DURBAN UNIVERSITY OF TECHNOLOGY

THE MANAGEMENT OF ELECTRONIC WASTE: A CASE STUDY OF THE UMBOGINTWINI INDUSTRIAL COMPLEX AND SOUTHGATE BUSINESS PARK IN KWAZULU-NATAL, SOUTH AFRICA

by

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DECLARATION

I, Krishna Govender, hereby declare that the work presented in this dissertation is based on my own research and that I have not submitted it in part or in full to any other institution of higher learning to obtain an academic qualification.

Further, all author references have been acknowledged accordingly.

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Krishna Govender Date

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DEDICATION

This dissertation is dedicated to my mother, Mrs. Chinna Muniamma Govender (Saras) and my late dad, Mr. Moonusamy Govender (Bobby), who made this life possible through their countless sacrifices to educate our family.

ABSTRACT

The phenomenal growth in the number of electronic devices in use has given rise to a huge increase in the volume of electronic waste (e-waste) generated. Electronic waste is comprised of toxic materials and chemicals, and if it is not disposed of in an environmentally friendly manner, it poses serious risk to the environment and to human health.

The perceived limited knowledge about the harmful effects of e-waste and the potential economic benefit of e-waste recycling in South Africa motivated this study. The study area consisted of two large industrial parks in Durban, KwaZulu-Natal; namely, the Umbogintwini Industrial Complex and the adjacent Southgate Business Park. A total of 313 organisations are located within the study area, which is spread over approximately 550 hectares.

Based on the findings of the study, it is estimated that the Umbogintwini Industrial Complex and the Southgate Business Park would generate approximately 593 tons of e-waste between the period 2015 and 2020, averaging approximately 119 tons per year. Although South Africa is classified as a developing country, it is the most developed country in Africa, and if one were to extrapolate the potential volume of e-waste generated for five years from the study area to the rest of KwaZulu-Natal's industrial parks, then in five years, the province's industrial parks would generate approximately 3 340 tons of e-waste.

The study also revealed that there is no effective e-waste management strategy in place within the Umbogintwini Industrial Complex or the Southgate Business Park. A positive finding of the study was that the majority of the organisations surveyed were in favour of a proper e-waste management strategy at both the study sites, and would support the development of an e-waste recycling plant in this industrial zone.

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LIST OF ACRONYMS AND ABBREVIATIONS

BAN	Basel Action Network
BFRs	Brominated Flame Retardants
CRT	Cathode Ray Tube
DGFT	Directorate General of Foreign Trade
DWAF	Department of Water Affairs and Forestry
ECA	The Environment Conservation Act (Act 73 of 1989)
EEEW	Electrical and Electronic Equipment Waste
EPR	Extended Producer Responsibility
e-WASA	e-Waste Association of South Africa
E-waste	Electronic waste
IWMSA	Institute of Waste Management of Southern Africa
NEMA	The National Environmental Management Act
NWMS	National Waste Management Strategy
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
SPSS	Statistical Programme for Social Sciences
STEP	Solving The E-waste Problem
WEEE	Waste from Electrical and Electronic Equipment

CHAPTER 1

OVERVIEW OF THE STUDY

1.1 Introduction

This chapter presents an overview of the study, and, *inter alia*, the background to the study is discussed, the research problem is identified, and the aim and objectives of the study are stated. Thereafter, the research methodology and design adopted for this study, as well as the structure of the dissertation are outlined.

1.2 Background to the study

The growing number of electronic devices in use today has given rise to a major environmental problem in the form of electronic waste. According to the Indian Institute of Technology (2009), electronic waste, commonly referred to as e-waste, can come from a number of electrical sources. Brambila (2010) reports that electronic waste is generated because of electronic equipment breaking down, becoming irreparable, and because rapid advances in electronic technology have made frequent upgrades the norm. Electronic waste is also referred to as Electrical and Electronic Equipment Waste (EEEW), but for the purposes of this study and for the sake of consistency, the term e-waste will be used.

The United Nations Environmental Programme reported that e-waste generated in 2014 from the sale of electronic goods would amount to approximately 18.8 billion US dollars, and without sustainable management, monitoring and good governance of e-waste, illegal activities may only increase, undermining attempts to protect health and the environment, as well as to generate legitimate employment (Rucevska, Nellemann, Isarin, Yang, Liu, Yu, Sandnaes, Olley, McCann, Devia, Bisschop, Soesilo, Schoolmeester, Henriksen and Nilsen, 2015). According to Greenpeace International (2010), the high demand for electronic equipment globally contributes to a tremendous increase in electronic waste, and this is potentially becoming the most dangerous threat to the environment and, ultimately, to one's health.

In Africa, there has been a substantial increase in the use and ownership of electronic goods, particularly cellular phones and computers. Data from the STEP (Solving The E-waste Problem) world map indicates that South Africa generates the largest quantity of e-waste in Africa (Esselaar, Gillwald, Moyo and Naidoo 2010). Research on e-waste undertaken in South Africa by Hewlett-Packard (2009) found that owners of electronic devices manage their e-waste in one or more of the following ways: store it, recycle it informally, add it to the domestic waste stream, or dump it illegally. The South African Department of Environmental Affairs (2010) recognises the rapidly emerging and serious issue of e-waste, and advises that e-waste must be managed in an environmentally responsible manner.

1.3 Research Problem

According to Finlay and Liechti (2008), electronic waste has become a major concern globally and many countries have introduced policy guidelines and legislation for the management thereof. In Durban, KwaZulu-Natal, where this study was conducted, the e-waste problem is exacerbated by the disposal of e-waste primarily at municipal landfill sites. To this end, the eThekwini Municipality (2013) has realised that a culture of recycling must be fostered within society, and that more opportunities need to be created for the recycling of waste by implementing the Waste Management Plan, whose main goal is to optimise waste management in the region so as to minimise its environmental impact. However, this opportunity has not been fully realised by the e-waste recycling sector. This is deduced from the fact that as of May 2015, eThekwini Municipality has no policies or by-laws regarding e-waste management.

By its very nature, e-waste is hazardous, and if not safely disposed of, it can have a negative impact on the natural environment. Given the size of the Umbogintwini Industrial Complex and the Southgate Business Park, the volume of e-waste generated annually is substantial, and if the organisations located within this highly populated industrial and manufacturing zone do not manage their e-waste in an environmentally responsible manner, it will have a significant adverse impact on the environment. To this end, this study investigated the potential quantity of e-waste that will be generated within the study area in the next five years (2015 – 2020) and the manner in which e-waste generated by these organisations is managed, with a view to recommending best practices for its safe disposal.

1.4 Aim and objectives of the study

The overall aim of the study was to investigate the generation and methods of management of e-waste within the Umbogintwini Industrial Complex and Southgate Business Park in Durban, KwaZulu-Natal.

The objectives of the study were:

- to establish the potential quantity of e-waste generated at the Umbogintwini Industrial Complex and the adjacent Southgate Business Park, and assess its economic benefit, if recycled;
- to examine the methods employed by organisations within the study area to dispose of their e-waste;
- to establish the extent to which e-waste generated within the study area was managed in an environmentally responsible manner, and
- to determine the attitude of organisations within the study area towards the establishment of an e-waste recycling operation.

1.5 Significance of the study

The study was undertaken with the approval and cooperation of the management of the Umbogintwini Industrial Complex and Southgate Business Park. The findings of this study will be shared with the managers of all the organisations located within the study area with a view to sensitising them to the negative impact of their e-waste on the environment and to encourage them to manage their e-waste in an environmentally responsible manner. By doing so, it is hoped that the negative impact of the e-waste generated at the Umbogintwini Industrial Complex and Southgate Business Park on the environment will be minimised, thereby contributing to a safer and better working environment, not only for the employees in the complex, but, for society at large.

1.6 Scope of the study

The study was confined to organisations located within the Umbogintwini Industrial Complex and Southgate Business Park, which is located in KwaZulu-Natal, South Africa.

Electronic waste emanating only from the following sources was considered: computers and their related peripherals; office electronic devices; air conditioners; electronic circuit boards, and electronic machinery and equipment used in the industrial and manufacturing sector.

1.7 Study site

The study was conducted within the Umbogintwini Industrial Complex (UIC) and the adjacent Southgate Business Park (SBP). The Umbogintwini Industrial Complex (UIC) (due to undergo a name change to Acacia Operational Services) is a 350 hectare industrial complex that is occupied by twenty international industrial organisations and 91 South African organisations. The UIC is located south of Durban, along the National Highway (N2) and is five minutes south of the old Durban International Airport.

The owners (Heartland Leasing) manage and supply bulk utilities such as electricity, steam, gas, water, effluent treatment, fire protection, security, and provide other specialised services. As a national key-point, the park has been unaffected by the electricity outages experienced by other industrial and commercial parks. (See Annexure A for the list of organisations in the Umbogintwini Industrial Complex).

The Southgate Business Park is a 200 hectares light manufacturing park situated alongside the Umbogintwini Industrial Complex. The 202 organisations within this manufacturing park produce mainly finished goods. Although the manufacturing park consists mainly of local organisations, there are a few international organisations located in the park. The manufacturing park allows operators to either lease an existing warehouse or purchase the land and erect their own purpose-constructed building. (See Annexure B for the list of organisations in the Southgate Business Park).

1.8 Research methodology and design

A literature study using secondary sources of information was conducted with the objective of establishing, assembling and integrating theory with regard to the management of electronic waste. In this regard, academic journals, newspaper and magazine reports, as well as government and non-governmental organisations' reports and publications were accessed. Primary data was collected via self-administered questionnaires which were targeted at organisations located within the Umbogintwini Industrial Complex and Southgate Business Park.

The data from the completed questionnaires was captured on an Excel spreadsheet for statistical analysis. Descriptive statistics was used to analyse the preliminary data, and inferential statistics was used to present the data in a statistical format so that important patterns, relationships and analysis became more meaningful. The Statistical Program for Social Sciences (SPSS), version 21.0 for Windows, was used to analyse the data and to conduct the relevant statistical tests, and the results were presented in the form of tables and charts.

1.9 Structure of the dissertation

The dissertation is divided, as follows, into five chapters:

Chapter 1: Overview of the study

Chapter one provides a brief background to the study; identifies the research problem, and states the aim and objectives of the study. The significance and scope of the study is outlined. The research methodology employed, as well as the structure of the dissertation are briefly explained.

Chapter 2: Literature review

In this chapter a review of relevant literature regarding the management of e-waste, both internationally and domestically, was undertaken. The review covered, *inter alia*, e-waste legislation, the social and environmental impact of e-waste, as well as e-waste recycling methods and its benefits.

Chapter 3: Research methodology and design

This chapter focuses on the research methodology employed for this study. It includes a discussion of the research design, the research instrument, data collection methods, data analysis techniques, and the methods used to ensure that the research is valid and reliable.

Chapter 4: Presentation, analysis and discussion of results

The results of the study are contextualised within the literature reviewed, and where appropriate, are compared with the results of similar studies conducted elsewhere. The preliminary analysis of the data is presented graphically via bar graphs and pie charts, and tables are also presented to aid in the analysis and discussion of the results.

Chapter 5: Review, Conclusion and recommendations

This chapter contains a summary of the key findings of the study and makes recommendations for further research. The conclusion highlights sustainable e-waste practices that can be undertaken at the Umbogintwini Industrial Complex and Southgate Business Park.

1.10 Conclusion

This chapter presented an overview of the study. More specifically, the background to the study, the problem statement, as well as the aim and objectives of the study were outlined. In addition to the above, the significance and scope of the study, as well as the research methodology employed were briefly explained. In the next chapter, the literature pertaining to corporate electronic waste is analysed and discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter the literature on the various aspects pertaining to electronic waste (e-waste), is presented and analysed. The literature review covers, *inter alia*, an examination of the various definitions of e-waste; a discussion of the types and amounts of e-waste generated both globally and in South Africa; an analysis of the hazardous components of e-waste; a review of e-waste management practices; e-waste legislation, and e-waste recycling.

2.2 Definitions of e-waste

Whilst there is no one standard definition of e-waste, a number of literary sources were consulted for an appropriate e-waste definition. Some of the definitions include:

- e-waste is a generic term embracing various forms of electric and electronic equipment that have ceased to be of any value to their owners (Widmer, Oswald-Krapf, Sinha, Schnellmann and Boni 2005: 439);

- e-waste is waste that comprises both electronic white goods and brown goods which have reached the end of their current owner's needs (Kalana 2010: 132);

- e-waste refers to any white goods, consumer and business electronics, and information technology hardware that is at the end of its useful life (Khurrum, Bhutta, Omar and Yang 2011: 2);

- e-waste is the term used to describe old, end-of-life electronic appliances such as computers, laptops, televisions, DVD players, cellular phones, MP3 players etc. which have been disposed of by their original users (Enviroclaim 2012: 3);

- e-waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use (United Nations University and Step Initiative 2014: 4);

- anything that works with electricity or batteries and it is no longer needed or it is no longer working is classified as e-waste (Africa E-waste 2015: 4), and

- any device that held or required an electric charge for its intended operation and which has reached the end of its useful life (KZN Department of Economic Development, Tourism and Environmental Affairs 2015: 6).

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

2.3 The sources of e-waste

The main sources of e-waste are residue materials from the manufacture of electronic products; redundant electrical and electronic equipment discarded by repair shops; obsolete electrical and electronic equipment from various public and private organisations and obsolete electrical or electronic products from households (Kalana 2010).

According to the European Parliament and The Council of The European Union (2012), waste from electrical and electronic equipment (WEEE) can originate from the following sources:

- large household appliances (refrigerators, stoves, etc.);
- small household appliances (toasters, irons, etc.);

- IT and telecommunications equipment (desktop computers, laptops, cellular telephones, etc.);
- consumer equipment (televisions, hi-fi's, musical instruments, etc.);
- lighting equipment (globes, electric lamps, etc.);
- electrical and electronic tools (including control boards and large-scale stationary industrial tools);
- toys, leisure and sports equipment (video games, remove controlled toys, etc.);
- medical devices (radiotherapy equipment, cardiology equipment, nuclear medicine equipment, etc,);
- monitoring and control instruments (electronic control desks, screens, etc.), and
- automatic dispensers (vending machines, automatic teller machines, etc.).

In the industrial and manufacturing sectors, the areas of focus of this study, PHA Consulting Associates (2006), have identified various sources of e-waste, and these are grouped into the following categories:

- electrical and electronic tools (office equipment, security scanners, timers);
- drills and cutting machines;
- equipment for turning, milling, sanding, grinding, sawing, cutting, shearing, drilling, making holes and punching;
- sewing and trimming machines;
- folding, bending or similar processing of wood, metal and other materials;
- tools for welding, soldering or similar use;
- equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means;
- smoke detectors, alarm systems and other security systems;
- large industrial heating and cooling systems, including regulators and thermostats;
- measuring, weighing or appliances used as laboratory equipment;
- other monitoring and control instruments used in industrial installations (e.g. in control panels, sensors, etc.);

- air-conditioners;
- telecommunication systems;
- cabling and wiring – electrical or data usage, and
- logistics equipment (bar code readers, delivery vehicles, tracking equipment).

From amongst all the sources of e-waste, the personal computer is the largest contributor to this waste, and to track the amount of e-waste generated worldwide, a good indicator would be the volume of computers sold. According to eTForecasts (2011), in 1975, less than 50 000 computers, valued at approximately $60 million, were sold. However in 2010, over 320 million personal computers, with a retail value of approximately $320 billion, were sold, and it is estimated that approximately 2.1 billion personal computers will be sold by the end of 2015.

Factors that contribute to the progressive growth of e-waste are the rising consumption of electronic and electrical equipment (EEE), increasingly rapid obsolescence (due to sustained technological advances) of electronic devices, and the decreasing product lifespan (Marriott 2011). WorldLoop (2013) also agrees that the lifespan of electronic devices is getting shorter, and that this trend has a negative impact on the use of scarce resources. Table 2.1 below lists a number of electronic products; their approximate mass, and their estimated lifespan.

Table 2.1: Source of e-waste, their approximate mass and life span

Type of electronic item	Mass (kg)	Estimated life (years)
Air conditioner	55	12
Cellular phone	0.1	2
Dish washer	50	10
Electric cooker	60	10
Electronic game consoles	3	5
Fascimile machine	3	5
Food mixer	1	5
Freezer	35	10
Hair-dryer	1	10
High-fidelity system	10	10
Iron	1	10
Kettle	1	3
Microwave	15	7
Personal Computer	25	3
Photocopier	60	8
Radio	2	10
Refrigerator	35	10
Telephone	1	5
Television	30	5
Toaster	1	5
Tumble Dryer	35	10
Vacuum cleaner	10	10
Video recorder/DVD Player	5	5
Washing machine	65	8

Source: Gaidajis, Angelakoglou and Aktsoglou (2010: 194)

Whilst the electronic items identified in Table 2.1 above are not solely composed of industrial electronic equipment, a number of the items listed are used in the industrial environment. The last column in Table 2.1 indicates that electronic equipment has a finite lifespan and will eventually end up as e-waste, and the consequence of this relatively short product lifespan is the burgeoning quantity of e-waste that, if not recycled, poses a significant challenge to the environment.

2.4 Volumes of e-waste generated globally

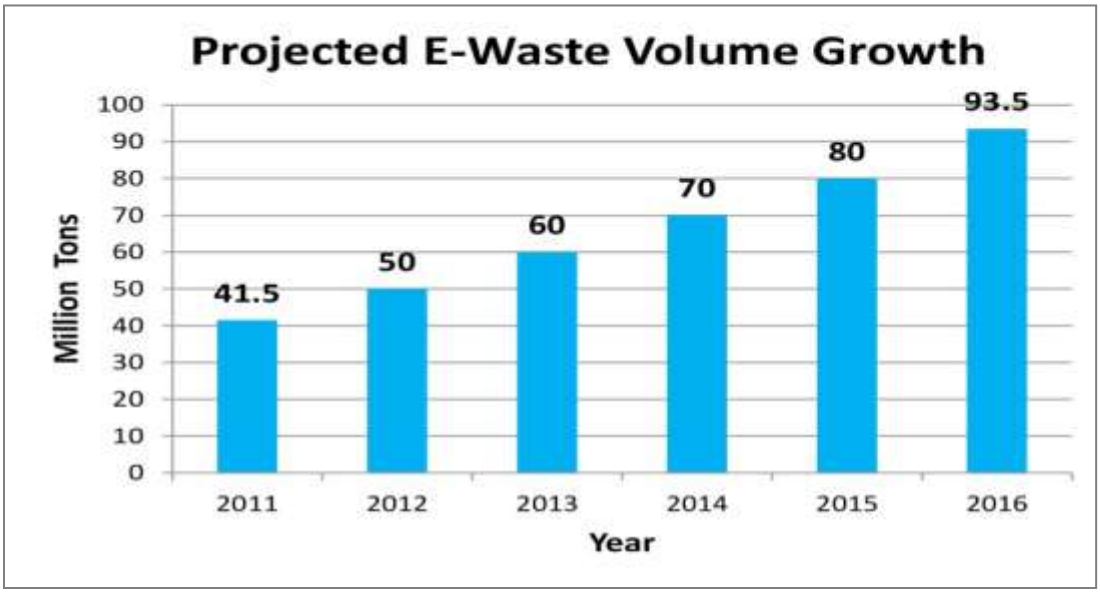
In the 1970s, Gordon E. Moore theorised that the processing power of computers doubles in about every eighteen months, especially relative to cost or size. His theory, known as Moore's Law, has proved largely true. While this is good news for both the consumer and the manufacturer, it results in an ever increasing source of electronic garbage (Wright 2010).

In 2008, Greenpeace International (2008) predicted that the amount of electronic products discarded globally will skyrocket, with approximately 30-50 million tons discarded annually. In trying to visualise the amount of e-waste generated, Greenpeace International indicated that if the estimated amount of e-waste generated annually were placed into containers on a train, it would go once around the world.

The United Nations Environment Programme Report (United Nations 2009) state that global electronic waste generation was growing annually, with approximately forty million tons of e-waste added per year and further estimated that e-waste levels could rise by as much as 500% by the year 2020. The report further state that by 2018, the e-waste generated by India and China will increase by eighteen times and seven times, respectively.

Electronics Recyclers International Incorporated (2013) has calculated the progressive growth of global volumes of e-waste up until 2016, and have indicated that it would have reached approximately seventy million tons in 2014, as illustrated in Figure 2.1 below.

Figure 2.1: Projected global growth e-waste volume



Source: Electronics Recyclers International Incorporated (2013:1)

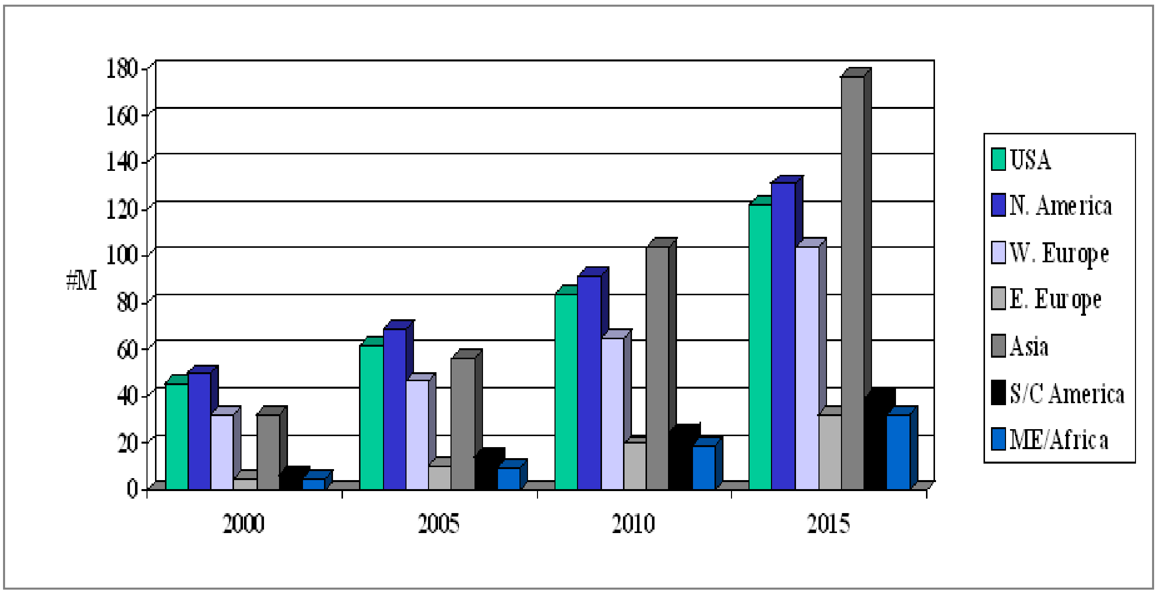
In a study undertaken by Baldé, Wang, Kuehr and Huisman (2015), the authors concluded that the global quantity of e-waste generated in 2014 was approximately 41.8 million tons, and not 70 million tons as reflected in Figure 2.1 above. This comprised of 1 million tons of lamps, 3 million tons of small hand-held computer devices, 6.3 million tons of screens and monitors, 7 million tons of temperature exchange equipment (cooling and freezing equipment), 11.8 million tons of large electronic equipment and 12.8 million tons of small electronic equipment (Baldé *et al*. 2015).

An on-line web portal, known as Worldometers (2012), keeps a real-time track of computers in use and have indicated that the computer market is growing fast. Hence, the e-waste volumes will grow rapidly as well. Worldometers (2012) have estimated that there will be around 2.1 billion computers sold by 2015, and state that while it took 27 years to reach the one billion mark, it will take about seven years to grow from one billion to two billion. In terms of potential e-waste, by using the average weight of 25 kilograms for a personal computer (Table 2.1), the amount of e-waste generated from computers in 2015 alone, is estimated to be 52.5 million tons.

