessibility issues, and outdated e-waste recycling information. This has resulted in the need to update information resources, provide awareness and education programmes on how, why, and where to recycling e-waste. This education factor includes the training of waste workers to streamline job opportunities and maximize the value of WEEE for economic growth. The use of various financial, environmental and community incentives that consumers have supported will encourage more active e-recycling. Lastly, it has been determined that age is a significant demographic factor as the middle-aged population has been engaged the most in e-waste recycling, while household income does not influence e-waste recycling behaviour based on previous e-recycling practices.

These following areas are suggested for further research based on the results of the current study:

- To improve the study's credibility and draw more accurate generalizations about electronic waste management and disposal in Gauteng, it is recommended that future research include all income groups of the households in all sub-cities, and WEEE in offices, businesses and government departments.
- Knowledge of e-waste statistics is useful, and more research should be done to examine how e-waste is handled in other provinces.
- Future research on e-waste recycling should attempt to investigate deeper into the other stakeholders in the e-waste value chain such as e-waste recycling companies, and dealers of refurbished EEE.
- It is also recommended that future research investigates the processes involved in the selling and buying of refurbished EEE from second-hand dealers to investigate the data destruction/removal processes, warranty, and the effectiveness of repairs to assist in creating a more positive perception of refurbished devices to decrease the volume of end-of-life WEEE entering the waste stream.

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