Annual computer sales for the main regions of the world are summarised in Figure 2.2 below. According to eTForecasts (2014), prior to 2007, the United

States of America was the country with the highest computer sales, but subsequently, the Asian region began to dominate the computer sales market (eTForecasts 2014).

Figure 2.2: Global computer sales (in millions of units)



Source: eTForecasts (2014: 1)

The United States of America is one of the largest contributors of e-waste; but with Asia recording the highest sales in personal computers, which is five times more than the Middle East and Africa combined, it is fast becoming the number one contributor of e-waste in the world (eTForecasts 2014).

A United Nations report (United Nations 2009) indicated that in 2008, countries in the European Union (EU) sold over 9.3 million tons of electronic appliances, which eventually became e-waste. Statistics from the United Nations (2009) indicate that about 44 million large household appliances, 48 million desktops and laptops, 32 million televisions and about 776 million light fittings were sold in 2008. Huisman, Magalini, Kuehr and Maurer (2008) reported that in terms of industrial e-waste, it was estimated that approximately 42 800 tons of industrial e-waste were generated per year by European Union member countries. This e-waste emanated from discarded smoke detectors, heating regulators, thermostats, measuring instruments, weighing equipment, laboratory equipment and other monitoring and control instruments used in industrial installations.

Chancerel and Rotter (2009) report that in Germany, almost 110 000 tons of e-waste from the IT and telecommunications sectors were collected and recycled. According to Ongondo, Williams and Cherrett (2010), the annual amount of e-waste from private Germany households has been estimated to be between 1 to 1.4 million tons. In the United Kingdom, e-waste is one of the fastest growing waste streams with nearly 1.4 million tons of e-waste discarded annually and with an average of 21.8 kilograms of e-waste produced per person per year (Solving The E-Waste Problem 2014).

Government statistics in China estimated that in 2009, approximately 2.4 million tons of e-waste was generated and comprised of 25 million televisions, 5.4 million refrigerators, 10 million computers, 6 million printers and 40 million cellular phones (Ongondo, Williams and Cherrett 2010). China is the world's largest exporter of electronic goods but it also imports approximately 35 million tons of e-waste from developed countries per year, making it the world's largest importer of e-waste (Jinglei, Meiting, Williams 2009). According to the United Nations' "Global e-waste monitor" report, the top three Asian countries with the highest e-waste generation in absolute quantities are China with 6 million tons, Japan with 2.2 million tons, and India with 1.7 million tons (Baldé *et al*. 2015).

In 2013, the Australian Communications and Media Authority (2013) reported that there were 31.09 million cellular phones in operation in Australia, which will eventually become e-waste. Clean Up Australia Ltd (2009) reported that annually, approximately three million computers were sold in Australia, but only a small percentage was being recycled, and an estimated 37 million obsolete computers were dumped in landfill sites.

2.5 E-waste volumes generated in Africa

The demand for electronic and electrical equipment is rising at a significant rate across Africa, and is driven primarily by growing disposable incomes (The Southern African NGO Network 2011). In 2014, the total e-waste generated in Africa was 1.9 million tons (Baldé *et al.* 2015). A study undertaken by Fetzer (2009) indicated that the lack of enforcement of legislation has led to developed countries using developing countries, such as the African countries of Kenya and

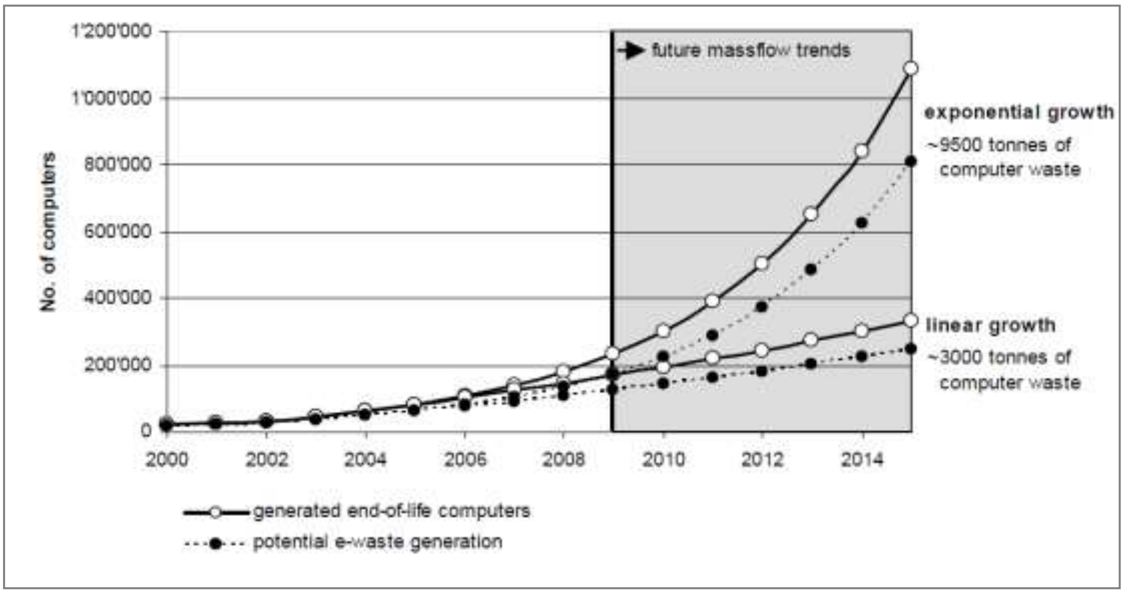
Ghana, as dumping grounds for their e-waste. Ogungbuyi, Nnorom, Osibanjo and Schluep (2012) reported that in 2010 import statistics for Nigeria indicated that approximately 1.2 million tons of new and used electronic equipment was imported into the country. For 2010 it was estimated that the informal recyclers collected and processed around 360 000 tons of e-waste, and another 180 000 tons of waste from electrical and electronic equipment (WEEE) was collected through communal collection via household waste, which added up to 540 000 tons of e-waste being recycled.

In Egypt, the number of mobile phone subscribers increased from 4.3 million in 2001 to approximately 24 million in 2007, and this increased by approximately 83% to 44 million in 2009 (Kamel 2013). In 2013, the number of cellular phone users had increased to 96 million, representing an increase of approximately 118% from 2009 (Salah 2013). Whilst the growth in the ICT sector in Egypt exceeded 20% during 2007 and 2008 (Kamel 2013), in 2013, approximately 39.2% of the population had access to the internet (Salah 2013).

The growth in Egypt's technology sector resulted in increased demand and use of electronic devices, and this impacts adversely on the volumes of e-waste generated. Moreover, in an effort to stem the growing electronic waste problem, the Egyptian Minister of Trade and Industry issued a decree prohibiting the importing of personal computers that were older than five years (Salah 2013).

In Tanzania the e-waste trends, based on exponential growth of end-of-life computers, indicate that between 500 000 and 800 000 computer units will be discarded in 2015, which is equivalent to approximately 9 500 tons of e-waste (Magashi and Schluep 2011). Furthermore, World Bank data from Tanzania showed that during the last decade personal computer penetration rates have risen ten-fold, and the number of people who own a mobile phone have increased by a factor of 100 (Marriott 2011). This growth pattern is illustrated in Figure 2.3 below.

Figure 2.3: Tanzania's exponential growth potential of computer e-waste



Source: Magashi and Schluep (2011: 6)

In Kenya, the volume of e-waste generated from computers, monitors and printers in 2008 was calculated to be about 3 000 tons (Fetzer 2009), but in 2014 the e-waste volume was calculated to be 44 000 tons (Solving The E-waste Problem 2014). This was the result of an increase in the importation of electronic goods and the increased use of computers. In Morocco, the volume of e-waste generated in 2008 was estimated at approximately 30 000 tons, of which computers accounted for approximately 45% (Fetzer 2009), and in 2014, the e-waste volume was calculated to be 121 000 tons (Solving The E-waste Problem 2014).

In 2007, The United Nations Environment Programme estimated that 32 000 tons of computers, 6 800 tons of printers, 1 900 tons of cellular phones, 35 800 tons of televisions and 22 300 tons of refrigerators were sold in South Africa, all of which eventually became e-waste (United Nations 2009). According to the e-waste world map created by Solving The E-waste Problem (2014), in 2012, each South African, on average, purchased approximately 9.94 kilograms of electrical and electronic equipment and generated approximately 6.63 kilograms of e-waste, and in 2014 alone, South Africa generated approximately 346 000 tons of e-waste, which was the highest in Africa. Koka (2015) contends that electronic waste in South Africa contributes approximately 5% to 8% of the municipal solid waste, and it is growing at a rate three times faster than other forms of solid waste.

It is evident that e-waste is a growing problem not only in developed countries but also in developing countries. As the economies of African countries grow and a greater proportion of the population uses electronic equipment, the e-waste problem will continue to grow (Groupe Speciale Mobile Association 2013). Moreover, the e-waste problem in Africa is exacerbated by the dumping of e-waste by developed countries in African countries, often under the guise of donations.

2.6 Africa: The dumping ground for e-waste

The e-waste problem in African countries is compounded by the practice of developed countries using them as dumping grounds for their e-waste. Rucevska, Nellemann, Isarin, Yang, Liu, Yu, Sandnaes, Olley, McCann, Devia, Bisschop, Soesilo, Schoolmeester, Henriksen and Nilsen (2015) state that this is due to the high costs of treating and disposing hazardous and other wastes in developed countries, coupled with weak environmental regulations, poor law enforcement and low environmental awareness in developing countries.

While environmentalists argue that it is immoral and unethical for developed countries to export their (hazardous) e-waste to developing countries, Larry Summers, a former economist at the World Bank, justifies this practice. He argues that the less developing countries, especially those in Africa, are under polluted, and can benefit from pollution trading schemes as they have air and water to spare. He further contends that environmental protection for health and aesthetic reasons is essentially a luxury of the rich, as mortality is such a great problem in developing countries that the relative minimal effects of increased pollution pale in comparison to the problems these areas already face (Oteng-Ababio 2012).

The Electronic Waste Association of South Africa (eWASA) cautioned that Africa has become a dumping ground for e-waste from America and Europe, under the guise of donations, and this has introduced higher levels of pollution into the environment (The Southern African NGO Network 2008). Nnorom and Osibanjo

(2008) affirm that developing countries are facing huge challenges from electronic equipment, like computers, that is imported as donations. The donated electronic equipment, together with locally generated e-waste, are eventually disposed of either through illegal dumping (e.g., through burning or burying) or they are placed with other municipal waste and disposed of at official dumpsites (Magashi and Schluep 2011).

Carnie (2015) states that thousands of tons of e-waste were falsely declared as second-hand goods when they were exported to developing countries; for example, waste batteries were described as plastic or mixed-metal scrap, while televisions cathode ray tubes and computer monitors were listed as metal scrap. Sepúlveda, Schluep, Renaud, Streicher, Kuehr, Hagelüken and Gerecke (2010) reported that the bulk of the profits out of the illegal importing of e-waste is retained by unscrupulous traders on both sides of the ocean, with the informal sector usually obtaining only a small portion of the value added in the whole chain, while bearing all the health and safety risks.

The impact of e-waste dumping has been observed in Ghana, especially in the town of Agbogbloshie, which has become Africa’s biggest electronics wasteland, with thousands of televisions and other electronic products being dumped there daily (Oteng-Ababio 2012). Every month approximately 500 containers of electronic waste are imported into Ghana (Vitola 2011). Lambert Faabelnon, the Director of the Ghanaian Environmental Protection Agency, states that developed countries have taken advantage of Ghana’s limited resources to track and detect the import of e-waste (Vitola 2011).

To assist countries in Africa combat the illegal dumping of hazardous materials, The Basel Convention has set up Basel Convention Regional Centres (BCRC) offices in four countries, namely, Egypt, Nigeria, Senegal, and South Africa. Their aim is to deliver training, disseminate information, consult on e-waste matters, raise awareness and engage in technology transfer on matters relevant to The Basel Convention, and to ensure that organisations practise environmentally sound management procedures of hazardous and other wastes (Basel Convention Regional Centre for Training and Technology Transfer for the Arab States 2011).

2.7 The toxic composition/constituent elements of e-waste

In 2007, Dalrymple, Wright, Kellner, Bains, Geraghty, Goosey and Lightfoot (2007) predicted that the entry into the waste stream of short lifespan products, such as mobile phones, will mean that the make-up of e-waste scrap will start to vary, and that there will be a wider range of metals encountered than the tin, lead and copper that was associated with traditional printed circuit boards.

According to Sepúlveda *et al.* (2010), waste from electrical and electronic equipment contain different materials, many of which are toxic. In addition to lead, tin and copper, e-waste contains a number of other heavy metals such as zinc, beryllium, iron, aluminium, with traces of germanium, tantalum, vanadium, terbium, gold, titanium, ruthenium, palladium, manganese, bismuth, niobium, rhodium, platinum, carbon, americium, antimony, arsenic, barium, boron, cobalt, europium, gallium, indium, lithium, manganese, nickel, palladium, ruthenium, selenium, silver, tantalum, molybdenum, thorium, yttrium, silicon and carbon (Lundgren 2012).

The Electronic Waste Association of South Africa (2011) attests that toxic substances in e-waste come from such materials as lead and cadmium in CRT screens; mercury in LCD monitors and alkaline batteries; beryllium in power supply boxes which contain silicon controlled rectifiers and x-ray lenses; polychlorinated biphenyls in older capacitors and transformers; brominated flame retardants on printed circuit boards, plastic casings, cables and polyvinyl chloride cable insulation. Borthakur and Singh (2012) states that highly toxic dioxins and furans are released when obsolete/redundant electronic devices are burnt to retrieve copper.

Zhang and Krumdick (2011) have estimated that 500 million personal computers contain approximately 2 872 000 tons of plastics, 718 000 tons of lead, 1 363 tons of cadmium and 287 tons of mercury. A cathode ray tube (CRT) monitor can contain between 1.8 and 3.6 kilograms of lead alone and big screen televisions contain even greater quantities of lead. Flat panel televisions and monitors contain less lead but many use toxic mercury lamps (Electronics Take Back Coalition 2012).

2.8 The environmental impact of e-waste

One of the concerns that this research highlights is the effect of e-waste on the environment. Lindgren, Morigiwa and Bengtsson (2010) state that computer usage and its development has grown rapidly during the last few decades, with business sectors and activities depending on computer usage, and the benefits that they have brought to society are immeasurable. However, the consequence of this growth is that e-waste has become the fastest growing hazardous waste stream globally (United Nations 2013).

Even the greenest products cannot prevent tertiary emissions if inappropriate recycling technologies are used, and this is a big challenge in developing countries, where backyard recycling, with open sky incineration, cyanide leaching, and burning of circuit boards impacts negatively on the health of the citizens and the environment (Solving the E-Waste Problem 2009). The toxins made up of dangerous carcinogens and chemicals leach out, poisoning the soil and dirtying underground water aquifers causing contamination (Rani, Singh, Maheshwari and Chauhan 2012), which later enter into crops, animals and the human body.

As a result of the toxic substances contained in electronic products, the usual management practice of e-waste crushing (compression) before or during discarding in landfills can increase the volumes of leachate leaked into the environment (Gaidajis, Angelakoglou and Aktsoglou 2010). In the city of Guiyu, Southeast China, known as the largest e-waste recycling site in the world, wind patterns disperse toxic particles released by open-air burning across the Pearl River Delta Region, which is home to 45 million people. In this way, toxic chemicals from e-waste enter the food chain, which is a significant route for heavy metals exposure to humans. These chemicals are not biodegradable and persist in the environment for long periods, increasing exposure risk (Robinson 2009).

According to Olowu (2012) e-waste has the potential to cause global warming, climate change, and depletion of the ozone layer, which is the result of the earth's limited capacity to assimilate waste. Robinson (2009) has observed that e-waste from older obsolete refrigerators, freezers and air conditioning units contain ozone-depleting chlorofluorocarbons (CFCs). This ozone destroying gas escapes from electronic items dumped in landfills. Ogungbuyi *et al.* (2012) contend that e-waste is contributing to acute chemical hazards and the long-term contamination at the dumpsites, as well as emitting ozone-depleting substances and greenhouse gases into the atmosphere. Gaidajis, Angelakoglou and Aktsoglou (2010) report that globally, despite recycling efforts, e-waste results in approximately 5 000 tons of copper being released annually into the environment. E-waste does not only negatively affect the natural environment, but it also has an adverse effect on human health.

2.9 The impact of e-waste on human health

Nnorom and Osibanjo (2008) confirm that e-waste contains hazardous constituents that negatively affect the environment and affect human health if not properly managed. Khurrum *et al.* (2011) explained that when obsolete/redundant electronic equipment is thrown in landfills or incinerated, it poses health risks due to the hazardous materials it contains. This improper disposal of electronic products leads to the increased exposure to environmental toxins, resulting in elevated risks of cancer and developmental and neurological disorders. According to Priyadharshini and Meenambal (2011), long-term exposure to e-waste substances damages the physiological systems such as nervous systems, reproductive and endocrine systems. Some of them are carcinogenic (cancer-causing substances) and neurotoxic (toxins that damages or destroys nerve tissue).

Waema and Mureithi (2008) highlight the environmental and social consequences of e-waste and have documented the negative effects on people's health. Examples of this include lead poisoning, mercury-causing cancer, people physically getting hurt (cuts, pricks, explosion from batteries in fire or other wounds from discarded waste). According to Electronics Take Back Coalition (2012), the following health concerns are associated with certain e-waste metals:

- lead and lead exposure causes brain damage in children;

- mercury – even low doses of mercury are toxic, and cause brain and kidney damage. It is reported that just 1/70th of a teaspoon of mercury can contaminate twenty acres of a lake, making the fish unfit to eat;
- cadmium – it accumulates in the human body and poisons the kidneys, and
- brominated flame retardants (BFRs) – this may seriously affect hormonal functions critical for normal development.

According to Grant, Goldizen, Sly, Brune, Neira, Van den Berg and Norman (2013), medical research undertaken on people working with e-waste showed increases in spontaneous abortions, stillbirths, premature births, reduced birth weights and birth lengths. People living in e-waste recycling towns or working in e-waste recycling plants had evidence of greater DNA damage than those not living or working in these towns.

According to Granatstein (2013), in Guiyu, Southeast China, the health impact of e-waste is so severe that:

- daily drinking water has to be trucked into the town because the ground water and surface water is too polluted;
- the soil and water have the highest levels of cancer causing dioxins in the world;
- pregnant ladies are six times more likely to experience miscarriages, and
- seven out of ten children have too much lead in their blood.

The Ghanaian Journal (2010) also asserts that in developing countries recycling and the disposal of e-waste involve significant risk to workers and communities. If left unchecked, the toxic effluent of the affluent will flood towards the world's poorest nations, where labour is cheap and occupational and environmental protection is inadequate (Borthakur and Singh 2012). In 2013, Kuehr and Magalini (2013) carried out the first global survey to investigate the impacts of e-waste recycling on child health. The survey was carried out among epidemiologists, toxicologists, child health experts, industry representatives, representatives of non-governmental organisations, and policy makers, who are actively involved in the study of e-waste and the health sector, and they all concluded that e-waste remains a considerable global health challenge.

A documentary (Problem of e-waste 2014) reported that tests on the soil at Agbogbloshie in Ghana revealed that:

- cadmium levels are thirty times over the acceptable levels and this high level causes cancer, kidney failure and bone diseases, and
- levels of lead that attack the nervous system topped 100 times the recommended maximum dose.

Other social impacts include diminished value of property and damage to property by illegal dumping, people fighting over recycled material for monetary gain, the unsightliness of e-waste dumps because of piles of discarded electronic goods, and the lack of appreciation for computers and other electronic goods because of its short life span. In South Africa, Finlay and Liechti (2008) reported that the negative social impacts include the open burning of plastics cables, both to extract value from metals such as copper as well as for warmth. Another concern is the vulnerability of e-waste collectors to e-waste traders in the sense that collectors do not have much leverage or bargaining power when negotiating with scrap metal traders on prices.

Skinner, Dinter, Lloyd and Strothmann (2010) assert that until a standard international definition of e-waste is in place and the economic causes of illegal e-waste export and handling are addressed, enforcing regulatory compliance and eliminating the health and environmental hazards related to e-waste will remain difficult. Enoch Massiah, a computer technician in Ghana expressed a further concern about unscrupulous e-waste recyclers retrieving confidential information about people or organisations from discarded hard drives (Vitola 2011).

According to Rucevska *et al*. (2015), without any significant enforcement efforts dedicated to the mapping, investigation and possible prosecution of criminals involved in illegal waste collection, illegal dumping and transport activities are likely to grow, as will the associated threats to human health and environmental security. A survey carried out by Kuehr and Magalini (2013) highlighted the need for joint action to tackle health issues related to e-waste management around the world, and this is discussed further in section 2.11 below.

From the discussion above it is evident that e-waste, if incorrectly handled and disposed off, poses serious health issues. Despite the harmful effects of e-waste, e-waste contains a variety of valuable minerals and materials.

2.10 Materials and minerals in e-waste

Gregory, Magalini, Kuehr and Huisman (2009) state that there are valuable materials, such as gold, copper, aluminium and ferrochrome metals found in e-waste, and the recovery of these materials can reduce the mining for virgin materials. For example, a metric ton of computers contains more gold than that recovered from seventeen tons of gold ore. However, Priyadharshini and Meenambal (2011), caution that the reprocessing technology to recover the valuable materials from e-waste, with minimal environmental impact, is expensive.

The demand for precious metals by manufacturers of electrical and electronic equipment has increased significantly. Although precious metal concentrations in appliances are decreasing, these metals (e.g. iron and copper) have a high economic and environmental relevance compared to other substances present in much higher quantity, and emerging technologies and research provide opportunities to add value to recovered materials (Chancerel and Rotter 2009).

Lundgren (2012) indicates that e-waste recycling is a business opportunity in most developing countries, as e-waste is viewed as a resource and income-generating opportunity of increasing significance, given the volumes of e-waste being generated and the valuable materials in them. Finlay and Liechti (2008) support the extraction of these valuable materials and maintain that there are numerous business opportunities in the refurbishment and recycling sectors, with e-waste recycling having the potential for small and micro-business development.

Osuagwu and Ikerionwu (2010) report that after electronic goods are recycled, the following categories of valuable minerals and materials can be sold to various industries, namely:

- printed circuit boards may be sold to precious metals refiners;
- plastics are recycled or mixed plastics are shredded before being sold to plastic recycling companies;
- ferrochrome metals are sold to steel mills (primary or secondary);
- copper is sold to copper smelters;
- aluminium is sold to secondary aluminium smelters, and
- glass is sold to lead smelters, manufacturers of CRTS, light bulb manufacturers and others who use leaded glass (e.g. in cathedral glass and architectural glass applications), or to glass manufacturers (non-leaded glass only).

There are various valuable minerals and materials used in the manufacture of electrical and electronic equipment, which can be recovered during e-waste recycling. For the next section, e-waste recycling to extract these valuable materials is discussed.

2.11 The management of e-waste

The future depends upon how waste is managed, and as an integrated part of sustainable development, effective waste management can reduce the global carbon footprint. Ignoring or neglecting the challenges of waste, however, can lead to significant health, environmental and economic consequences (Rucevska *et al*. 2015). Fetzer (2009) defines e-waste management as the collection, refurbishing, recycling and disposal of electronic equipment. An e-waste management term called “e-cycling” is used in the recycling industry, and according to Osuagwu and Ikerionwu (2010), “e-cycling” is the practice of re-using, or distributing for re-use, electronic equipment and components, rather than discarding them at the end of their life cycle.

In developing countries, the management of e-waste has become an environmental concern as economic development and urbanisation continues to take place (Priyadharshini and Meenambal 2011). The European Parliament and The Council Of The European Union (2012) advocate that the collection, storage, transport, treatment and recycling of waste from electrical and electronic equipment (WEEE), as well as its preparation for re-use should be conducted with an approach geared to protecting the environment and human health and preserving raw materials.

Kalana (2010) observed that whilst e-waste management is relatively widely practised by the industrial sector, it is at the domestic/household level that e-waste management is an issue. According to Gregory *et al.* (2009), in the USA, a Recycling Fee, also known as a Recovery Fee, is paid by consumers when they buy new equipment thereby ensuring that consumers bear the costs for the management of e-waste at its end-of-life phase. In China, Wang, Kuehr, Ahlquist and Li (2013) observed that electronic retailers who participated in this programme, sold new equipment to consumers at a ten percent discount and then forward the tickets/coupons of the consumers, certifying that they will turn their e-waste appliance to a formal collector, or to the government for reimbursement for the electric appliances sold.

Inglezakis and Zorpas (2011) advise that e-waste should initially be sorted by its origin (industrial, medical, nuclear waste). Subsequently, it should be sorted by its composition (glass, plastic, organic waste), and finally, it should be sorted out according to the level of danger it poses to humans and the environment (hazardous, non-hazardous, radioactive), and finally, by the way it is managed and treated (e.g. municipal, urban, landfilled waste).

The inverted pyramid shown in Figure 2.4 below illustrates the most preferable to the least preferable methods of waste management (Zero Waste SA 2015). Although no evidence has been found regarding the hierarchical management of e-waste, parallels can be drawn from Figure 2.4 for the management of e-waste. The activities at the top of the inverted pyramid are the most preferable and those at the bottom of the pyramid are the least preferred.

Figure 2.4: Waste Management Hierarchy

Source: Zero Waste SA (2015: 21)

While the Waste Management Hierarchy in Figure 2.1 above seems like the most preferable method of waste management, both from an economic and environmental perspective, Lindgren, Morigiwa and Bengtsson (2010) contend that re-use, as far as electronic equipment is concerned, might not be the best option. In general, electronic equipment does not have a very long lifespan because of the rapid development of new technology. Furthermore, older equipment might be less energy efficient for re-use or contain hazardous chemicals that are prohibited in newer products (Lindgren, Morigiwa and Bengtsson 2010).

According to Lazenby (2010), the trend for e-waste management in corporate organisations was to choose among three options on how to dispose of redundant computer hardware. These options are: refurbishing personal computers for donation to charities; refurbishing personal computers with the intention of making the refurbished computers available to the client's own staff at reduced prices, or refurbishing with the intention that it can be sold to the general public.

In support of the international management of hazardous waste, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted in 1989 and it came into force in 1992. It is the most comprehensive global environmental agreement on hazardous wastes and other wastes (Basel Convention 2011). The Basel Convention was to prevent exports of hazardous waste, like e-waste, from developed to developing countries. The Basel Action Network (2008), in a report called the Basel Ban Amendment, states that the management of e-waste is important for two primary reasons:

- to prevent damage to the environment and human health caused by the disproportionate export and disposal of hazardous wastes to countries that did not create them, and where there are less infrastructure and resources to mitigate the great risks associated with such wastes, and
- to prevent waste generators from avoiding taking responsibility to minimise the generation of hazardous wastes through clean production technologies and methods, by externalisation of their costs to countries where disposal is less costly than at home.

The Organisation for Economic Co-operation and Development (OECD) (2011) has developed a policy document on Extended Producer Responsibility (EPR) which is being propagated as the latest paradigm in waste management. The OECD (2011) defines EPR as an environmental policy approach in which a producer’s responsibility for a product is extended to the post-consumer stage of the product’s life cycle, including its final disposal. The EPR policy is in line with the “Polluter-pays Principle”, which is characterised by the shifting of responsibility away from the municipalities to include the costs of treatment and disposal into the price of the product, which will handle the environmental impacts of the product.

According to Whitehouse (2012), one of the goals of the National Strategy for Electronics Stewardship in the United States of America (USA) is to increase the safe and effective management and handling of used electronics in the USA. In North Carolina, the state has enacted the Solid Waste Management Act of 2007, which includes provisions regarding the management of discarded computer equipment. The law also instructed the State Department of Environment and

Natural Resources to implement a public education programme regarding computer equipment re-use and recycling (Luther 2008). The Organisation for Economic Co-operation and Development (2011) recommends that the promotion of environmentally friendly devices ("green" products) could help significantly limit the environmental impact of e-waste.

The Electronic Waste Association of South Africa (2011) has recommended, via its Integrated Industry Waste Industry Management Plan that e-waste management programmes should focus on a wide range of issues that *inter alia* should include the following:

- motivate original equipment manufacturers (OEM's) to improve product recyclability, reduce the use of toxic materials and integrate these concepts into product design;
- prevent toxic materials from entering landfills or being incinerated;
- recover scrap materials from the products, thereby avoiding the environmental burdens associated with producing virgin materials;
- ensure that e-waste is processed in an environmentally and socially responsible manner;
- share responsibility among stakeholders;
- motivate consumers to hand in equipment, and
- create an efficient and sustainable recycling system.

In support of e-waste management in urban areas in South Africa, shopping centres like the Pavilion Shopping Centre in KwaZulu-Natal, various Makro stores and Pick n Pay stores have set up e-waste recycling bins to collect redundant electronic equipment. The uMgungundlovu Municipal District local government in KwaZulu-Natal carried out an e-waste study (eWASA 2008), and concluded that just a handful of private organisations located within and near the uMgungundlovu District collect and disassemble e-waste. The study concluded that the recovery process was not optimised, and, therefore, the implementation of an integrated e-waste management system was needed.

In terms of e-waste management in Durban, where this study was conducted, in 2008, the first ever e-waste conference in Africa (called WasteCon2008) was held in Durban. It was held to discuss the management and consequence of e-waste in Africa. Delegates from local and international organisations drafted and signed a declaration called “The Durban Declaration on e-Waste Management in Africa”. According to the WasteCon2008 (2008) declaration, the development of a qualified and efficient e-waste management system is encouraged by:

- documenting tested and best available processes and practices;
- developing and improving recycling skills and competencies through training;
- satisfying the need for business models to ensure appropriate investments in the right technological and geographical level;
- connecting existing and new processes in the e-waste stream in so-called green e-waste channels, and
- ensuring continuous improvement of the recycling infrastructure through the establishment of standards and auditing procedures.

This section examined e-waste management internationally and locally. The next section examines the actual processes involved in e-waste recycling.

2.12 E-waste recycling

In many developed countries, electronic waste recycling or processing usually first involves dismantling the equipment into various parts (metal frames, power supplies, circuit boards, plastics), often by hand, but the use of automated shredding equipment is on the increase. According to Wang *et al.* (2013), the recycling of e-waste varies depending on the type of e-waste to be processed. The prevailing method for treating printed circuit boards is a combination of mechanical shredding and hydrometallurgical recovery of the precious metals, copper and other nonferrous metals. The recycling of CRT televisions entails cutting through the monitor with heated wire in order to separate the cone from the funnel glass, which is usually then re-sold (Ministry of Environment 2009).

The United Nations Environment Programme (United Nations 2009) advocates that e-waste recycling should operate and interact in a holistic manner to achieve overall recycling benefits. According to United Nations Environment Programme (United Nations 2009), the main objectives of e-waste recycling are to:

- treat the hazardous waste in an environmentally sound manner;
- recover valuable material maximally;
- create an eco-efficient and sustainable business environment, and
- consider the social impact and local context.

Lindgren, Morigiwa and Bengtsson (2010) contend that formal recycling efforts are necessary in order to manage the volume of e-waste generated, and in some industrialized parts of the world these processes are well established. On the contrary, Skinner *et al.* (2010) argue that without experiencing the benefit of environmentally sound recycling processes, informal recyclers will be reluctant to integrate their current manual operations into the formal sector of e-waste processing.

Table 2.2 below indicates the volume of e-waste trashed versus volume of e-waste recycled in the USA during 2010. According to the Electronics Take Back Coalition (2013), there is more disposal or trashing of e-waste than there is recycling of e-waste.

Table 2.2: Volumes of e-waste trashed vs recycled in the USA in 2010

Products	Total Disposed (tons)	Trashed (tons)	Recycled (tons)	Recycling Rate (%)
Computers	423 000	255 000	168 000	40%
Monitors	595 000	401 000	194 000	33%
Hardcopy devices	290 000	193 000	97 000	33%
Keyboards and Mice	76 800	61 4000	6 460	10%
Televisions	1 040	864 000	181 000	17%
Mobile devices	19 500	17 200	2 240	11%
TV peripherals	Not included	Not included	Not included	Not included
TOTAL (in tons)	2 440 000	1 790 000	649 000	27%

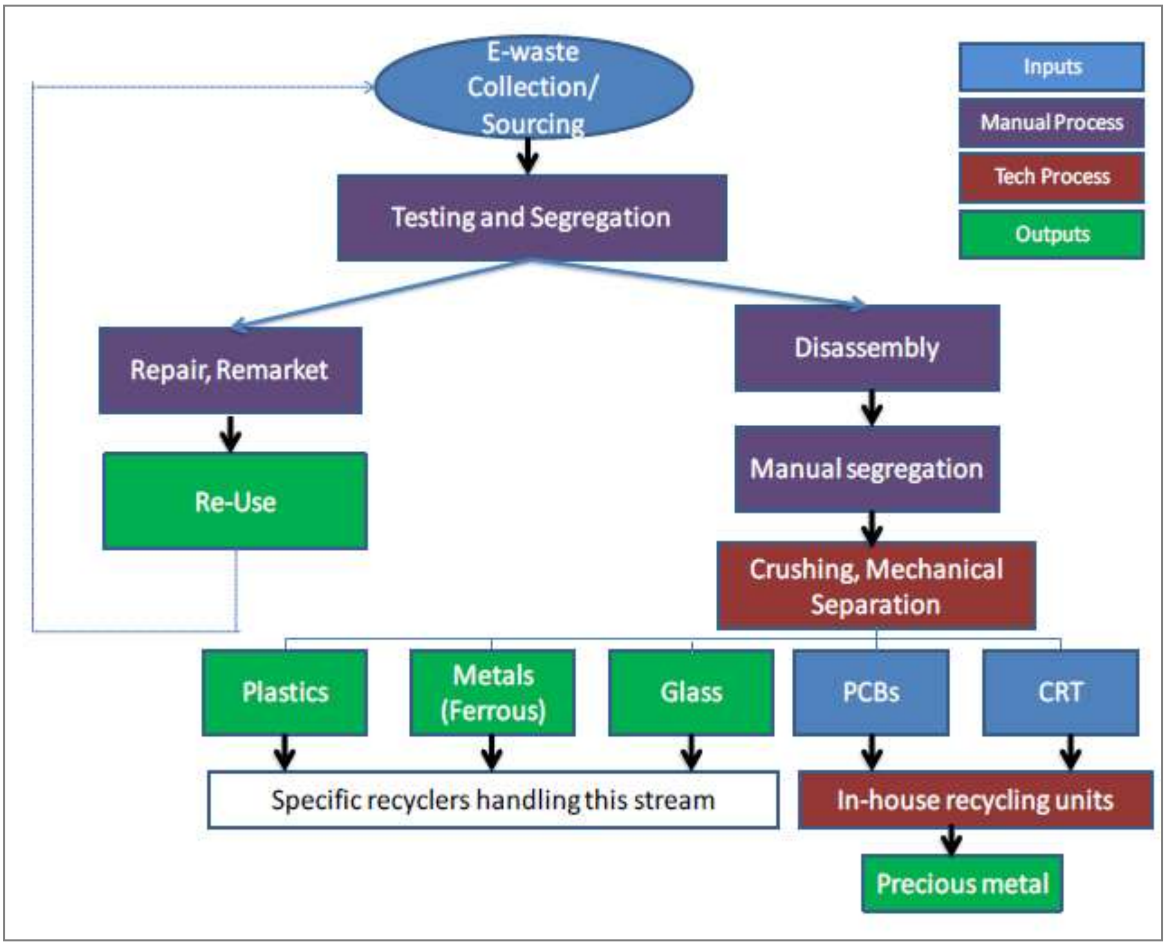
Source: Electronics Take Back Coalition (2013)

From Table 2.2 above, it emerges that the total volume of electronic products trashed (73%) far outweighs the total volume recycled (27%). The recycling rate (27%) has not reached a level to make a positive impact on the environment, in the sense that more e-waste is being disposed in dumps than can be recycled. The limited recycling rate in a number of countries, coupled with e-waste's hazardous nature has caused The Basel Action Network (2008), through the Basel Convention, to seek a full ban on the worst forms of international hazardous waste imports or exports.

There are a range of techniques that are employed in the informal sector for retrieving components and materials from e-waste. These informal recycling processes include physical dismantling by using tools such as hammers, chisels, screw drivers and bare hands to separate different materials. Other informal recycling processes include removing components from printed circuit boards by heating over coal-fired grills and stripping of metals in open-pit acid baths to recover gold and other metals. Some informal recyclers chip and melt plastics without proper ventilation then burn cables to recover copper; or burn unwanted materials in open air. Some recyclers try to refill toner cartridges with residual toner. The unsalvageable materials are disposed in fields and riverbanks, (Chi, Streicher-Porte, Wang and Reuter 2010). Carnie (2015) contends that at the end of this informal recycling process, residue components are dumped in open fields or next to river banks.

According to an e-waste feasibility study carried out by the KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs (2015), in formal e-waste recycling, e-waste that is recoverable is removed from the waste stream, and is then repaired and sold to the lower end market to be reused. Those components that cannot be repaired are sent to the disassembly section of the recycling plant for further processing. Here components are crushed, shredded or ground, thereafter sophisticated expensive equipment separates the various metal, plastics and glass which are sold to various smelters, plastics recyclers or other downstream users (KZN Department of Economic Development, Tourism and Environmental Affairs 2015). Figure 2.5 below illustrates the various phases in formal e-waste recycling.

Figure 2.5: A simplified diagram showing the various phases in e-waste processing



Source: IndigoEdge Insight (2013: 2)

Kuehr and Magalini (2013) emphasize that the efficient recovery of resources sometimes requires the use of state-of-the-art recycling technologies, as well as proper disposal of hazardous components due to the complexity of product design and the difficulty of separating highly commingled materials. However, Lundgren (2012) cautions that implementing a high-tech, capital-intensive recycling process is not appropriate in every country or region because of the high start-up costs.

2.13 The benefits of e-waste management

Ongondo, Williams and Cherrett (2010) contend that when materials are not recovered from e-waste, raw materials have to be extracted from the earth and processed to make new products, resulting in significant loss of resources and environmental damage necessitated by mining, manufacturing, transport and energy use. According to Bueti (2012), improving a developing country's e-waste recycling policies can have the potential to generate decent employment, curb health problems, cut greenhouse gas emissions and recover a wide range of valuable metals, including silver, gold, palladium, copper and indium, by turning an "e-challenge" into an "e-opportunity". Madubula and Makinta (2013) concur with Bueti (2012) regarding the benefits of e-waste recycling, and add that particularly the poor, previously disadvantaged, and lowly skilled people will benefit from the employment opportunities.

Recycling of e-waste through proper technologies is considered to be a profitable business in developed countries due to the presence of precious metals in printed circuit boards (Chatterjee and Kumar 2009). The Social Sciences and Humanities Research Council of Canada (2010) expressed similar sentiments wherein they indicated that there is almost no such thing as waste, but that there is always value in waste. The report states that the greater the extent to which e-waste is processed, the higher the profit margin; so there is no need to classify it as waste. One of the main benefits of e-waste management, as stated by Priyadharshini and Meenambal (2011), is the prevention of dangerous toxins seeping into the soil and groundwater, and thus preventing contamination and pollution.

According to Huisman *et al.* (2008), the social benefit of e-waste management revolves around low-income households who cannot afford to buy new electronic goods, but would be able to buy refurbished electronic goods. Similarly, a Cape Town based computer company called "Just PC" believes that it is closing the so-called digital divide by supplying refurbished computers, which are affordable and reliable and run genuine software, to children, low-income households, non-profit organisations, schools and small businesses (Lazenby 2010).

Another benefit of e-waste management is the associated job creation and job opportunities. Jobs are created at various points in the e-waste value chain, namely: collection, dismantling, sorting, segregation and metal recovery (KZN Department of Economic Development, Tourism and Environmental Affairs 2015). According to Fetzer (2009), the waste recycling sector provides valuable jobs for people who cannot easily access formal employment, in the sense that informal collectors, dismantlers and recyclers are playing an increasingly larger role in the processing of domestic e-waste. An American e-waste recycling plant, Electronic Recyclers International Incorporated (ERI) reported that besides keeping landfills free and providing smelters with raw materials, their facilities provide “green collar” jobs, and have created over 400 jobs (Louie 2011).

In India, estimates show that at least 150 000 people are involved in the e-waste recycling and recovery operations in Delhi alone (Batist 2013). In Switzerland, 470 persons are employed in e-waste recycling (Gully 2011). The recycling activities by an e-waste management organisation called WorldLoop has resulted in 954 tons of e-waste being collected and recycled; preventing 1 474 tons of CO_2 emissions being circumvented and more than fifty new jobs created in sub-Saharan Africa during 2012 (WorldLoop 2013). In the Guiyu area of southern China, 100 000 people work in e-waste recycling (The Economist 2013). According to eWASA, in the Western Cape, an e-waste recycling plant is generating income and creating employment opportunities for locals, with the project owners optimistic about the growth potential of this project that initially created sixteen jobs (The Southern African NGO Network 2008).

The additional benefit of e-waste management and the use of recycled materials, is in the energy and cost saving value of producing new electronic equipment from remoulded e-waste materials. Rani *et al.* (2012) contend that e-waste recycling has the potential to conserve energy and to keep the environment free of toxic materials, and the limited production of electronic equipment from virgin materials decreases the amount of carbon released into the atmosphere, thereby reducing global warming. Economic and technical data shows that the effect of recycling on greenhouse gas emissions presents definite advantages for all municipalities in all countries, regardless of the social and economic disparities (Madubula and Makinta 2013). Table 2.3 below indicates the percentage of greenhouse gas saved by European Union countries, the USA and developing countries when the main waste materials that are found in e-waste are recycled from the municipal waste.

Table 2.3: Percentage of greenhouse gas saved from recycling of municipal waste (ton of CO_2/ million ton of waste)

Waste Material	EU Countries	USA	Developing Countries
Plastic (HDPE)	-0.49	-1.26	-0.44
Glass	-0.25	-0.27	-0.23
Metal (Iron)	-1.48	-1.63	-1.25
Aluminium	-9.07	-12.31	-5.06

Source: Madubula and Makinta (2013: 214)

In another study, WorldLoop (2013) calculated that approximately 1.44 tons of CO_2 emissions are prevented from being released into the atmosphere for every ton of e-waste collected and recycled. Baeyens, Brems and Dewil (2010) also report that recycling glass, which is a major residue of e-waste, has major energy and emission reduction benefits. It is thus evident that effective e-waste management includes some form of e-waste recycling.

2.14 The business case for e-waste recycling

According to Baldé *et al*. (2015), in 2014 the intrinsic material value of global e-waste was estimated to be 48 billion euros. The material value was dominated by gold, copper and plastics contents. Approximately 320 tons of gold and more than 7 500 tons of silver are used annually to make computers, cellular phones, tablet computers and other new electronic and electrical products worldwide, adding more than $21 billion in value each year to the fortunes in metals available through urban mining of e-waste (Solving the E-Waste Problem 2012). The American Environmental Protection Agency has reported that recycling one million cellular phones can recover about twenty-four kilograms of gold, 250 kilograms of silver, nine kilograms of palladium, and more than 9 000 kilograms of copper (Electronics Take Back Coalition 2013).

In America, a company called Electronic Recyclers International Incorporated (ERI) has grown to become a multimillion-dollar business around recycling electronic waste and in 2010 had seven recycling plants throughout the USA. The company employs a combination of manual labour and machine power to separate and shred televisions, computer monitors and cellular phones. The Chief Executive Officer of ERI, Mr John Shegerian, has reported that ERI's profits were $45 million in 2010, and that the profits would increase to $65 million in 2011, then to $100 million in 2012 (Louie 2011).

Another recycling company in the USA, called e-Cycle, recycles iPhones and refurbishes and sells them abroad, and shares the profit with corporations, businesses, and institutions that donate their electronic devices. From a two-person start-up, this company has grown into the eighth fastest-growing environmental service company as of 2010. The company's revenue grew 400% in three years, from $700 000 in 2006 to $3.5 million in 2010 (Wong 2010).

In India approximately 390 grams of gold can be extracted for every ton of e-waste recycled, which can trade for approximately $18 745 (IndigoEdge Insight 2013). According to The Economist (2013), recycling e-waste in China has become lucrative with 5 500 workshops in Guiyu, recycling 1.5 million tons of e-waste a year and generating an income of approximately $75 million. Forbes (2012) reports that there has been a demand for the materials streams derived from e-waste recycling and that e-waste recycling is a sustainable worldwide industry because there is no single company in the world that can handle the e-waste stream at the rate it is growing.

In South Africa, Sindawonye Granulators and Processors was the first black empowered formal e-waste recycling company in this field. The company possesses the most sophisticated granulation and non-ferrous shredding plant in the southern hemisphere for handling e-waste. The company operates from a 25 000m² factory in Gauteng and a 10 000m² factory in Port Elizabeth (Sindawonye 2014).

Another successful South African formal e-waste recycling company is Desco Electronic Recyclers, which is situated in Kempton Park, Gauteng. It markets itself as a leader in e-waste recycling and is an ISO 14001 compliant recycler. The company has over forty-four pick-up and drop-off points throughout the country, and has partnered with companies like HiFi Corporation, Incredible

Connection, Makro and various shopping centres to form a network of e-waste collection points (Desco Recyclers 2011).

The above discussion reveals that e-waste recycling can, indeed, be a profitable venture, and if e-waste recycling efforts are increased, more jobs, albeit menial jobs, can be created, thereby positively impacting on unemployment and poverty in South Africa. In the next section, the legislation governing the management of e-waste, both internationally and in South Africa, is examined.

2.15 Legislation governing the management of e-waste

In view of the ill-effects of hazardous waste on the environment and human health, several countries supported the need for a global agreement to address the problems and challenges posed by hazardous waste (Borthakur and Singh 2012). Leading this cause is the Basel Convention on the control of trans-boundary movements of hazardous wastes and their disposal. The overarching objective of the Basel Convention is to protect human health and the environment against the adverse effects of hazardous wastes (United Nations 2011).

E-waste legislations cover many aspects, from specifying the types of electronic devices covered under a legislation, to how a collection and recycling programme will be financed. According to Luther (2008), the legislations also guide the collection and recycling criteria that must be met to minimise the impact on human health and the environment; and defines the restrictions or requirements that electronic products must meet to be sold within a country. A discussion on e-waste legislation implemented in various countries appears below.

2.15.1 E-waste legislation in America

In the United States of America, the United States Environmental Protection Agency (2014) assert that there is no federal mandate to recycle e-waste but there have been numerous attempts to develop a federal law. However, many states have instituted “State Mandatory Electronics Recovery Programs”. The Electronics Take Back Coalition (2014) reports that 25 states have passed legislation mandating state-wide e-waste recycling. Several more states are working on passing new laws or improving existing laws. All states, except California and Utah, use the Producer Responsibility approach, where the manufacturers must pay for recycling. This implies that approximately 65% of the population of the USA is covered by state e-waste recycling laws.

The European Parliament has proposed stricter rules to halt growing volume of e-waste. The European Union lawmakers indicated that they wanted member states to collect at least 85% of discarded electronics by 2016, compared with only 33% in 2010. Under the proposed new laws, electronics producers will be expected to foot the bill for collecting discarded appliances (Dou 2011). The new law, which is an update to the 2003 Waste Electrical and Electronic Equipment (WEEE) Directive, is to curb dumping of electronic goods such as mobile phones, computers and television sets in landfill sites. This new law states that by 2016 European Union member states will have to collect forty-five tons of e-waste for every 100 tons of electronic goods put on sale during the previous three years, and by 2019, the target will rise to sixty-five tons (British Broadcasting Corporation 2012). The European Parliament has passed Directive 2012/19/EU on e-waste. The Directive 2012/19/EU states that if equipment containing gases that are ozone depleting or have a global warming potential (GWP) above 15, such as those contained in foams and refrigeration circuits, then the gases must be properly extracted. These gases must be properly treated in accordance with Regulation (EC) No 1005/2009 (European Parliament and The Council of the European Union 2012).

2.15.2 E-waste legislation in China

According to Wang *et al.* (2013), China is one of the world's largest exporters of electrical and electronic equipment, and importers of e-waste. China have implemented a variety of environmental laws, regulations, standards, technical guidance and norms related to e-waste management over the past decade. Some of these are:

- a list of prohibited goods to be imported for processing or trade - compiled in the year 2000;

- Technical Policy on Pollution Prevention and Control of WEEE - promulgated in the year 2006;
- Ordinance on Management of Prevention and Control of Pollution from Electronic and Information Products - promulgated in the year 2007;
- Administrative Measures on Pollution Prevention of Waste Electrical and Electronic Equipment - promulgated in the year 2008, and
- Regulations on Recovery Processing of Waste Electrical and Electronic Products - promulgated in the year 2009.

2.15.3 E-waste legislation in India

According to Priyadharshini, Haganesh and Meenambal (2012), the Indian government has instituted a number of regulations for better management of general hazardous waste in the country, but no specific legislation regarding e-waste have been passed. Some of these regulations included:

- The Hazardous Wastes (Management and Handling) Rules 1989/2000/2003. These rules define hazardous waste as waste which by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics causes danger or is likely to cause danger to health or environment, whether alone or when on contact with other wastes or substances;
- DGFT (Exim policy 2002-07): Second hand personal computers (PCs)/laptops are not permitted for import;
- The Ministry of Environment and Forests Guidelines for Management and Handling of Hazardous Wastes, 1991;
- Guidelines for Safe Road Transport of Hazardous Chemicals, 1995;
- Batteries (Management and Handling) Rules, 2001;
- The National Environmental Tribunal Act, 1995;
- Bio-Medical Wastes (Management and Handling) Rules, 1998, and
- Municipal Solid Wastes (Management and Handling) Rules, 2000 and 2002.

In 2011, the Indian Government embarked on an initiative called "The E-waste Management and Handling Rules" to address issues related to e-waste. These rules are applicable to every producer, consumer or bulk consumer involved in the manufacture, purchase and sale, or processing of electrical and electronic equipment; collection centres; dismantlers and recyclers of e-waste. The responsibilities of producers, collection centres, consumers, dismantlers and recyclers are defined and incorporated so that they can abide by the E-waste Management and Handling Rules (Borthakur and Singh 2012).

In May 2012, India introduced the Extended Producer Responsibility (EPR) legislation. The original equipment manufacturers (OEM) of the products are responsible for collection of end of life products through community drives, retail outlets and other mechanisms, which are then to be sold or delivered to recyclers (IndigoEdge Insight 2013).

2.15.4 E-waste legislation in Africa

According to The Guardian (2013), African leaders met in June 2013 at a convention in Bamako to discuss the impact of hazardous waste in Africa. The outcome of the convention was to develop tougher laws to end the influx of electronic waste to African countries. This was amid renewed concerns over toxic components being dumped on the continent. The African representatives called for enforcement of the Basel Convention and for tougher national laws to prevent e-waste dumping.

The 45 countries (out of the 54) in Africa that are signatories to the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal, are listed in Table 2.4 below. Notable African countries which are not signatories to the Basel Convention are Angola, Uganda, Western Sahara and Sierra Leone.

Table 2.4: African countries that are signatories to the Basel Convention

Country	Date of enforcement
Algeria	14/12/1998
Botswana	18/08/1998
Burkina Faso	02/02/2000
Burundi	06/04/1997
Cameroon	10/05/2001
Central African Republic	25/05/2006
Chad	08/06/2004
Congo	19/07/2007
Côte d'Ivoire	01/03/1995
Democratic Republic of the Congo	04/01/1995
Djibouti	29/08/2002
Egypt	08/04/1993
Equatorial Guinea	08/05/2003
Eritrea	08/06/2005
Ethiopia	11/07/2000
Gabon	04/09/2008
Gambia	15/03/1998
Ghana	28/08/2003
Guinea	25/07/1995
Guinea-Bissau	10/05/2005
Kenya	30/08/2000
Lesotho	29/08/2000
Liberia	21/12/2004
Libya	10/10/2001
Madag	31/08/1999
Malawi	20/07/1994
Mauritania	14/11/1996
Mauritius	22/02/1993
Morocco	27/03/1996
Mozambique	11/06/1997
Namibia	13/08/1995
Niger	15/09/1998
Nigeria	05/05/1992
Rwanda	06/04/2004
Senegal	08/02/1993
Somalia	24/10/2010
South Africa	03/08/1994

Sudan	09/04/2006
Swaziland	06/11/2005
Togo	30/09/2004
Tunisia	09/01/1996
Uganda	09/06/1999
United Republic of Tanzania	06/07/1993
Zambia	13/02/1995
Zimbabwe	30/05/2012

Source: Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (2011: 5)

In Ghana, a wide range of environmental legislation exists, but there are no specific laws for e-waste recycling. However, a National Working Group was constituted by the Environmental Protection Agency to help formulate a strategy for e-waste recycling, but the outcome of the deliberations is yet to be made public (Oteng-Ababio 2012).

According to Baldé *et al*. (2015), only Cameroon and Nigeria have enforced national e-waste related legislation, while e-waste legislation in Ghana, Ethiopia and Kenya is awaiting approval. Other conventions such as the Bamako Convention, a regional trade agreement for the African region, have introduced regulations aimed at preventing the illegal transboundary transportation of hazardous materials (Rucevska *et al*. 2015).

2.15.5 E-waste legislation in South Africa

In South Africa, Acts like the National Environmental Management Waste Act No. 59 of 2008 are being used to control the illegal disposal of e-waste. The Act helps to protect public health and the environment (Finley 2008). Other legislation impacting on e-waste management in South Africa include:

- The South African Constitution (1996), which includes the following rights that can have an impact on e-waste management:
  - an environment that is not detrimental to one's health;
  - just administrative action, and
  - access to information.

- The National Environmental Management Act No. 107 of 1998 (NEMA) makes provision for waste management. The principles that the Act covers, and that are relevant to e-waste management, are the avoidance or minimisation, and the remediation of pollution. Other principles that are mentioned are waste reduction, re-use, recycling and proper disposal (South Africa 1998).

- The Environment Conservation Act No. 73 of 1989 (ECA) enforces the effective protection and controlled utilisation of the environment. Section 20 of the Act refers specifically to waste management. A minimum requirements series of documents was established that guides the disposal of waste at landfills by stipulating the requirements, standards and procedures for the waste disposal and handling facilities (South Africa 1989).

- The White Paper on Integrated Pollution and Waste Management regulates and guides pollution prevention, waste minimisation, impact management and remediation. It provides for guidance for the allocation of environmental and waste management functions as well as powers for national, provincial and local governments. The following waste management hierarchy is mentioned in the White Paper (Department of Environmental Affairs 2000):
  - avoidance, minimization and prevention of waste;
  - recycling and reuse;
  - treatment and handling, and
  - storage and final disposal.

- The National Waste Management Strategy (NWMS) is a legislative requirement of the National Environmental Management Waste Act No. 59 of 2008. The purpose of the NWMS is to achieve the objectives of the Waste Act No. 59 of 2008, and was brought about through a joint venture between the Department of Environmental Affairs and Tourism and the Department of Water Affairs and Forestry (DWAF). NWMS states that Industry Waste Management Plans (IndWMPs) will be developed and targets set for waste reduction and for re-use, recycling and recovery and this will also be requested for selected electronic waste (e-waste) streams and batteries (Department of Environmental Affairs 2011). NWMS deals with the following:

- integrated waste management planning;
- waste information system;
- general waste collection;
- waste treatment and disposal;
- capacity building, education, awareness and communication, and
- implementing instruments.

Up until 2008, South Africa had no specific legislation dealing with the hazardous substances in e-waste (Finley and Liechti 2008). The Electronic Waste Association of South Africa (2009) used to report that South Africa did not have any dedicated legislation pertaining to e-waste. However, with lobbying from e-waste activists, The Waste Act No. 59 of 2008 and Notice GN 718 of 3 July 2009 have been promulgated. The Act makes it illegal for individuals or companies to dispose of anything that constitutes hazardous substances including e-waste. Whether a light bulb, hairdryer, or server – these appliances need to be recycled in a responsible way. Government, together with organisations like eWASA, has instituted guidelines to ensure sustainable and safe recycling processes are in place (Africa E-waste 2011). However, eWASA's criticism of e-waste legislation is that difficulties can arise because of the conflict between different government departments, or different levels of government, enforcing these laws with no uniform approach in dealing with e-waste or hazardous waste in general (Electronic Waste Association of South Africa 2009).

Annexure C contains a list of Government Policy, National Acts, Regulations and Local Government By-Laws for the control of hazardous substances in e-waste. It contains a more comprehensive list of the Laws and Acts that govern waste management. Although these laws and Acts do not refer directly to e-waste, it helps in addressing the issue of hazardous waste management and the protection of the environment.

Whilst there is adequate legislation governing the management of e-waste in South Africa, local organisations, like the Durban Solid Waste (DSW), do not have the capacity to address the e-waste stream and its legislation (KZN Department of Economic Development, Tourism and Environmental Affairs 2015). In the next section, a brief discussion centres on the responsibility of manufacturers of electronic devices to take into consideration recycling issues when designing and manufacturing their products.

2.16 Design of electronic devices for ease of recycling

A trend in the electronic manufacturing industry is a type of design called “recycle and inverse manufacturing” design. In the past, electronic goods were designed without considering recycling issues, but presently many electronic products are designed in a manner that facilitates recycling. Electronic Waste Association of South Africa (2011) has recommended that product design should be undertaken from an eco-efficiency perspective. Manufacturing processes should have design-for-recycling-motivated product design changes and recommends that products must be evaluated from a life-cycle perspective to ensure that end-of-life considerations are balanced with other eco-design principles.

To mainstream and disseminate information on environmentally sound e-waste management practices in developing countries, the United Nations Environment Program has a work plan on the focal area for e-waste recycling that proposes to develop sustainable business plans which will include an effective take-back system, a manual dismantling facility, local pre-processing activities and sound end-processing activities (United Nations n.d.).

According to Osuagwu and Ikerionwu (2010), responsibilities of the electronic industry include:

- generators of e-waste should take responsibility to determine the output characteristics of wastes and if hazardous, should provide management options;
- all personnel involved in handling e-waste in industries including those at the policy, management, control and operational levels, should be properly qualified and trained;

- companies can and should adopt waste minimisation techniques, which will make a significant reduction in the quantity of e-waste generated and thereby lessening the impact on the environment;
- manufacturers, distributors, and retailers should undertake the responsibility of recycling/disposal of their own products, and
- manufacturers of computer monitors, television sets and other electronic devices containing hazardous materials must be responsible for educating consumers and the general public regarding the potential threat to public health and the environment posed by their products.

The international pressure to manage e-waste has been to South Africa’s advantage because global companies that manufacture electronic products in South Africa are informed by corporate best practice and reputation management, and, hence, whether operating in Canada or in South Africa, follow a uniform e-waste management plan. This, in turn, has encouraged many South African owned companies to develop a comparable waste management strategy, thereby increasing the awareness of e-waste in the corporate market (Africa E-waste 2011).

2.17 Conclusion

From a review of the relevant literature, it is evident that the volume of electronic waste generated both locally and globally is accelerating at an alarming rate, due, primarily, to the rapid pace of technological advances. Given the toxic nature of many components used in the manufacture of electronic equipment and machinery, e-waste has the potential to impact negatively on both the environment and on human health, if incorrectly managed. However, as a review of the literature has indicated, a host of valuable minerals and materials can be harvested from e-waste, and, e-waste recycling can, indeed, be a profitable venture. In the next chapter, the research methodology employed in the study is discussed.

CHAPTER 3

RESEARCH METHODOLOGY AND DESIGN

3.1 Introduction

This chapter commences by restating the objectives of the study that were not addressed by the literature reviewed. This is followed by a detailed description of the salient aspects pertaining to the research methodology and design adopted for this study.

3.2 Objectives of the study

- to establish the potential quantity of e-waste generated at the Umbogintwini Industrial Complex and Southgate Business Park and assess its economic benefit, if recycled;
- to examine the methods employed by organisations within the study area to dispose of their e-waste;
- to establish the extent to which e-waste generated within the study area is managed in an environmentally responsible manner, and
- to determine the attitude of organisations within the study area towards the establishment of an e-waste recycling operation.

3.3 The research design

For the study, a quantitative research methodology was selected. Leedy and Ormrod (2010) explain that quantitative research involves either identifying the characteristics of an observed phenomenon, or describing or exploring possible correlations among two or more phenomena. This quantitative approach was used to quantify the problem by way of generating numerical data or data that can be transformed into useable statistics. The collected data was entered into a computer where it was counted, stored and manipulated and was used to quantify attitudes, opinions, behaviors, and other defined variables (Wyse 2011).

The quantitative research design involved gathering data through the use of a structured questionnaire, which was both personally delivered (hard copy) and e-mailed to the sample chosen. The methodology also clarifies the techniques used by the researcher to present, analyse and discuss the statistics and correlations. In undertaking the empirical component of the research, the “five Ws” of research, as identified by Malhotra (2010), were considered, and its answers sought (captured in brackets). They are:

- who? (organisations located within The Umbogintwini Industrial Complex and Southgate Business Park);
- when? (between August 2013 to November 2013);
- where? (The Umbogintwini Industrial Complex and Southgate Business Park, KwaZulu-Natal, South Africa);
- why? (To investigate the volumes of potential e-waste generated and the management of electronic waste), and
- way? (Use of a structured questionnaire).

Bailey (2008) states that when research is conducted at a fixed time, as in this case where the organisations were surveyed within a fixed period, the research lends itself to cross-sectional research methodology. Fink (2013) explains that cross-sectional surveys are studies that take place at a single point in time and are regarded as a snapshot of a group of people or organisations. The cross-sectional study is a frequently used research design and involves the collection of information from any given sample of population elements only once (Malhotra 2010).

The fundamental approach to the study was a formal, objective and systematic process in which numerical data was sourced through a questionnaire and the data utilised to calculate the quantity of current and potential e-waste generated. Thereafter, the data was analysed and the current management methods of this e-waste within the study area was determined. By using the research instrument, the responses were elicited from an objective and unique perspective. The researcher remained neutral and detached from the research subjects to ensure objectivity in the research process (Hesse-Biber and Leavy 2011).

3.4 Target population

The target population comprised of organisations located within the Umbogintwini Industrial Complex and the adjacent Southgate Business Park, Durban, KwaZulu-Natal, South Africa, as illustrated in Figure 3.1 below. The study area had 313 organisations operating within its mixed industrial and manufacturing zones. These organisations comprised of micro (less than five employees); very small (between five to twenty employees); small (between twenty one to fifty employees); medium (between fifty one to 200 employees) and large (over 200 employees) organisations.

Figure 3.1: Geographic location of Umbogintwini Industrial Complex and the adjacent Southgate Business Park

Source: Tourism KwaZulu-Natal (2014)

The study area is populated by industrial and manufacturing organisations and the potential to generate e-waste is relatively high. Hence, its selection as the study area. For ethical reasons, permission was first sought and received from the management of both the Umbogintwini Industrial Complex and the Southgate Business Park before the questionnaires were administered (See Annexures A and B, respectively).

3.5 The sample size

The total number of organisations located in the study area was 313, and as they were spread over approximately 550 hectares, a convenience sampling technique was chosen. Jackson (2011) defines convenience sampling as obtaining research participants wherever one can find them within a study area.

According to the sample size table developed by Sekaran and Bougie (2014), if the target population is close to 320, then, at the 95% confidence level, the appropriate sample size is 179. Excluding the pilot study, a total of 179 questionnaires were distributed to organisations within the study area.

3.6 The research instrument and data collection

The research instrument was a critical component in the research project, and the designed data-collection procedure established an effective link between the questions asked and the information required (Feinberg, Kinnear, and Taylor 2013). A poorly designed research instrument could have affected the results, and would not have achieved the outcomes of the study. For this study, the research instrument used was a structured questionnaire. According to Fink (2013), structured questionnaires are efficient tools for systematically collecting data from a broad spectrum of respondents within a study area, and are efficient in that many variables can be measured without substantially increasing the time or cost.

In designing the questionnaire, the following points were taken into consideration:

- questions were not invasive and did not require confidential company data;
- questions were not leading or made the respondent feel embarrassed;
- questions were not complex so that respondents were not required to do research before answering the questions;
- questions only required one response at a time;
- questions were clear and comprehensible;
- the questionnaire was not too long so as to discourage the respondent from completing it;
- the questionnaire structure and content was based on the research objectives and the literature reviewed, and
- the questionnaire was broken down into meaningful sections, grouping together questions related to the same subject (University of Strathclyde Glasgow n.d.).

The questionnaire consisted of nineteen closed-ended questions and one open-ended question (refer to Annexure H), and comprised of the following three sections:

- Section A: quantifying the amount of e-waste generated within the Umbogintwini Industrial Complex and the adjacent Southgate Business Park. The purpose of calculating the total quantity of e-waste generated in this area was to determine its impact on the environment, if it was not recycled, as well as its economic benefit, if managed appropriately;

- Section B: management of e-waste. The questions in Section B of the survey instrument were designed to establish if information on e-waste recycling was available in the study area, as well as the methods employed by the organisations to manage their e-waste, and

- Section C: the questions in Section C of the survey instrument were designed to ascertain the opinions and relative importance that organisations within the study area placed on e-waste recycling. It also intended to establish the respondents' attitude towards the establishment of an e-waste recycling operation within the study area.

In terms of completing the questionnaire, respondents were given options for all of the questions, whilst six of the questions were structured along the Likert rating scale. A Likert scale is a summated rating scale, which consists of statements that express either an agreeable or a disagreeable attitude towards the objects investigated (Cooper and Schindler 2014). For some statements, the respondents were asked to indicate their degree of agreement by choosing between ranges of "strongly disagree" to "strongly agree".

The self-administered questionnaires were hand delivered, and some were e-mailed to 179 organisations located in the study area. The questionnaires were addressed to the Information Technology Manager or the Operations Manager in each organisation. The rationale behind selecting these personnel is that they were more familiar with the electronic and/or electrical equipment in the organisation. The contact details of these managers were obtained from the official directory of the Umbogintwini Industrial Complex and Southgate Business Park (Annexure A and B, respectively).

3.7 Reliability and validity

According to Greenwood and Levin (2011), reliability and validity in research function is the researcher's shield. The primary concern of the researcher was that the findings of this study should be reliable and valid. Welman, Kruger and Mitchell (2010) emphasise that in determining whether the research findings are reliable, the researcher should be able to answer the following question: "Will the evidence and conclusions stand up to close scrutiny?" A further point on reliability is that if anyone else were to repeat the research, he or she should be able to obtain the same results as those obtained originally. Greenwood and Levin (2011) also state that reliability must have the arguments and processes necessary for someone to trust the research results.

The reliability of the research instrument was checked by assessing inter-item consistency with the use of appropriate descriptive tests, including the calculation of the mean, medians, modes and standard deviations and the appropriate inferential tests including the appropriate correlation testing. This ensured a high degree of reliability of the data collected through the questionnaire.

Saunders, Lewis and Thornhill (2012) define validity as the extent to which the data collection method and/or related methodologies accurately measure what they intended to measure. To ensure validity, the researcher adhered to the following recommendations which were proposed by Welman, Kruger and Mitchell (2010):

- prepare a well-designed research instrument so that it fully addressed the research objectives of the study;
- check internal validity against the related literature reviewed for the study and ensure that the research instrument adequately covers the topic;
- undertake a pilot test to help eliminate errors or ambiguity;
- ensure as large a response as possible is achieved from the study area, and
- do not engage in inaccurate or misleading measurement practices.

3.8 Pilot study

According to Caspar, Peytcheva and Cibelli (2011), some form of testing must occur before data collection begins and this can involve a variety of activities designed to evaluate a questionnaire’s capacity to collect the desired data, the capabilities of the selected mode of data collection, and the overall adequacy of the survey to meet the objectives of the study. A pilot test of the measuring instrument was undertaken to assist in detecting ambiguous questions, assess the time taken to fill in the questionnaire and determine if it was aligned to the objectives of the study. Rothgeb (n.d.) refers to pilot studies as "dress rehearsals" and as one of the most critical aspects of a successful survey operation, which ultimately results in good survey data.

An important goal of the pilot study was to ensure that data collected from the respondents can be statistically analysed and that logical conclusions can be obtained from the processed data. The pilot study was conducted among ten randomly selected organisations within the study area, and based on the feedback, a few questions were rephrased, and two questions were omitted as they were considered as not being directly relevant to the study.

3.9 Analysis of data

Bryman (2012) states that data analysis is fundamentally about data reduction and is concerned with reducing the large volume of information that the researcher has gathered so that he or she can make sense of it. The completed questionnaires were sorted, codified according to pre-determined values, and the raw data captured on a Microsoft Excel Spreadsheet thereafter is was input into the Statistical Program for Social Sciences (SPSS) version 21.0.

In this study, both descriptive and inferential statistical analyses were used. The descriptive statistics were used in the organising, summarising and defining the quantitative data that was collected via the structured questionnaire. According to Laerd Statistics (2013), descriptive statistics are used to summarize groups of data using a combination of:

- tabulated description (frequency and percentages tables);
- graphical description (line graphs, pie charts and bar charts), and
- statistical commentary (a discussion of the results).

Inferential statistical analysis was concerned with the calculation of potential e-waste volumes for the entire study area as well as for the period of five years. Inferential statistics techniques allowed the researcher to use the data from the sample of organisations to make generalizations about the population of the study area. It was, therefore, important that the sample accurately represented the population within the study area (Laerd Statistics 2013). The researcher was aware that inferential statistics arise out of a sample and was not expected to perfectly represent the population.

The analysis looked at frequencies, for example, the number of times a certain response was made, and then this was summated. To assist with the analysis, the researcher codified the variables by grouping and assigning numeric values to each particular question so that the data could be thematically synthesised according to its strength of effect (Joanna Briggs Institute 2014). For quantitative studies, the researcher produced tables or averages by grouping textual material into categories or themes (Bryman 2012). With the assistance of SPSS computer software and Microsoft Excel, the mode, median, mean, standard deviation, confidence intervals and Chi-squared test values were calculated (Welman, Kruger and Mitchell 2010).

The codified data was also analysed by calculating the correlations of the data collected. Saunders, Lewis and Thornhill (2012) describe correlation as a statistical technique that can show whether, and how strongly, pairs of variables are related. For example, in this study, correlation was used to measure the relationship between the purchase of new computers, and the disposal of old computers.

The Kolmogorov Smirnov test was used to determine whether distributions were normally distributed. Since all of the *p*-values were less than the level of significance of 0.05, it implied that the distributions were skewed (Annexure L). Hence, non-parametric tests were used, such as the Wilcoxon test (Annexure K)

(Black 2010). The Spearman's rank correlation coefficient (r_s-value) was used to determine the relationships between the variables within the data sets (Annexure M); and a positive value (r_s-value) indicated a directly proportional relationship between the variables, and a negative value (r_s-value) indicated an inverse relationship between the different types of variables within the paired data sets. Chapter 4, Section 4.3 explains the correlation between the variables.

3.10 Letter of information and consent

An introductory letter was sent out to organisations within the study area outlining the study and seeking their informed consent to participate in the study (Annexure D). The letter of information and consent gave the potential respondents an opportunity to ask questions about the study and make a decision to participate in the research. The researcher also assured potential respondents that their identities, as well as the identity of their organisations would remain confidential.

The letters of information and consent were accompanied by letters from the management of both the Umbogintwini Industrial Complex and Southgate Business Park, granting permission to carry out the study (Annexures E and F, respectively),

3.11 Maintaining ethics during research

According to Bryman (2012), ethical issues during research cannot be ignored as they relate directly to the integrity of the research, and that ethical issues are central to discussions about research than ever before. This was further confirmed by Hesse-Biber and Leavy (2011) who advocate that the moral integrity of the researcher is a critically important aspect of ensuring that the research process and the researcher's findings are trustworthy and valid.

For this study, the researcher ensured that ethical integrity was maintained by:

- sending a letter of consent to the respondents;
- not invading the privacy of the respondents;

- not engaging in any deceptive means to gather data from the participants;
- acknowledging all references used in the study;
- ensured that the respondents were treated with respect and courtesy during the research process, and
- assured the respondents that information collected was confidential and for ethical use only, and that the respondents can withdrawn at any time from the survey.

3.12 Conclusion

This chapter discussed the salient aspects pertaining to the research methodology and design adopted for this study.

In the next chapter the results of the survey are presented, analysed and discussed.

CHAPTER 4

PRESENTATION, ANALYSIS AND DISCUSSION OF RESULTS

4.1 Introduction

This chapter presents, analyses and discusses the results of the study. The results are presented using descriptive statistics in the form of graphs, tables and charts for the quantitative data collected via the responses from the questionnaire. Using a variety of appropriate statistical tests, the data emanating from the survey is analysed and interpreted, with a view to identifying important patterns and relationships.

4.2 The response rate

The researcher distributed 179 questionnaires to organisations in the study area and 78 fully completed questionnaires were returned, representing a response rate of 43.57%. The response rate was adequate to draw meaningful inferences, and was higher than the response rate to a similar e-waste study conducted in Windsor, United States of America, where the response rate of 31.3%, from a sample size of 230 (organisations), was deemed acceptable to draw meaningful conclusions (Coalition for American Electronics Recycling 2013).

The findings from the empirical research are presented, analysed and discussed below, in the sequence of the questions in the research instrument.

4.3. SECTION A: QUANTIFYING THE VOLUME OF E-WASTE GENERATED IN THE STUDY AREA

Section A discusses the type of organisations within the study area and the number of electronic devices that were in use or were obsolete/redundant. The purpose of collecting this data was to calculate the current and potential e-waste volumes generated by the target population and then determine its possible environmental and economic impact within the study area.

In comparing electronic devices that were in use against obsolete/redundant devices stored by organisations within the study area, the level of significance was measured at a 95% confidence interval. Since the data collected from the waste of electrical and electronic equipment (WEEE) are not distributed equally, non-parametric tests, such as the Wilcoxon test (*p*-value), were used to compare sets of data (Annexure K). The tolerance level of error, or the level of significance or *p*-value, was 5%, and represented an acceptable parameter value for the analyses.

In terms of correlation, the bivariate correlation known as Spearman's rho (r_s-value) was also performed on the (ordinal) data to measure the relationship between selected variables (Annexure M). If the correlation coefficient (r_s-value) resulted in a positive value, then it indicated a directly proportional relationship between the variables; and a negative r_s-value indicated an inverse relationship. If the r_s-value was between 0.10 and 0.29, or between -0.10 and -0.29, then it indicated a weak correlation; if it was between 0.30 and 0.49, or between -0.30 and -0.49, then it indicated a moderate correlation, and if the r_s-value fell between 0.50 and 1.0, or between -0.50 and -1.0, it indicated a strong correlation (Black 2010).

4.3.1 Business categories to which organisations in the study area belonged

Table 4.1 below reflects the most common categories to which organisations in the study area belonged. Apart from the unnamed categories within "Other", the largest number of respondents (12.8%) from the study area were from the chemicals, rubber or plastic products industry, followed by construction and building materials suppliers (10.3%), and electronic and electrical equipment manufacturers and suppliers (9%).

Table 4.1: Business catogories to which organisations belonged

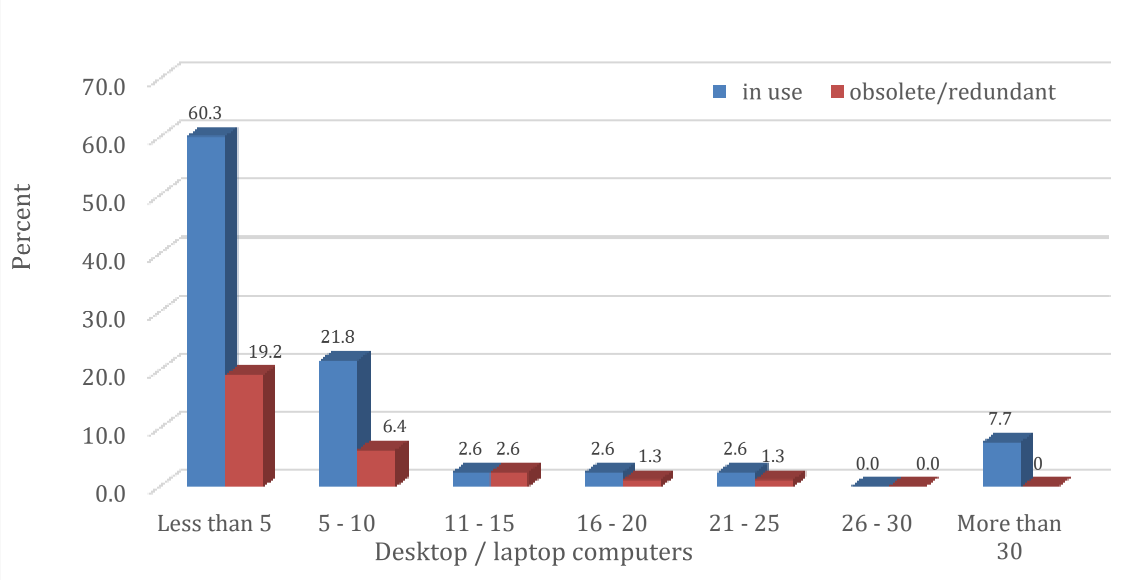
Category of business	Frequency	Percent
Chemicals, rubber or plastic products	10	12.8%
Construction & building materials	8	10.3%
Electronic & electrical equipment	7	9.0%
Engineering	5	6.4%
Transport, communication & storage	4	5.1%
Health services	4	5.1%
Food producers & processors	3	3.8%
Financing, insurance, real estate & business services	2	2.6%
Clothing, footwear, and textiles	2	2.6%
Paper, printing & publishing	2	2.6%
Retail trade	2	2.6%
Educational services	1	1.3%
Leisure, hotels & catering services	1	1.3%
Wholesale trade	1	1.3%
Other	26	33.2%
Total	**78**	**100.0%**

The "Other" category consisted primarily of recruitment, cleaning and administration companies. As can be ascertained from the Table above, the range of businesses located at the study site are diverse.

4.3.2 Quantity of e-waste generated from desktop/laptop computers in the study area

The quantity of e-waste generated and its impact was measured by determining the number of operational and obsolete/redundant electronic devices within the study area. Figure 4.1 below reflects the frequency and dispersion of responses with respect to the number of desktop/laptop computers that were in use and those that were obsolete/redundant and were being stored on the company premises.

Figure 4.1: Desktop/laptop computers in study area



Most respondents indicated that the average numbers of desktop/laptop computers was less than 5 (60.3%), with approximately one-fifth (21.8%) stating that the number of desktop/laptop computers was between 5 and 10.

In terms of correlations, the Spearman's rho (r_s-value) value between the number of desktop/laptop computers that were in use versus the number of desktop/laptop computers that were obsolete/redundant was 0.506 (Annexure M). This indicated a strong directly proportional relationship between these two variables. This implied that the greater the number of working computers in an organisation, the greater the number of obsolete/redundant computers, and vice versa. This positive correlation implies that when organisations purchase new computers, they do not necessarily trade-in or dispose of their old computers.

The following formula, developed by Robinson (2009), was used to estimate the volumes of e-waste generated from electrical and electronic equipment in the study area:

$$E = \frac{MN}{L}$$

Where E represents the contribution of an item to the annual E-waste volume (kg/year); M represents the mass of the item (in kg); N represents the number of units in service (and obsolete), and L represents the average lifespan (in years) of the item.

Using the above formula, calculations for the entire study were undertaken to determine the total quantity of e-waste generated from desktop/laptop computers. This was computed using the actual numbers of companies that were surveyed and projecting it for the entire study area. The total estimated quantity of e-waste was calculated by multiplying the average weight of a computer (kg), which according to Table 2.1, was 25kg, by the number of companies, and the median of each group (i.e. less than 5; 5 – 10; 11 – 15; 16 – 20; 21 – 25; 26 – 30; more than 30).

Table 4.2: Potential quantity of e-waste generated from desktop/laptop computers

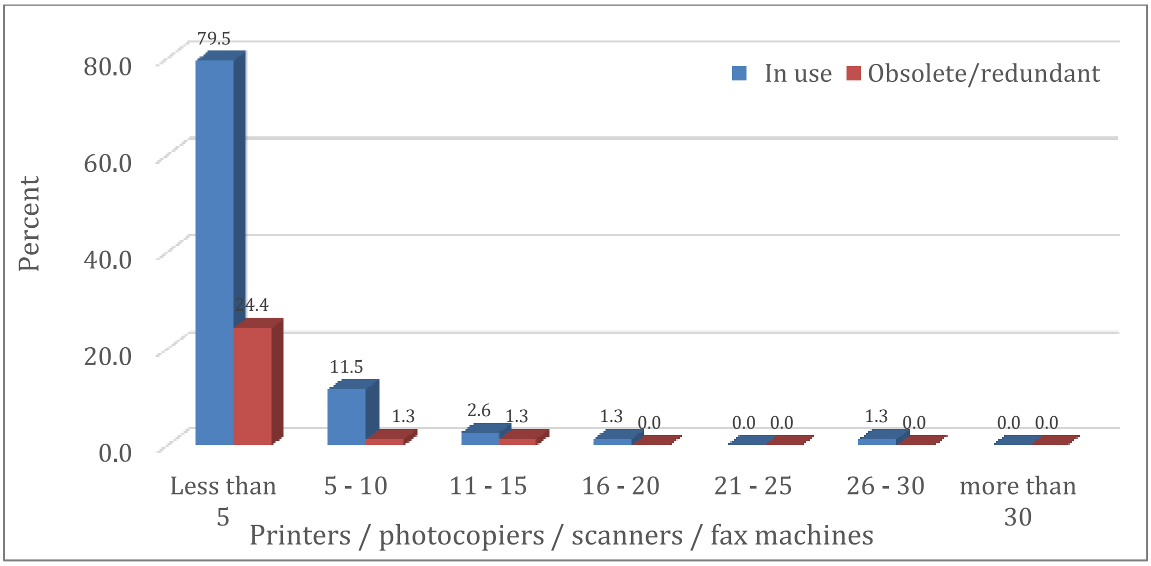
Status of desktop/laptop computers	Weight in kg
In use	54 975.64
Obsolete/redundant	14 747.12
Total	69 722.76
Annual contribution to e-waste	23 240.92

On the assumption that the average life span of a desktop computer is 3 years (Table 2.1), the annual contribution to the e-waste volume was calculated to be approximately 23 240 kg (refer to Annexure J: Tables J1 and J2).

4.3.3 Quantity of e-waste generated from printers, photocopiers, scanners and facsimile machines

The number of printers/photocopiers/scanners/fax machines that were in use and the the number that were obsolete/redundant within the study area are shown in Figure 4.2. Printers/photocopiers/scanners/fax machines are usually shared among many users within a work environment; hence, the majority of the respondents (79.5%) indicated that the number of printers/ photocopiers/scanners/fax machines in use was less than five units.

Figure 4.2: Printers/photocopiers/scanners/fax machines in the study area



The calculated Wilcoxon *p*-value of 0.114 (Annexure K) was greater than the level of significance at 0.05 and indicated no significance. This implied that there was no correlation between the number of printers/photocopiers/scanners/fax machines that were in use and the number of obsolete/redundant printers/photocopiers/scanners/fax machines that were stored on the company premises.

According to Priyadharshini, Haganesh and Meenambal (2012) the increased use of printers is a serious concern, as they are difficult to recycle because of their toxic composition. The same concern can be raised in the study area if the e-waste from the printers is not recycled in an environmentally sustainable manner. The data set from Figure 4.2 was used to calculate the quantity of e-waste that was generated annually from printers/photocopiers/scanners/fax machines within the study area.

The total estimated quantity of e-waste from printers/photocopiers/scanners/fax machines was calculated using the actual numbers of companies that were surveyed and projecting it for the entire study area. The total estimated quantity of e-waste (Table 4.3) was calculated by multiplying the average weight of a printer//photocopier (kg), which according to Table 2.1 was 60kg, by the number of companies and the median of each group (i.e. less than 5; 5 – 10; 11 – 15; 16 – 20; 21 – 25; 26 – 30; more than 30).

Table 4.3: Potential quantity of e-waste from printers, photocopiers, scanners and facsimile machines

Status of printers/photocopiers/ scanners/fax machines	Weight in kg
In use	77 286.92
Obsolete/redundant	18 539.23
Total	95 826.15
Annual contribution of e-waste	11 978.27

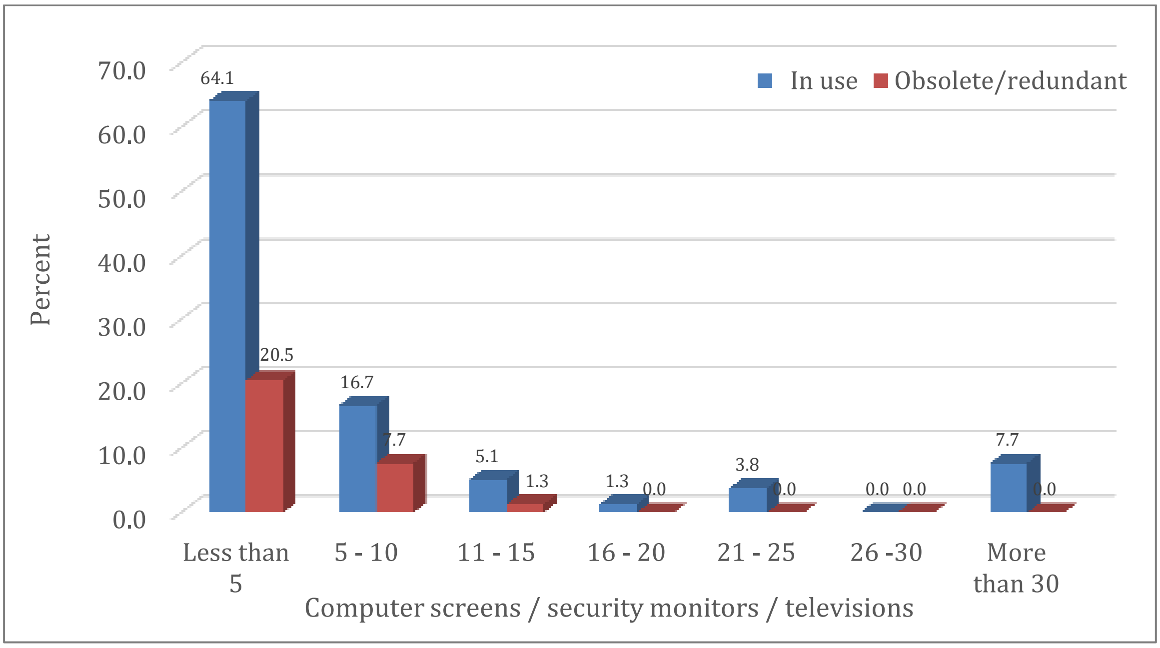
It was estimated that the life span of printers/photocopiers/scanners/fax machines was 8 years (Table 2.1). Hence, the annual contribution to the e-waste volume from printers/photocopiers/scanners/fax machines in the study area was calculated to be approximately 11,978 kg (refer to Annexure J: Tables J3 and J4 for details).

The high concentration of businesses within the study area results in relatively large volumes of e-waste being generated from printers and photocopiers; hence, a need for specialised e-waste recycling services to handle the discarded toner cartridges was identified.

4.3.4 Quantity of e-waste generated from computer screens, security monitors and televisions

The frequency and dispersion of responses pertaining to the number of computer screens/security monitors/televisions in use and the number that were obsolete/redundant is represented in Figure 4.3 below.

Figure 4.3: Computer screens/security monitors/televisions in the study area



The collected data indicates that the majority of the respondents (64.1%) had less than five computer screens/security monitors in their organisation (Figure 4.3). The calculated Wilcoxon *p*-value of 0.015 (Annexure K), which was less than the level of significance at 0.05, implies that, statistically, there was strong evidence that there were fewer obsolete/redundant screens/security monitors/televisions than working screens/security monitors/televisions within the study area.

Some of the screens/security monitors/televisions in the study area are in operation continuously as they monitor security; are recording or displaying various industrial processes that are on-going within the factories. As a result of their continuous operation, their life expectancy may be reduced; hence, screens/security monitors/televisions within the study area become obsolete at a rapid pace. The analysis revealed a correlation (r_s-value) of 0.904 (Annexure M) between the number of screens/security monitors/televisions in organisations that were in use and the number of computer screens/security monitors/televisions that were obsolete/redundant. This was directly related proportionality and implied that the greater the number of broken screens/security monitors/televisions in the organisation, the greater the number of working screens/security monitors/televisions as well.

The data shown in Figure 4.3 was used to calculate the quantity of potential e-waste that was generated annually from screens/security monitors/televisions, which have an average life span of five years. The total estimated quantity of e-waste from screens/security monitors/televisions was calculated using the actual numbers of companies that were surveyed and projecting it for the entire study area. The total estimated quantity of e-waste (Table 4.4) was calculated by multiplying the average weight of a screen/security monitor/television (kg), which according to Table 2.1 was 30kg, by the number of companies and the median of each group (i.e. less than 5; 5 – 10; 11 – 15; 16 – 20; 21 – 25; 26 – 30; more than 30).

Table 4.4: Potential quantity of e-waste from computer screens, security monitors and televisions

Status of screens/security monitors/televisions	Weight in kg
In use	68 137.69
Obsolete/redundant	12 399.62
Total	80 537.31
Annual contribution of e-waste	16 107.46

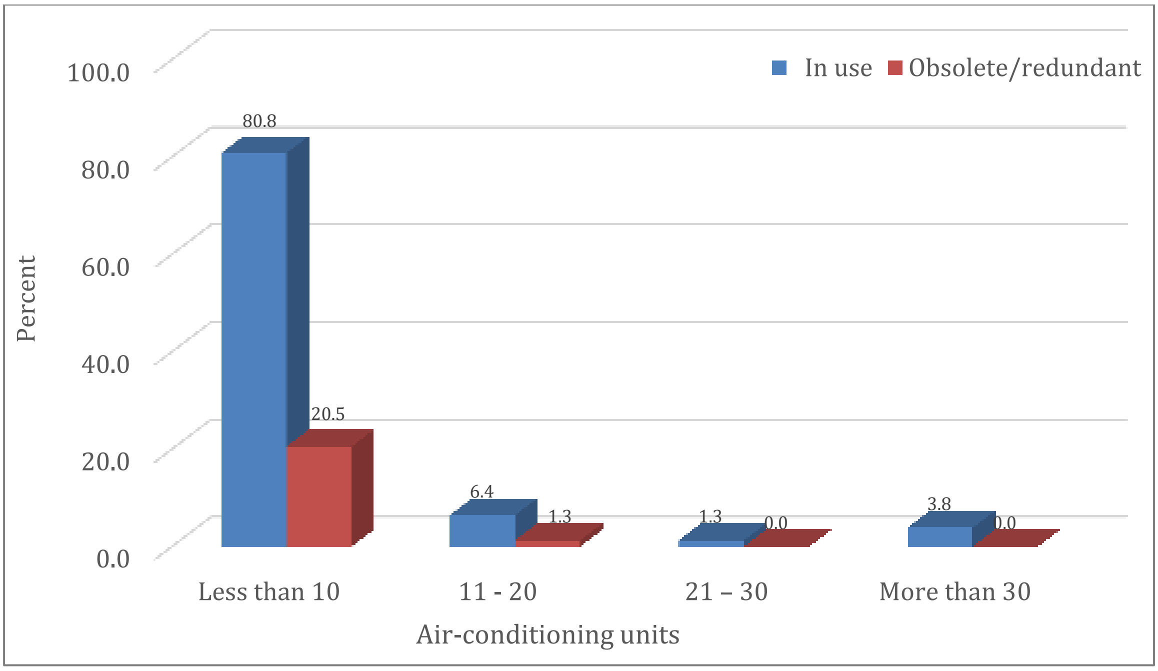
The total potential e-waste generated from screens/security monitors/televisions was approximately 80 537 kg (refer to Annexure J: Tables J5 and J6). As the average life span of screens/security monitors/televisions was estimated to be five years (Table 2.1), the annual contribution to the e-waste volume was calculated to be approximately 16 107 kg.

In the absence of proper recycling solutions, a high risk of mercury emissions from obsolete/redundant computer screens exist (Huisman, Magalini, Kuehr and Maurer 2008); therefore, organisations within the study area should ensure that the collection and recycling of obsolete/redundant computer screens is responsibly managed in order to prevent the negative environmental impact of mercury emissions.

4.3.5 Quantity of e-waste generated from air-conditioning units

The frequency and dispersion of responses pertaining to the number of air-conditioning units that were in operation and number that were obsolete/redundant, and were being stored on site is reflected in Figure 4.4. The majority of the respondents (80.8%) had less than 10 air-conditioning units in operation, and approximately 21% of the respondents stored obsolete/redundant airconditioning units on their premises.

Figure 4.4: Air-conditioning units with the study area



The quantity of potential e-waste (Table 4.5) from the working air-conditioning units as well as obsolete air-conditioning units was computed by multiplying the average weight of an air-conditioner (kg), which according to Table 2.1 was 55kg, by the number of companies and the median of each group (i.e. less than 10; 11

– 20;21 – 30; more than 30). The calculation of the total potential e-waste that will be generated from air-conditioning units is shown in Annexure J: Table J7 and Table J8.

Table 4.5: Potential quantity of e-waste from air-conditioning units

Status of air-conditioning units	Weight in kg
In use	112 118.21
Obsolete/redundant	20 966.99
Total	133 085.19
Annual contribution of e-waste	11 090.43

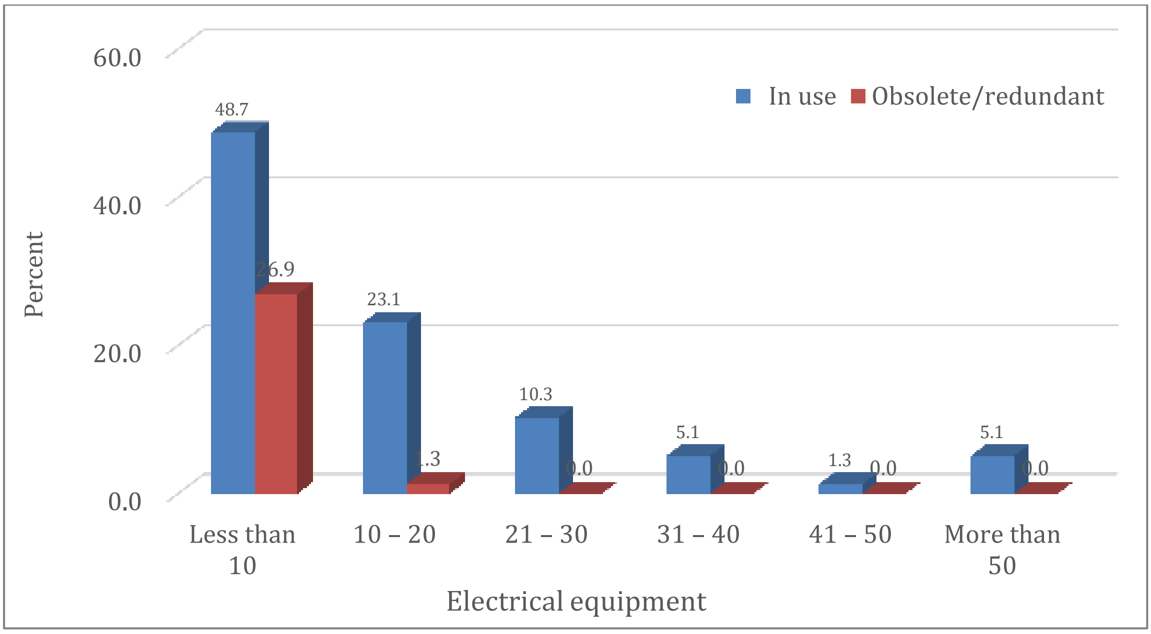
As the average life span of an air-conditioning unit was estimated to be 12 years (Table 2.1), the annual contribution to the e-waste volume was calculated to be approximately 11 090 kg.

The ozone depleting substances in air-conditioners, such as chlorofluorocarbon (CFC) and hydro chlorofluorocarbon (HCFC), have a very high global warming potential (United Nations 2009); hence, effective recycling of obsolete/redundant air-conditioner units within the study area will minimise their negative impact on the environment.

4.3.6 Quantity of e-waste generated from electrical industrial equipment

Figure 4.5 below displays the frequency and dispersion of responses with regard to electrical industrial equipment that was in use and those that were obsolete/redundant.

Figure 4.5: Electrical industrial equipment in the study area



According to the data presented in Figure 4.5, 48.7% of the respondents had less than 10 pieces of functional electrical industrial equipment in their organisation. The calculated Wilcoxon *p*-value of 0.001 (Annexure K) was less than the level of significance at 0.05, implying that statistically there was strong evidence that in the study area there were fewer obsolete/redundant electrical industrial equipment than functioning electrical industrial equipment.

The low quantity of obsolete/redundant electrical industrial equipment is the result of organisations constantly repairing or replacing defective electrical equipment to maintain the continuous manufacturing cycle. This was evident when the majority of the respondents (56.6%), as shown in Figure 4.8, indicated that they would replace their electrical equipment if it cannot be repaired. The market-related cost of rental space is also a motivating factor for organisations to dispose of obsolete/redundant electrical industrial equipment, instead of storing it within their premises.

A variety of electrical industrial equipment of varying sizes and different weights was used within the study area. Therefore, for the purpose of calculating the potential quantity of e-waste generated from electrical industrial equipment, a conservative weight of 60kg (the weight of two electronic ARC Welding Machines weighing 30 kg each) was selected (Ardent Engineers 2014). The potential quantity of e-waste generated is reflected in Table 4.6 below.

Table 4.6: Potential quantity of e-waste generated from electrical industrial equipment

Status of electrical industrial equipment	Weight in kg
In use	252 566.92
Obsolete/redundant	28 892.31
Total	281 459.23
Annual contribution of e-waste	56 291.85

The average life span of industrial electrical equipment is assumed to be five years. Hence, the annual contribution to the e-waste volume was calculated to be approximately 56 291 kg (refer to Annexure J: Tables J9 and J10).

The study area is an industrial site that generates hazardous chemicals, effluent waste and other hazardous waste, and one of its solid hazardous waste is industrial e-waste. The South African National Waste Management Strategy (South Africa 2011) cautioned that the increasing complexity of industrial waste management is compounded by the fact that hazardous waste mixes with general waste. Therefore, this industrial area needs to have clear procedures to handle the large volume of industrial waste from electrical and electronic equipment (WEEE).

4.3.7 The total quantity of e-waste generated by organisations within the study area

A summation of all the categories of potential e-waste generated within the study area is reflected in Table 4.7 below.

Table 4.7: Potential quantity of e-waste that will be generated by organisations in the study area over the next five years

Sources of e-waste	In use (kg)	Obsolete/ redundant (kg)	Total weight (kg)	Average life-span of devices (years)	Volume of e-waste generated per year (kg)	Amount of e-waste generated over 5 years(kg)
Desktop/laptop computers	54 975.64	14 747.12	69 722.76	3	23 240.92	116 204.59
Printers/photocopiers/scanners/ fax machines	77 286.92	18 539.23	95 826.15	8	11 978.27	59 891.35
Computer screens/security monitors/televisions	68 137.69	12 399.62	80 537.31	5	16 107.46	80 537.31
Air-conditioning units	12 118.21	20 966.99	133 085.19	12	11 090.43	55 452.16
Electrical Industrial equipment	252 566.92	28 892.31	281 459.23	5	56 291.85	281 459.23
TOTAL			**60 630.64**		**118 708.93**	**593 544.64**

As the study area is an industrial and manufacturing site, the greatest amount of potential e-waste generated was from electrical industrial equipment. However, given the indispensable role of computers, even in the industrial sector, computers and its peripherals (screens, cables, and keyboards) will generate a significant amount of e-waste, as reflected in Table 4.7 above.

During the next five years (2015–2020), organisations located within the Umbogintwini Industrial Complex and Southgate Business Park will generate approximately 593.5 tons of potential e-waste. This is approximately 1.07 tons of e-waste per hectare within the study area. KwaZulu-Natal is a developing province, and has a number of industrial parks in various district municipalities as listed in Table 4.8 below.

Table 4.8: Industrial Parks in KwaZulu-Natal

Name of Industrial Park	Approximate size in hectares
Umbogintwini Industrial Park	350
Southgate Manufacturing Park	200
Phoenix Industrial Park	230
Cato Ridge Industrial zone	120
Kuleka Industrial Park	200
Hammersdale Industrial Park	161
Isithebe Industrial Park	364
Pinetown/New Germany Industrial	496
Newcastle Industrial Zone	320
Westmead Industrial Park	655
TOTAL	**3 096**

Source: KZN Department of Economic Development, Tourism and Environmental Affairs (2012:18)

Using the potential volume of e-waste generated per hectare in the study area, and extrapolating it to KwaZulu-Natal's industrial parks, revealed that the province has the potential to generate a substantial volume of e-waste at its various industrial parks. Using the total number of hectares of industrial park space in KwaZulu-Natal (Table 4.8), over the next five years, the potential volume of e-waste that can be generated by the province's industrial parks is approximately 3 341 tons.

One of the purposes of calculating the total quantity of e-waste generated within the Umbogintwini Industrial Complex and the adjacent Southgate Business Park was to assess its economic benefit if recycled within the study area, and this is discussed in the next section.

4.3.8 The potential economic benefit of recycling e-waste generated within the study area

In determining the potential economic benefit of recycling the e-waste within the study area, the researcher assessed the benefits in terms of job creation; generating revenue from the sale of recycled e-waste components, and the sale of carbon credits. The economic benefits were calculated for a period of five years, as many of the current electronic devices in use would either become obsolete or malfunction during this period.

Whilst e-waste has various negative impacts, as discussed in Chapter 2, responsible management of e-waste within the study area can ensure that its negative environmental impacts are minimised, and its economic benefits are maximised. When interviewed on the 18 February 2015, Combrinck (e-waste recycling company manager) stated that his company's average revenue from the sale of processed e-waste was approximately R4 000 per ton. Using this value of e-waste per ton, one can deduce that over the five year period, approximately R 2 374 160 can be earned from the sale of recycled plastics and precious metals like gold, copper, lead, silver and other processed e-waste from the study area.

At the time of the study, there was no e-waste recycling plant within the study area, and organisations within the study area were paying a service provider to dispose of their e-waste. In terms of e-waste disposal costs, an e-waste recycler quoted R2 500 per ton to transport e-waste to a hazardous waste facility and recycle it (Multi Taskers 2014). The additional costs that organisations will incur for disposal of the projected 593.54 tons of e-waste over a five years period would be in excess of R1 483 861, as the costs usually escalate every year. An e-waste facility, if established within the study area, will assist organisations save on disposal costs as the e-waste recycler within the study area would pick up the e-waste at no cost to the organisations.

In terms of storage space that the potential e-waste will require, the storage capacity of a 20-foot steel container was used as a space measurement unit since e-waste was exported via this type of steel containers. A standard 20-foot steel container can hold a net load of 28.2 tons of goods, which excludes the weight of the container (Wikipedia 2014). Therefore, it would take approximately 21 steel containers to store 593.54 tons of potential e-waste.

Using the total length and breadth of a 20-foot steel container, the maximum land surface area that will be taken up will be approximately 21 x 6.05m x 2.43m = 308.732m^2. Using the market-related rental cost of R12 p/m^2 for industrial land within the study area (Tsouros 2014), the projected costs of leasing the land to store this e-waste for the next five years, if not disposed of appropriately, will be approximately R222 287. This cost can be minimized if the containers on site were stacked. The leasing cost for the five year period would usually escalate every year.

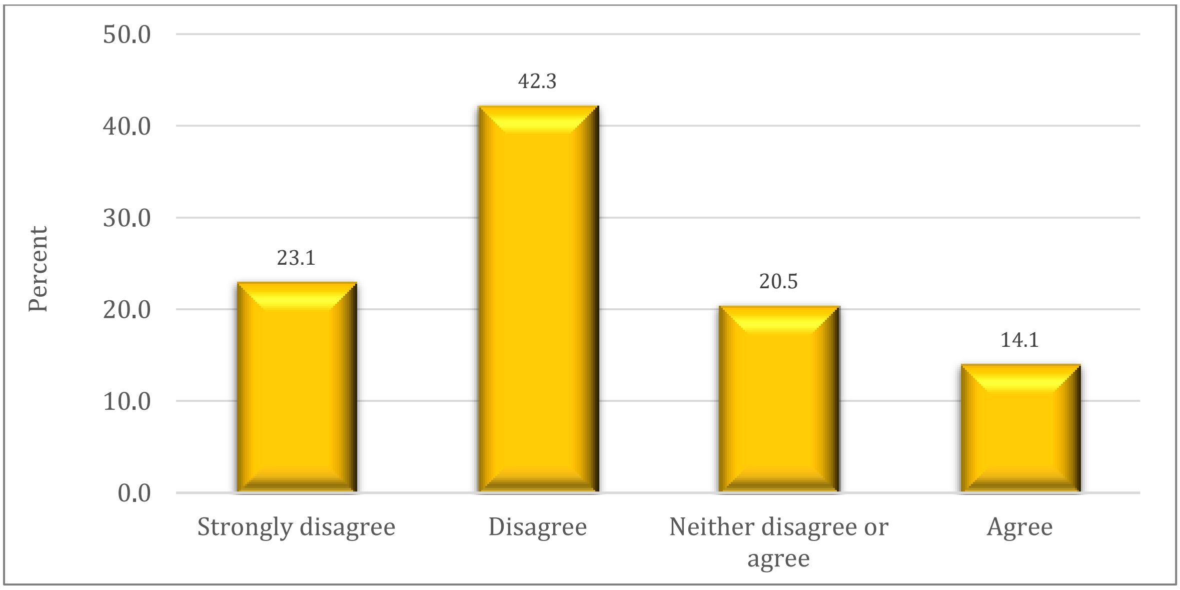
Another economic benefit of recycling this e-waste will be in the form of job creation and protecting the environment. E-waste management has the potential to create jobs at various points in the e-waste value chain, from collectors, to transporters and the people that work within the recycling plant. According to USE-IT (2014), an e-waste recycling company in KwaZulu-Natal, in 1 year approximately 12 jobs were created by processing 28.5 tons of e-waste at their recycling plant. For the study area, projected calculations show that approximately 50 jobs can be created to process the e-waste in one year. This excludes the number of people who will be involved in collecting and transporting the e-waste to the processing plant from various other areas and organisations outside the study area.

Effective e-waste management within the study area will include the collection and recycling all electronic hazardous waste; hence, preventing it from entering landfill sites, thereby limiting toxic chemicals and emissions seeping into the natural environment. The recycling of e-waste will also minimise the carbon footprint of this industrial area. In Chapter 2, the harmful effects of e-waste and the toxic chemicals contained in them, as well as the carbon dioxide (CO_2) emissions released from discarded electronic devices were discussed. According to WorldLoop (2013), for every ton of e-waste collected and recycled 1.44 tons of CO_2 emissions are prevented from being released into the atmosphere. If all of the potential e-waste from the study area is recycled, approximately 854.69 tons of CO_2 emissions will be prevented from entering into the atmosphere. Companies are paying to offset their carbon footprint, with the average price being €7.76 per ton of CO_2 as at 19 July 2015 (Fusion Media Limited 2015). As at 19 July 2015, this was equivalent to R103.98 per ton of CO_2, at an exchange rate of €1 = R13.4 (South Africa Reserve Bank 2015). The revenue from carbon trading that e-waste recycling can generate during the five year period is estimated to be approximately R 89 000.

4.3.9 Perceptions regarding organisations' potential to generate a substantial volume of e-waste

As the Umbogintwini Industrial Complex and Southgate Business Park are densely populated manufacturing parks, the potential to generate waste from electrical and electronic equipment is great. However, when questioned if their organisations had the potential to generate large volumes of e-waste, the majority of the respondents either strongly disagreed (23.1%) or disagreed (42.3%) with this statement (Figure 4.6).

Figure 4.6: Perceptions regarding organisations' potential to generate a substantial volume of e-waste



Approximately 65% of the respondents expressed the viewpoint that their organisations did not generate substantial volumes of e-waste, while 14% of the respondents agreed with the statement that their organisations did have the potential to generate a substantial volume of e-waste. The high number of respondents who disagreed (65.4%) that their organisation generated a substantial volume of e-waste could be associated with this being an industrial park, and may also indicate a lack of awareness of what constitutes e-waste.

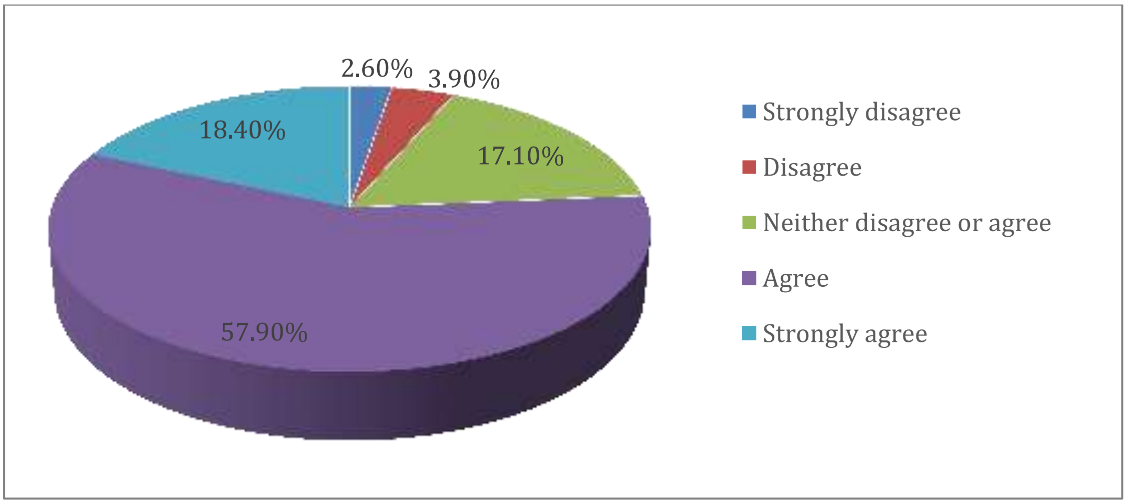
4.4. SECTION B: THE MANAGEMENT OF E-WASTE

Section B discusses the practices that organisations within the study area employed to manage their e-waste, and their exposure to e-waste recycling information.

4.4.1 Organisations' exposure to e-waste information in the study area

A summary of the responses to a 5-point Likert-scale question concerning the exposure of organisations within the study area to e-waste management information is presented in Figure 4.7. An analysis of the responses revealed that more than three-quarters (76.3%) of the respondents agreed or strongly agreed that limited information was available on e-waste management, while 6.5% disagreed or strongly disagreed, and approximately 17% neither agreed or disagreed with the statement that limited information was available on e-waste management.

Figure 4.7: Organisations' exposure to e-waste information in the study area



The above findings correlated with the findings of a similar study undertaken by Pinto (2008) in India where a majority of the respondents stated that there was a lack of information and clarity on e-waste management. In South Africa, an e-waste study conducted in the uMgungundlovu District, concluded that the lack of knowledge of e-waste management prevented viable recycling projects being conceptualized and implemented (eWASA 2008).

At the 2008 e-waste conference held in Durban (WasteCon2008), the lack of e-waste information was also identified as a concern. In an attempt to address this, the conference delegates proposed that e-waste awareness should be created at all levels of society, and information should be made available through appropriate channels like websites, training and e-waste awareness campaigns.

It can be deduced that the limited e-waste information available in the study area, will perpetuate the low levels of awareness of e-waste's hazardous nature and/or of the management of e-waste amongst the orgainsations in that area. This sentiment was shared by WorldLoop (2013), who stated that the lack of awareness and experience about e-waste can be the barrier to it being properly managed and in developing regional e-waste solutions to this dilemma.

4.4.2 Dealing with malfunctioning electronic equipment

In analysing the responses of organisations from the study area, it was observed that the organisations use different procedures or methods when electrical and electronic equipment malfunction.

Figure 4.8: Dealing with malfunctioning electronic equipment

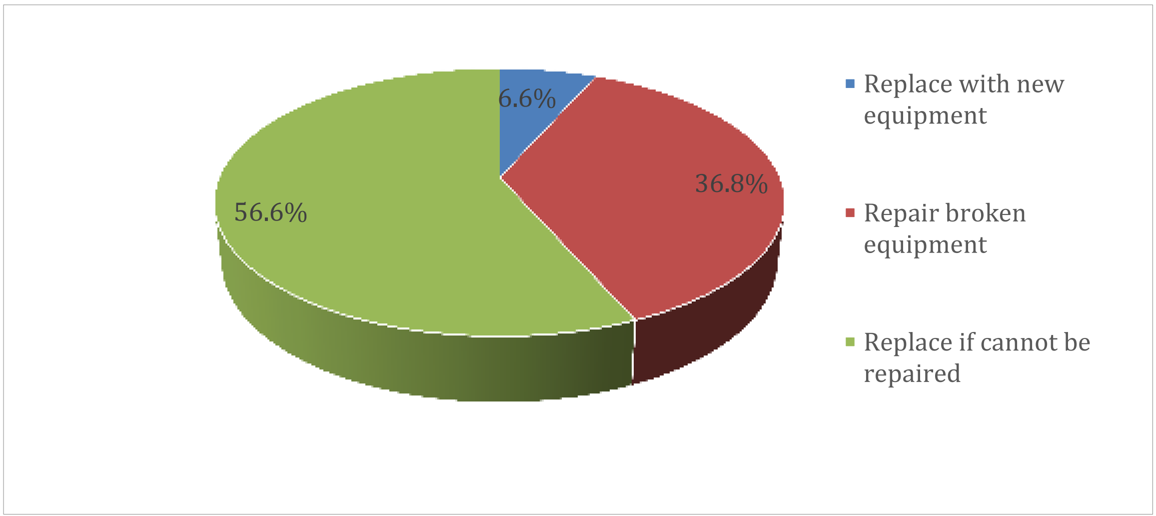
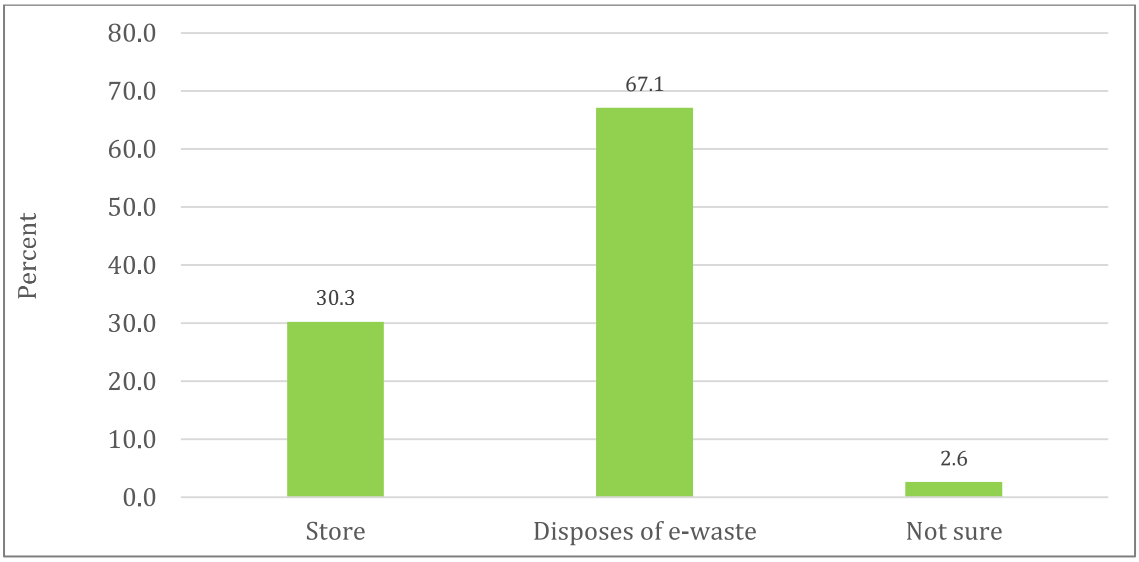


Figure 4.8 reveals that the majority of the respondents (93.4%) initially attempted to repair broken/malfunctioning electronic equipment, with 56.6% of the respondents replacing the equipment if it could not be repaired. As most electronic equipment is imported, and given the poor rand-dollar exchange rate, the primary consideration for most respondents opting to repair malfunctioning electronic equipment may be cost, and not because of their concern for the environment. (Chapter 2 highlighted the fact that repairing and re-use of electronic equipment was considered as one of the best forms of e-waste management, as it limits the volume of e-wase entering the waste stream).

4.4.3 Methods organisations use to manage their e-waste

One of the objectives of the study was to ascertain the methods organisations within the study area employed to manage their obsolete/redundant electronic equipment, and their responses are reflected in Figure 4.9 below.

Figure 4.9: Methods organisations use to manage their e-waste



As reflected in Figure 4.9 above, just over two-thirds (67.1%) of the respondents indicated that their organisations disposed of their obsolete/redundant equipment. However, 30.3% of the organisations indicated that they stored their obsolete/redundant electronic and electrical equipment on site, while a small percentage of respondents (2.6%) were not sure as to how their organisations handled obsolete/redundant equipment.

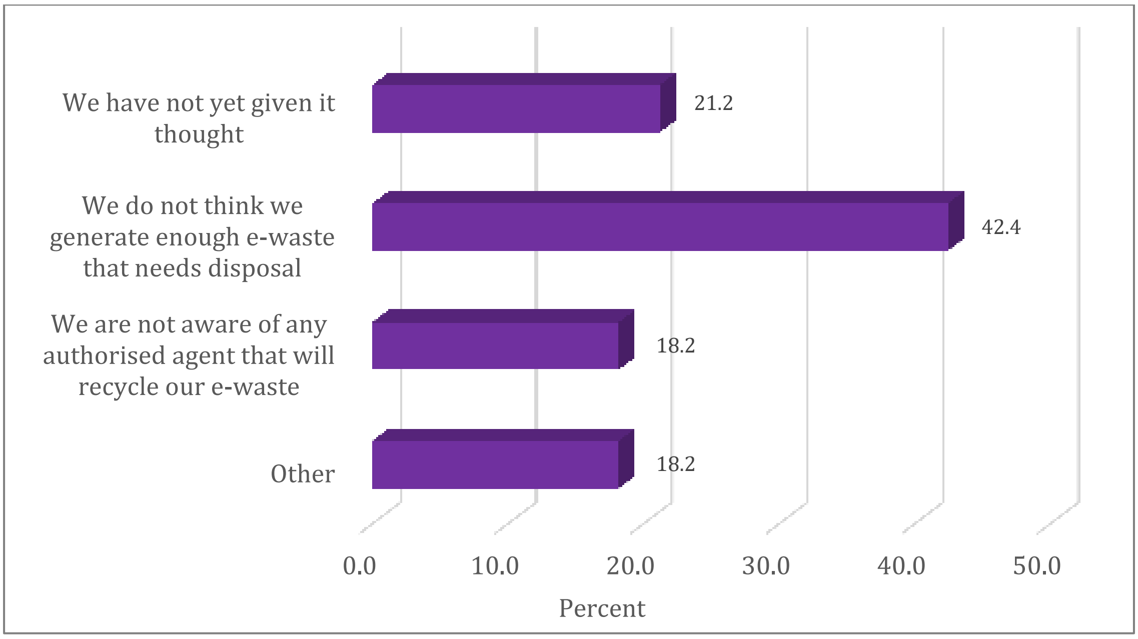
In terms of the core business activity of organisations within the study area and the method used to dispose of e-waste, the results of a Chi-square test (Annexure N) indicated that there was a significantly strong relationship between an organisation's core business activity and the method it employed to dispose of its e-waste.

The correlation value (r_s-value) between "Does your organisation currently store broken, obsolete/redundant electronic and electrical equipment?" and "To what extent do you agree or disagree with this statement: "our company has the potential to generate a large volume of e-waste"?" is -0.393 (Annexure M). This value was a moderate negative correlation and implied an inverse relationship. This means that organisations who are storing more obsolete/redundant electronic equipment are less likely to generate e-waste, as they are most likely to use them for spare parts.

4.4.4 Reasons for not recycling obsolete/redundant electronic equipment

Figure 4.10 below reflects the frequency of responses advanced by organisations within the study area for not disposing of their e-waste.

Figure 4.10: Reasons for not disposing obsolete/redundant electronic equipment

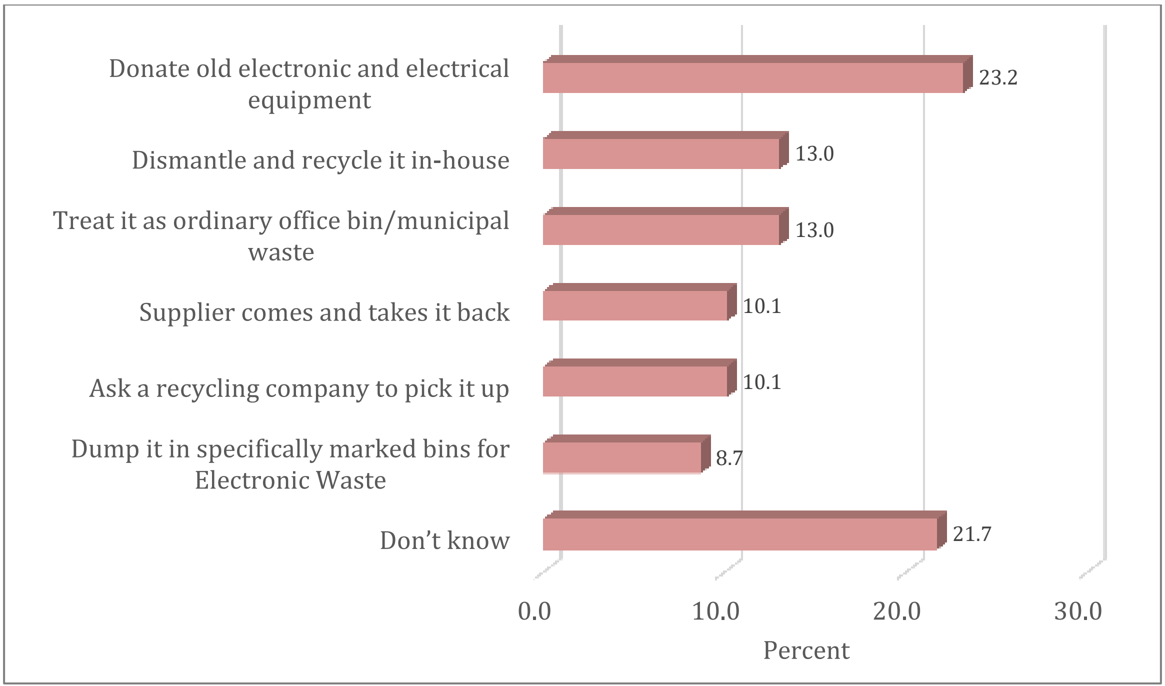


As depicted in the stacked horizontal bar garphs in Figure 4.10 above, of the organisations surveyed, 42.4% stated that they did not generate enough e-waste that needed recycling. This response correlated with the response to question seven of the survey, where the majority of the respondents (65.4%) indicated that their organisations did not have the potential to generate a large volume of e-waste. The second largest number of respondents (21.2%) stated that they had not thought about recycling their e-waste. This indicated that e-waste management, to some degree, was not a high priority activity within these organisations. This response correlates with the perceived lack of information regarding the hazardous nature of e-waste within the study area, and the importance of disposing e-waste in an environmentally responsible manner.

4.4.5 Methods used by organisations in the study area to dispose of their e-waste

A number of options were presented to respondents in respect of how their organisations disposed of their e-waste, and the frequency of the responses for each of these options is presented in Figure 4.11 below.

Figure 4.11: Methods employed by organisations to dispose of their e-waste



As illustrated in Figure 4.11 above, the largest percentage of respondents (23.2%) stated that they donated their old electrical equipment. Finlay and Liechti (2008), in their e-waste assessment of South Africa, also observed that donating obsolete/redundant electronic equipment was one of the most popular methods of disposing e-waste. Kalana (2010) in his study in Malaysia, also found that donating old electronic equipment was regarded as one of the best ways of getting rid of e-waste if there was no efficient recycling scheme for consumers. However, Lindgren, Morigiwa and Bengtsson (2010) contend that many companies tend to feel insecure about donating or reselling their computers, as they did not trust the procedures for deleting sensitive data. The authors cited a Swedish survey that found that although 90% of the companies were aware of the potential of re-use, approximately 65% elected to discard their old equipment instead of donating them, due to these concerns.

The second highest number of respondents (21.7%) indicated that they did not know how their companies disposed of their obsolete/redundant electronic equipment, while 13.0% of the respondents indicated that their companies dismantled or recycled obsolete/redundant electronic equipment in-house, or treated it as ordinary office bin/municipal waste. In a study undertaken in Beijing by Wang, Kuehr, Ahlquist and Li (2013), it was concluded that most organisations regarded their e-waste as ordinary office waste, and disposed it in the same manner as the office waste was disposed. The practice of treating e-waste as ordinary office bin/municipal waste is of concern because hazardous substances from e-waste at municipal dumps eventually leak out and contaminate the soil and the water table (Luther 2010).

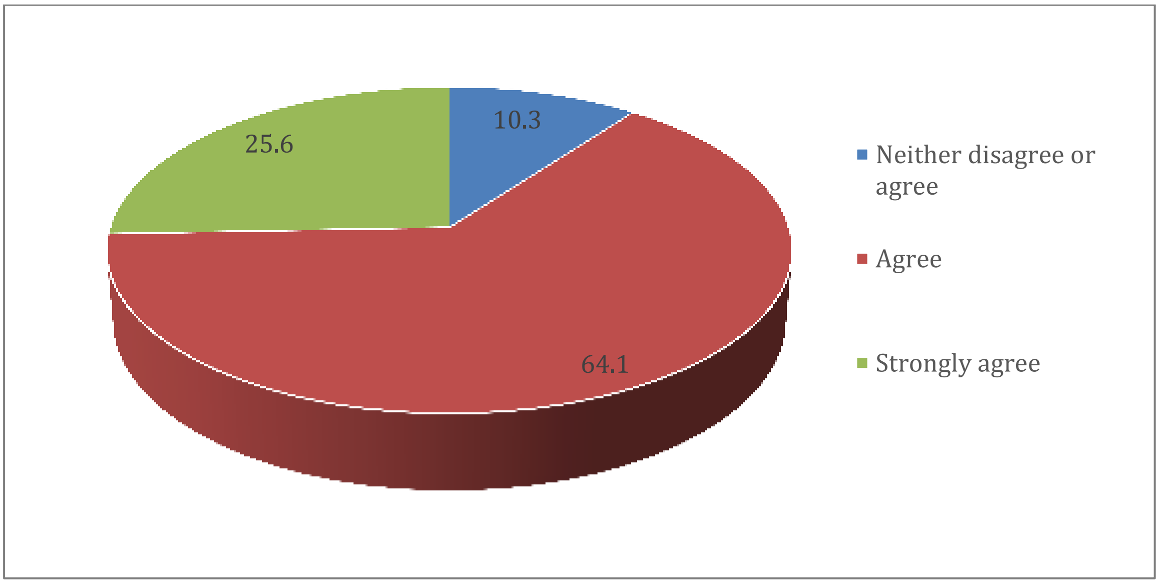
As reflected in Figure 4.11, there is no single method favoured by the organisations within the study area to dispose of their e-waste, and, in this regard, Mansfield (2013) states that the methods of managing obsolete/redundant electronic equipment are generally more complex than handling most other waste products because electronics contain many dangerous substances.

4.4.6 The importance of an e-waste management strategy

To gauge respondents' viewpoint within the study area regarding the importance of a strategy to manage e-waste, a Likert scale was used in the questionnaire. Figure 4.12 indicates that almost 90% of the respondents strongly agreed (64.1%) or agreed (25.6%) that it was important to have a strategy to manage e-waste.

The overwhelming support for an e-waste strategy for the study site, was a positive indicator, in that companies were willing to manage their e-waste in a responsible manner. This is in line with the policies of the South African Department of Environmental Affairs (2010) which advocates that organisations develop strategic waste management plans to be used internally or by external service providers.

Figure 4.12: Importance of an e-waste management strategy



Any future e-waste management strategy employed in the study area should be aligned to the Framework for the National Waste Management Strategy (2011) and The White Paper on Integrated Pollution and Waste Management (2000). These policy documents advocate a shift from the focus on waste disposal to integrated waste management and prevention as well as minimisation.

The correlation value between “total number of electrical equipment that are obsolete/redundant” and “to what extent do you agree or disagree with this statement: “it is important for organisations to have a strategy for the management of obsolete/redundant electronic and electrical equipment” was -0.436 (Annexure M). The negative r_s-value implied an inverse relationship, and indicated that the more obsolete/redundant electrical equipment that was stored at an organisation’s premises, the less likely they were to have a strategy for the management of e-waste.

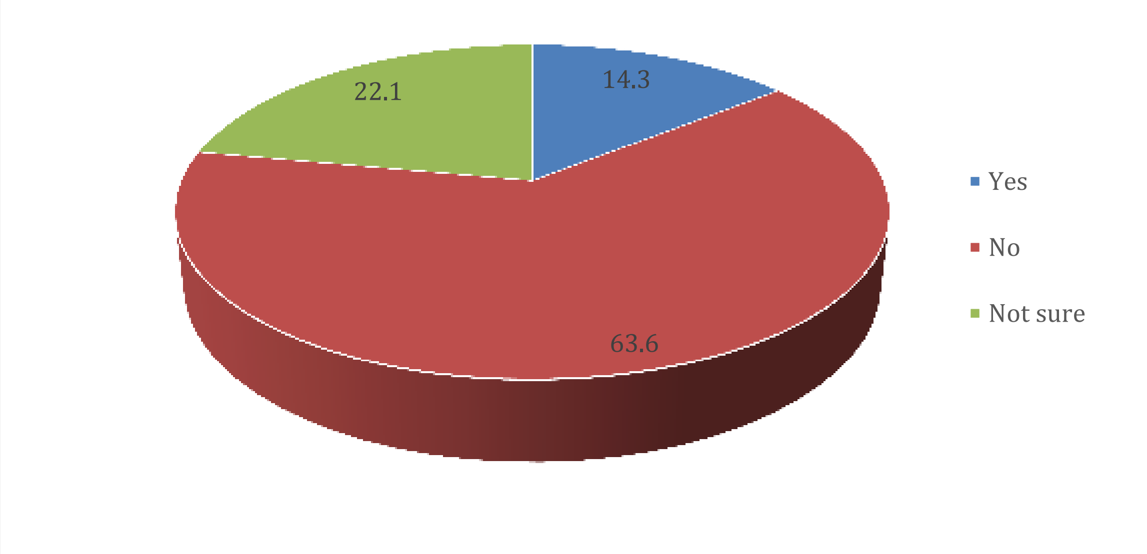
4.5 SECTION C: THE IMPORTANCE OF E-WASTE RECYCLING WITHIN THE STUDY AREA

In this section, respondents were questioned about the importance of e-waste recycling; their understanding of e-waste legislation; whether they were aware that e-waste contained harmful chemicals, and whether they would support an e-waste recycling plant in the area.

4.5.1 Awareness of e-waste legislation

To gauge their level of awareness of e-waste legislation, respondents within the study area were asked if they were aware of any legislation that dealt with the disposal of broken/redundant electronic and electrical equipment. The majority of respondents (63.6%), as reflected in Figure 4.13 below, stated that they were not aware of any e-waste legislation. This response correlated with the majority of respondents (76.3%) who indicated that there was limited information on e-waste recycling (Figure 4.7) within the study area.

Figure 4.13: Awareness of e-waste legislation



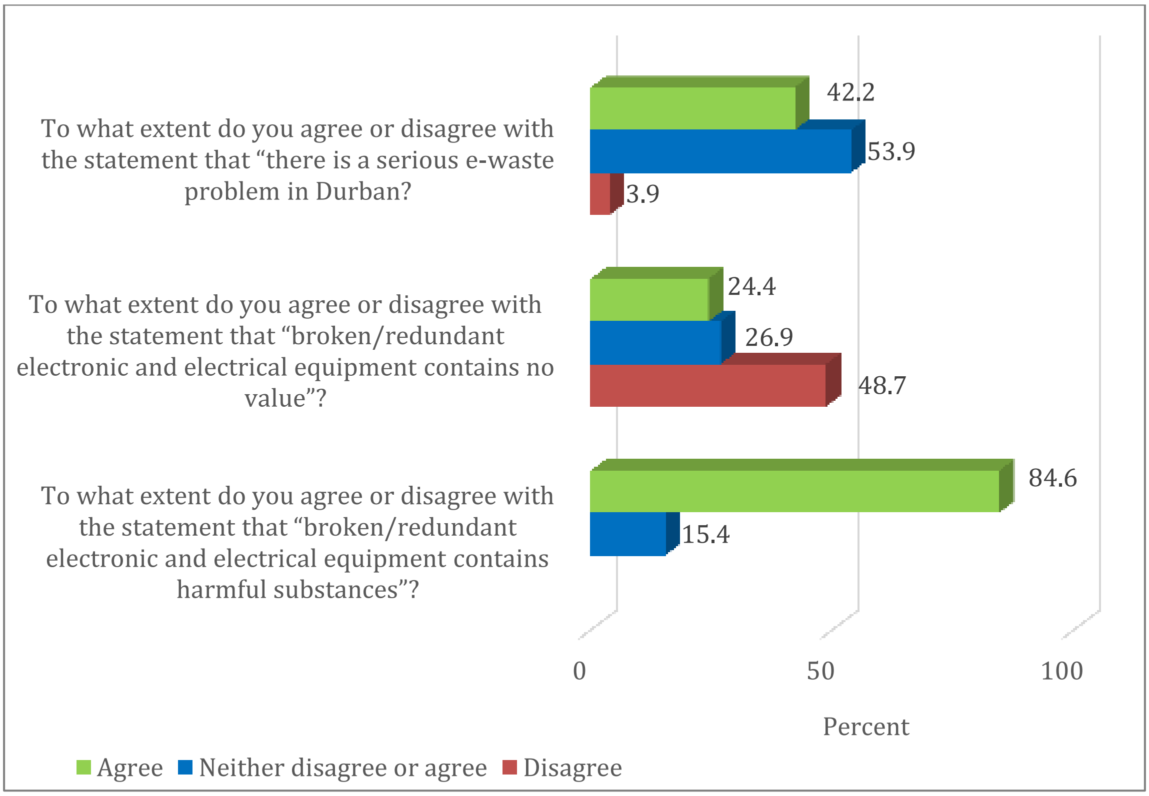
Those respondents within the study area who had no awareness of e-waste legislation (63.6%), and those who were undecided (22.1%), should be provided with e-waste legislative information. An increased awareness of e-waste legislation is beneficial, as a study undertaken by Anderson and Ecroignard (2011) concluded that the more aware organisations became of e-waste legislation, the more they began implementing recycling systems.

According to Mansfield (2013), the European Union has the most progressive e-waste legislation in the world, and he contends that if organisations understood e-waste legislation, it would promote effective and progressive e-waste management.

4.5.2 Environmental and economic impact of e-waste in the study area

The last three statements in the questionnaire dealt with the environmental and economic impact of e-waste within the study area and the frequency of responses are represented in Figure 4.14 below.

Figure 4.14: Environmental and economic impact of e-waste



When asked if Durban, the city in which this study was conducted, had a serious -waste problem, the majority of respondents (53.9%) were undecided, and (42.2% of the respondents agreed that Durban had a serious e-waste problem, as reflected in Figure 4.14 above.

In a similar study undertaken by Osuagwu and Ikerionwu (2010) in Nigeria, the researchers reported that government or industry created no awareness of the dangers of e-waste and that citizens were not fully aware of the extent of the e-waste problem and its environmental impact in that region. In Brisbane, Australia, Davis and Wolski (2008) also reported that there was a lack of awareness of individual responsibility for e-waste and that people were not aware of the environmental impact of e-waste in their city.

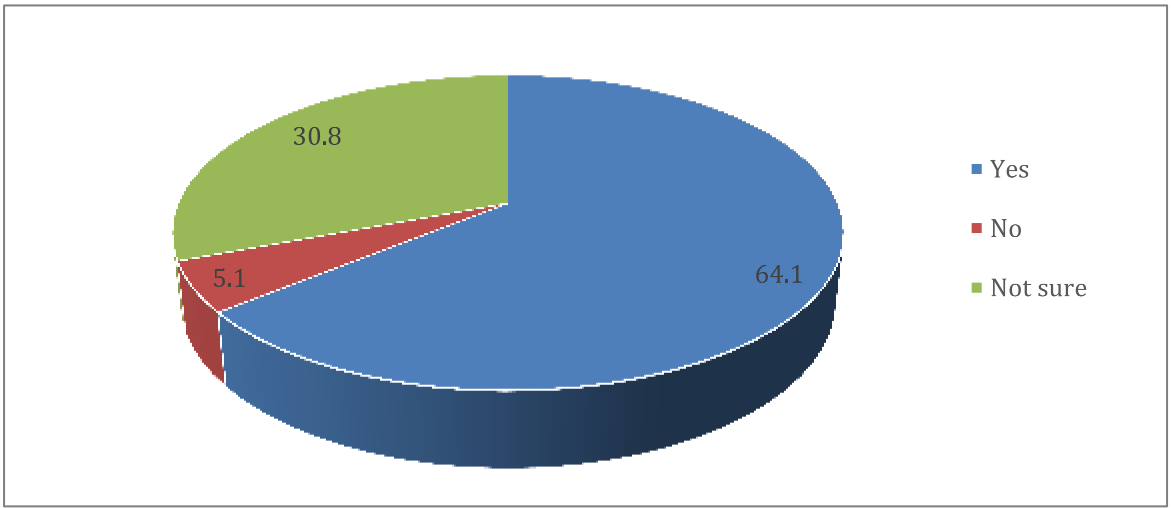
In terms of the valuable components of e-waste, 48.7% of respondents (Figure 4.14) disagreed with the view that obsolete/redundant electronic and electrical equipment contained no value; 26.9% of the respondents neither agreed nor disagreed on whether or not e-waste contained any value, while 24.4% of the respondents were of the view that e-waste contained no value. The latter response correlates with the lack of information available in the study area regarding the benefits of e-waste management.

In response to whether e-waste contains harmful substances that damage the environment, the majority of organisations (84.6%) ocated in the Umbogintwini Industrial Complex and Southgate Manufacturing Park had a high awareness level with regards to the dangers of e-waste. The above result corresponds with the results from a similar conducted by Kalana (2010) in Malaysia, where the majority of respondent (85%) indicated that they were aware of the hazardous materials present in electronic products.

4.5.3 Support for an e-waste recycling plant

Figure 4.15 below displays the frequency and dispersion of responses in respect of support for an e-waste recycling plant within the study area.

Figure 4.15: Support for an e-waste recycling plant in the study area



As depicted in the pie chart in Figure 4.15, of the organisations surveyed, 64.1% stated that they would support an e-waste recycling plant in the area, 30.8% of the respondents indicated that they were not sure, and 5.1% of the respondents stated that they would not support an e-waste recycling plant in the area. A possible reason for a relatively significant proportion of the respondents (30.8%) being unsure if they will support a recycling plant in the area could due to the limited information in the study area regarding e-waste management. However, as revealed in Figure 4.15, the support received from the majority of the respondents (64.1%) for a recycling plant at the study site bodes well for the future of both the industrial and manufacturing parks.

The majority of respondents who supported the collection and recycling of e-waste in the area was positive, and as observed by WorldLoop (2013), those who supported e-waste recycling plants helped to convert e-waste from a threat into a social, economic and environmental opportunity. A case study in Tanzania proved that for an e-waste recycling facility to be successful, it was important to first canvas support from the local business organisations (Magashi and Schluep 2011).

Gregory, Magalini, Kuehr and Huisman (2009) also state that it is important for organisations, as well as regional governments, to support the establishment of e-waste recycling plants, for them to be successful. Government support can be in the form of administrative assistance in the operation of recycling facilities, and government must ensure that recyclers follow legislations to minimise emissions and show maximum concern for the health of the employees (Khurrum, Bhutta, Omar and Yang 2011).

4.6 Conclusion

The data collected via the questionnaire facilitated the analysis and discussion on the state of e-waste management within the Umbogintwini Industrial Complex and Southgate Manufacturing Park. The analysis revealed that there was limited information on e-waste available to the organisations within the study area by the management of these sites, and that not all organisations within the study area were managing their e-waste in an environmentally-responsible manner.

The estimated volume of e-waste that will be generated within the study area over the next five years was calculated to be approximately 593 tons. If the other industrial hubs in KwaZulu-Natal were included, as well as the other eight provinces in South Africa, the estimated volume of e-waste that will be generated in South Africa over the next five years will obviously, be substantially higher. If this is not recycled in an environmentally responsible manner, not only will it result in the degradation of the environment, but it will also have an adverse impact on human health in South Africa.

The final chapter highlights the main findings of the study, draws conclusions, and makes recommendations for the effective management of e-waste within the study area.

CHAPTER 5

REVIEW, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In this chapter the major findings of the study are summarised; and based on the findings, some tentative conclusions and recommendations regarding the management of e-waste at both the Umbogintwini Industrial Complex and adjacent Southgate Manufacturing Park in KwaZulu-Natal are presented. The chapter concludes by outlining the limitations of the study, and by suggesting areas of future research.

5.2 Review of the major findings of the study

Below, is a summary of the major findings of the study, emanating from the literature reviewed (in Chapter 2), and an analysis of the results of the survey undertaken among organisations located within the Umbogintwini Industrial Complex and Southgate Manufacturing Park, in KwaZulu-Natal, South Africa.

From the literature reviewed for this study, the following important issues regarding e-waste and its management emerged:

- there is no universally accepted or standard definition of e-waste;
- due to the rapid technological advances, products are becoming obsolete much sooner; hence, the volume of e-waste generated globally is growing exponentially;
- due to the hazardous nature of e-waste, it poses a serious environmental problem;
- despite the Basel Convention banning the exportation of hazardous waste, this practice continues unabated;

- there is ample evidence that some developed countries are dumping their e-waste in developing countries, under the guise of philanthropy;
- improper handling of e-waste can lead to serious health issues, and
- due to the valuable minerals and materials used in the manufacture of electronic equipment, e-waste recycling can be profitable.

From the empirical research undertaken for this study, the following findings regarding the management of e-waste in the Umbogintwini Industrial Complex and Southgate Manufacturing Park were arrived at:

- more than three-quarters of the respondents (76.3%) agreed that limited information was available about e-waste in the study area;
- approximately 23% of the organisations donated their obsolete/redundant electronic and electrical equipment. This was the preferred method of e-waste disposal in the study area;
- despite e-waste legislation, over half of the respondents (63.6%) in the study area stated that they were unaware of any legislation that dealt with the disposal of obsolete/redundant electronic and electrical equipment in a responsible manner*;*
- nearly half of the respondents (48.7%) within the study area were aware that obsolete/redundant electronic equipment contained value if recycled;
- an overwhelming majority of the respondents (84.6%) were aware that e-waste contained harmful substances;
- sixty-four percent of the respondents were in favour of a strategy to manage obsolete/redundant electronic and electrical equipment within the study area;

- the majority of the respondents (64.1%) were favourably disposed towards the establishment of an e-waste recycling facility within the study area;

- over a five-year period, the Umbogintwini Industrial Complex and Southgate Business Park will generate approximately 597 tons of e-waste;

- projections indicate that over a five-year period, all of the industrial parks located in KwaZulu-Natal would generate approximately 3 340 tons of e-waste;

- projections reveal that if the potential e-waste generated within the study area within the next five years is recycled, income of approximately R2 374 000 from the sale of plastics and precious metals could be generated;

- approximately 50 jobs can be created to process the e-waste from the study area in one year;

- an additional revenue stream can be generated by carbon savings, that results from earning credits by recycling e-waste in an environmentally responsible manner. On the basis of the potential e-waste generated at the Umbogintwini Industrial Complex and the Southgate Business Park, over a five year period, there is the possibility of generating an income of approximately R 89,000, and

- in the absence of an e-waste recycling plant to service the organisations within the Umbogintwini Industrial Complex and the Southgate Manufacturing Park, over a five year period, it will cost organisations located within the study area approximately R1 480 000 to dispose of their e-waste.

5.3 Conclusion

While the rapid advances in technology may result in improved products and services; an increase in productivity of organisations, and an improved material standard of living for most people, the downside is that the volume of electronic waste generated is growing at an alarming rate. If drastic measures are not implemented soon to manage the growing e-waste problem, then the impact on both the environment and human health will be severe.

Due to time and cost constraints the study was restricted to one major industrial node in KwaZulu-Natal. However, the findings of the study could be useful for other researchers on this topic. E-waste recycling should not be an option, and perhaps, more effective policing of the various laws pertaining to the management of e-waste will compel organisations to recycle their e-waste in an environmentally responsible manner.

5.4 Recommendations

The first recommendation is that the management of both the Umbogintwini Industrial Complex and the Southgate Business Park should develop an e-waste management strategy for the sites. In the interim, the following tentative recommendations will assist in the management of e-waste within the Umbogintwini Industrial Complex and the Southgate Business Park:

- the management companies of the study areas initiate an e-waste educational campaign. An environmental officer (the Umbogintwini Industrial Complex currently has a fully qualified environmental officer) should co-ordinate an e-waste awareness campaign amongst all the companies within the study area. This awareness campaign can be in the form of:

    - pamphlets distributed to companies located within the study area. It should include information for all workers on various types of e-waste and its harmful effects;
    - e-mails from the park's environmental officer to all the managers within the study area on how to manage e-waste in an environmentally responsible manner, and
    - visible signage strategically placed within the study area indicating the location of e-waste metal skips.

- workshops (or featured as an item during staff training) be held with tenants of the park educating companies to be e-waste conscious and responsible;
- the management companies of the Umbogintwini Industrial Complex and the Southgate Business Park should engage the services of a qualified professional service provider to formulate a Policy For The Management of E-waste for the study area. This can be a separate policy on e-waste management or an addendum to their existing Solid Waste Management Policy;
- target and engage some of the larger companies within the Park on the issue of e-waste management by hosting training workshops and encouraging them to develop their own e-waste policy;
- have dedicated e-waste bins within each organisation and/or large clearly marked e-waste metal skips within the park which is easily accessible and identifiable so that organisations can deposit their e-waste, and
- the management companies of the study areas to more regularly engage the services of an external e-waste recycling company to collect the e-waste from the e-waste bins or the metal skips.

5.5 Limitations of the study

The following limitations pertaining to the study are acknowledged:

- the categories of electronic devices considered for the study were restricted to desktop and laptop computers, printers, photocopiers, scanners, fax machines, computer screens, security monitors, televisions, air-conditioning units, and electrical industrial equipment (such as: electronic tools, security scanners, timers, drills and cutting machines, welding machines, presses, sewing and trimming machines, cash registers, control boards, etc.). Thus, the e-waste emanating from cellular telephones, motorised devices, electronic cabling, access controlled devices, lighting devices, alarm sensors, and domestic electrical appliances, were not taken into consideration in determining the volume of e-waste generated. The inclusion of these additional categories would have increased the e-waste generation potential of the study area in KwaZulu-Natal, and

- the study was confined to an industrial complex and manufacturing park Therefore, the findings pertaining to the nature and volume of e-waste emanating from the study site cannot be generalised, as the nature and volume of e-waste generated at an office park or a light industrial area, will be different.

5.6 Recommendations for future research

The study focused on assessing the perceptions and behaviour of organisations regarding the management of electronic waste in a specific industrial node in KwaZulu-Natal. Future studies could investigate the management of e-waste in other business sectors in KwaZulu-Natal; for the entire province of KwaZulu-Natal, and/or in other provinces in South Africa. Allied to the above, a comparative study of the e-waste recycling initiatives in the various sectors of the economy could be undertaken.

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ANNEXURE A

Organisations located in the Umbogintwini Industrial Complex

NO.	COMPANY NAME	TEL. NO.
1	ABL Instrument Services	083 459 8167
2	ADJ Engineering Works	031 9144 719
3	AESSEAL	082 664 1439
4	Afritise Total Sign Solution	031 904 1392
5	Acme Thermo Insulators	031 307 4960
6	African Explosives-Modderfontein	011-606 0000
7	Antioxidants Aroma & Fine Chemicals	0357-97 6000
8	Ashkim Suppliers	031 904 1600
9	Atholl Munday Training Centre	031 904 3244
10	Auto Surgeon	031 904 3535
11	BASF	031 904 7865
12	Belzona Polymeric Systems	031 903 5438
13	Blizzard Refridgeration CC.	082 330 5776
14	Brightspark Engineering	031 904 2000
15	Bytes Communications	031 569 7333
16	Cele Landscaping	073 246 9917
17	Ceratech Coatings KZN	031 903 8533
18	Coastal Steel Installation	084 548 2009
19	Chemical Initiatives	031 904 9900
20	Cherry Pickers KZN	082 547 4807
21	Crest Chemicals	031 9043 540
22	D&D Amanzi Products cc	031 904 2334
23	Damascus Interiors	082 788 0211
24	Densit Construction	082 452 2437
25	Denzil Auto Surgeon	031 904 3535
26	Devishen Nayager	079 157 4384
27	Dulux Decorative	031 904 8000
28	Dyefin Textiles	031 904 1547
29	Easy Asset Tracking CC	031 903 1546
30	EDRS	0827 091 408
31	Emoyeni Suspended Flooring CC	031 467 0618
32	Enzyme Technologies (Pty) Ltd	083 274 7125
33	Enviroserve	031 902 1526
34	Enviromental Drilling & Remediation Service CC	087 700 8428

35	EvonikParoxide (Degussa)	031 904 9650
36	Ferron Engineers	031 465 3334
37	Finny's Bakery	083 262 3029
38	Gabhisas Sports	031 904 1566
39	Gensis Electrical	n/a
40	Glens Electrical	031 904 3229
41	Golf Woodcovers CC	n/a
42	GrupoAntolin	031 9041304
43	Harbs Engineering CC	031 903 7970
44	Hazrisks Consulting	031 904 1660
45	Heartland Leasing	031 949 2111
46	Heartland Services	032 949 2111
47	Huntsman Tioxide	031 910 3611
48	ImproChem	031 949 8200
49	Industrial Urethanes	031 904 9300
50	Insimbi Container Projects+B60	031 916 7871
51	International Industrial Brokers CC	031 914 0136
52	Isipingo Protective Clothing Cc	031 902 1156
53	Jade Rock 120 investments CC	031 9031 493
54	Jenifer Maharaj (Forest tissue)	031 902 2821
55	Jaref Hardware and Paints	031 904 3752
56	Kanty&Templer	084 862 3812
57	Kalvis	031 904 1683/4
58	KK Animal Nutrition	031 910 5100
59	Kunene and Biggs Associates CC	031 903 5889
60	KPG Investments	031 811 3321
61	Lake International Technologies	083 640 4548
62	Life Occupational Health (Clinic)	031 904 2010
63	L O Plant Hire CC	031 904 1101
64	LHS Electrotech Service CC	n/a
65	Lindon Corporation	083 230 2935
66	Manedla Security	083 300 7520
67	M2 Cleaning Services	073 346 5452
68	Messiah Weldworks	031 9041 544
69	Mickaylin's Transport (near Kalvis)	n/a
70	M & N Contractors cell number	n/a
71	Natal Fibre Rock & Mould Cc	n/a
72	Natal & Rural Sales	031 904 1577
73	Natal Pump Services	031 701 3261

74	Natrans & Road Freight	031 811 7600
75	ND Consulting	031 914 3906
76	Nick Koegelenberg	082 396 6907
77	Nyangile Elec &Instru. Cc	031 900 1244
78	Omega People Mnmgt Solutions	n/a
79	Outdoor Chillers	082 550 5387
80	Panel Beating Company (next to Jareffs)	
82	Perspex SA	031 904 8400
83	Phil Williams Contractors	031 914 0333
84	Popping Delicious	082 453 0707
85	Progate	082 466 4821
86	Protec	031 904 3550
87	Resinkem	031 904 9400
88	Rio`s Engineering	031 904 1472
89	SA Bioproducts Anchor Yeast	031 949 2222
90	Saiba Engineering	031 904 3225
91	Sammar Transport	031 904 3681
92	Sasol Polymers Distributors 351	083 630 7563
93	Saville Coatings	031 904 3761
95	Sekula Trading CC	031 9041 660
96	Sherwood garden	082 453 0703
97	Sibongintuthuko Trading CC	031 904 1532
98	Spilltechh CC	031 206 0919
99	SNS Synergistic Solutions CC	082 835 1390
100	Sunbow	031 9042 558
101	Take Away (next to Jarefs hardware)	
102	Technology Innovation Agency (Life lab)	031 9049 740
103	ThorexMaitanance Product CC	031 904 8533
104	Top-rope	031 904 1519
105	Toyota Container Yard NYK Logistics & BLL SA (PTY) Ltd	031 904 1077
106	Trinutri Feeds (Pty)Ltd	031 949 2208
107	Umbogintwini Riggers & LM Inspectors	031 904 1778
108	Umongo Investments	n/a
109	Webguru	n/a
110	Workmed	031 914 4892
111	Ricky Elsworth	319 042 008

ANNEXURE B

Organisations located in the Southgate Business Park

NO.	COMPANY NAME	TEL
1	456 Computers	031 914 3456
2	A M C AUTO	031 914 0017
3	Absorbetech Environmental	031 914 3939
4	ACMC Coastal - Caltex Garage	031 914 3605
5	ACT Networks cc	031 914 2154
6	ACV Auto Repairs	031 914 2055
7	ADJ Engineering	031 914 4719
8	Affirmative Blasting Contractors	031 914 4491
9	Affrisan	n/a
10	Afri Source Staffing Solution	031 914 0321
11	African Data & Electrical Contractors	031 914 0341
12	Akura	031 914 2176
13	Alba Air Systems cc	031 914 0984
14	Alfa Laval (Pty) Ltd	n/a
15	Allied Trim Components	031 914 3113
16	Alliott De Witt Saestad Inc	031 914-8300
17	AM Fabrication	031 914 2136
18	Amndla Services cc	031 914 2081
19	Ancher Auto Electrical	031 914 4638
20	Andre`s Electrical	031 914 0202
21	Angel Rose Catering	n/a
22	Apex Environmental	031 914 1004
23	Artistic Brass Hardware	031 914 2772
24	Artistic Steel	n/a
25	Avis Forklift Centre	011 397 1784
26	Baking Solutions	031 914 3745
27	Basics 4 U	082 771 2799
28	Beruseal	031 914 3812
29	Bin Lining & Canopy	n/a
30	Bingham Insurance Brokers	031 914 1018
31	Bloodhound	031 914 2926
32	BME Parkaging	031 914 2937
33	Brago Logistics	031 914 2114

34	Brewtech Engineering	083 571 6566
35	Bright Spark Engineering	n/a
36	Britec Laboratories (Pty) Ltd	031 914 0300
37	C3 Precision Engineering	031 914 4744
38	Camfly PVC	n/a
39	CCTS Solution	n/a
40	Celtic Freight	031 914 0270
41	Chemetall	031 914 0133
42	Chess Properties	031 914 0014
43	Circle Consultants	031 914 2082
44	CJS Electrical	031 914 4127
45	Coastal Blinds	031 914 0203
46	Colron Marketing	031 914 2749
47	Cool Perfection	n/a
48	Coprox	082 973 5922
49	Coronatech	031 914 0151
50	Corrochem	031 914 2432
51	Corruseal	082 557 8811
52	CPI Group	n/a
53	D & L Precision Engineering	031 914 0027
54	Deon's Electrical Services	031 914 4920
55	Design Global	031 914 3120
56	Designer Kitchens	n/a
57	DG Crane Services	031 914 4898
58	Dimensional & Torque	n/a
59	Discount Wooden Windows	031 914 4270
60	Dough Delite	084 774 1441
61	Duram Smart Paints	031 914 2245
62	Durban Lubricants	031 914 2927
63	Dynamic Instore Systems	031 914 4920
64	DYNVET - Project Planning	031 914 2154
65	East Coast Bakery Services	031 914 2920
66	Eco Roof Sheeting	031 914 0083
67	Edward Searle	n/a
68	Elba Chemicals	031 914 2437
69	Employ Africa	031 914 2437
70	EPW- eThekwini Precision Tools	n/a
71	E-quip South Africa	031 914 2910
72	ET Security	031 569 5656

73	Evertrade	031 914 5515/2
74	F & P Enterprises	n/a
75	F & R Catal Transport Solutions	031 914 4623
76	Fifth Factor Gym	n/a
77	Filtaman cc	031 914 2163
78	Flowers Direct	031 914 1002
79	FortekEnviro	031 903 5560
80	Fruit and Veg City	n/a
81	Function Planning & Hire	031 914 2473
82	Gemini Kitchens	031 914 4299
83	GIG Network Solutions	031 903 9300
84	Glass & Aluminium	031 914 4635
85	Gold Coast Chemicals	031 914 0388
86	Gotec	031 914 2214
87	GP Converters	031 914 2123
88	Greenpoint Alcohols	031 914 3210
89	Ikhabethe Kitchens & Furniture	074 686 9212
90	Ilanga Technologies	n/a
91	Impumelelo Stainless Steel (Pty) Ltd	031 914 0325
92	INDYS Fast Food	n/a
93	Inyanga Technical Service	n/a
94	IT Engineering	n/a
95	J & J Toll and Die	031 914 2174
96	JAG Rigging & Engineering	031 914 2898
97	JC Security	n/a
98	Jemplas	031 914 0163
99	JK`s Engineering	031 914 0035
100	K Recycled Waste	n/a
101	Kalros Engineering & Injection	031 914 0035
102	KZN Office Solutions	n/a
103	Liniton Hydraulic & Engineering	031 914 0951
104	Lion Heart Chemicals	n/a
105	Liquid Energy	031 914 2211
106	Logix Design and Development	031 914 0979
107	Lutron	031 914 0440/1
108	LVSA Valves	031 914 1025
109	M & F Giuricich Developments	n/a
110	Makwedeng Training	031 914 4743
111	Mandel Steelworks & Electrical	031 914 0330

112	Marlin Laboratory Manufacturer	031 914 2232
113	Meditek-Hemco (Pty) Ltd	031 914 2444
114	Memoir	031 914 2176
115	Mend-It Engineering	031 914 0030
116	Metal Packaging Technologies	031 914 4131
117	MIA Gas Suppliers	031 914 2894
118	Modern Waterproofing	031 914 4883
119	Moyizlela	031 914 4701
120	Mr Diagnostic	031 914 3770
121	Mzansi Chicken Fact	083 781 8324
122	Natcom Electronics	031 914 2074
123	ND Consulting	031 9143906/8
124	NFS Distributors	n/a
125	NMR Logistics	031 914 0260
126	Nova Refractory Installers	031 914 4604
127	On the Beach Laundry	082 759 9093
128	Osorno Steel & Pipe CC	031 914 3624
129	OT Chemicals	031 914 3764/5
130	Outsource Electrical	031 914 0041
131	Pack`d Fasteners	031 914 0240
132	PEC Metering	031 914 4763
133	PF Projects	031 914 4680
134	Phambili Interface	031 914 4712
135	Phil Williams Contractors	031 914 0333
136	Predictive Maintenance	031 914 0237
137	Prime Controls	n/a
138	Printing By Design	031 914 0298
139	Pro Pipe	031 914 2506
140	Professional Access	n/a
141	Prosperoh	031 914 0275
142	Pro-Wood Tech	031 914 2898
143	Quality Contract Cleaning	031 914 2100
144	Rapid Airtools Repairs	031 914 8100
145	Rebev	031 914 2757
146	Relief Valve & Pump	031 914 0000
147	Rent a Tool	n/a
148	Rho-Tech	031 914 0966
149	Robert Milne Family Trust	031 914 0150
150	Roto Print	031 910 9500

151	Royal Kitchens	031 914 2510
153	Rutherford Plumbing	031 914 4530
152	S & S Auto	031 914 0156
154	Sapco Industrial	031 914 0201
155	Schoeman`s Plumbers	031 914 0051
156	Seabreeze Awnings & Carports	031 914 2500
157	Shoreline Sales and Distribution	031 914 8400
158	Siyaduma Auto Ferries	031 914 2900
159	Skyjacks Hydraulic Access	031 914 4700
160	Southcoast Safety Supplies	031 914 3110
161	Southgate CV Joint Centre	031 914 0068
162	Southgate Electrical	031 914 4108
163	Southgate Motorcycles	n/a
164	Southgate Timber	031 914 4282
165	Steelcom	031 914 2870
166	Subcotex	n/a
167	Team Renovate (Pty) Ltd	031 914 3750
168	Terua Enterprises	031 916 7096
169	The Coffee Cup	031 914 0187
170	The Property Finder	n/a
172	Thekwini Tools & Die	031 902 6497
171	Thermobake Systems	031 914 4954
173	Tholile CC	031 914 2208
174	Tomrich Precision Engineering	031 914 3058
176	Toolworld	031 914 4102
177	Toscant Agencies (Party Shop)	n/a
178	Towel Cabinet Services	n/a
179	Toyota Tsusho Africa (PTY) Ltd -	031 949 5000
180	Transfrig Refrigeration Agents	031 914 0170
181	Transpaco Specialised Film	031 914 4102
182	Trimwise	031 914 0157
183	Triple E Training	031 914 3739
184	Tweedie Pallets	031 914 3747
185	Umkhumbi Logistics	031 914 0027
186	Unik Furniture Rentals	031 914 2933
187	Value Fencing	083 318 7777
188	Varelec Distributors	n/a
189	Venturer	031 914 2112
190	Vesar Research	031 836 0223

191	VIP Auto Styling	n/a
192	Vision & Value	031 9144971/2
193	Weaver Conference Centre	031 914 0959
194	Westward Engineering	031 914 0959
195	Wi-Fi Tower Trading cc	031 914 4706/7
196	Wonderland Ceramics	083 789 6982
197	Workmed	031 914 4892
198	Y Exhibit	083 262 0038
199	Yodata Electronics (Natal)	031 914 0288
200	Zambezi Signs	031 914 4643
201	Zantec Projects	031 914 3821
202	Zibo Containers	031 914 1796

ANNEXURE C

List of Government Policy, National Acts, Regulations and Local Government by-Laws for the control of hazardous substances

TYPE OF DOCUMENT	CHAPTERS, PARTS OR SECTIONS	AUTHORITY
The Constitution of The Republic of South Africa (Act 108 of 1996)	21, 32, 33, 39(1) and 231 (2)	National Assembly
POLICY		
Environmental Management Policy		Department of Environmental Affairs and Tourism
Integrated Pollution and Waste Management Policy		Department of Environmental Affairs and Tourism
A Minerals and Mining Policy for South Africa		Department of Minerals and Energy
Gauteng Policy for Healthcare Waste Management		DACEL
NATIONAL ACTS		
Environmental Conservation Act	(Act 73 of 1989) III, V, VI	Department of Environmental Affairs and Tourism
National Environmental Management Act	(Act 107 of 1998) 1, 2, 3, 4, 5, 6, 7	Department of Environmental Affairs and Tourism
Occupational Health & Safety Act	(Act 85 of 1993)	Department of Labour
National Water Act	(Act 36 of 1998) 20, 21	Department of Water Affairs and Forestry
Forest Act	(Act 122 of 1984) 75	Department of Water Affairs and Forestry
Minerals Act	(Act 50 of 1991) 39, 40	Department of Minerals and Energy
Mine, Health and Safety Act	(Act 29 of 1996) 5, 6, 12, 23, 98	Department of Minerals and Energy
Electricity Act	(Act 41 of 1987) 25	Department of Minerals and Energy
Nuclear Energy Act	(Act 131 of 1993)	Department of Minerals and Energy
Atmospheric Pollution Prevention Act	(Act 45 of 1965) 24	Department of Health
Hazardous Substances Act	(Act 15 of 1973) 2, 3, 19, 29	Department of Health
Health Act	(Act 63 of 1977) 20, 27, 30, 31, 33, 34, 36, 38	Department of Health
Human Tissue Act	(Act 65 of 1983) 37	Department of Health
Development Facilitation Act	(Act 67 of 1995)	Department of Land Affairs
Physical Planning Act	(Act 125 of 1991)	Department of Provincial and Local Government
Local Government: Municipal Structures	(Act 117 of 1998)	Department of Provincial and Local Government
Local Government: Municipal Systems Act	(Act 32 of 2000)	Department of Provincial and Local Government
National Building Regulations and Building Standards Act	(Act 103 of 1977) 10, 11, 12, 17	Department of Trade and Industry
National Roads Act	(Act 54 of 1971)	Department of Transport

	16	
Road Traffic Act	(Act 29 of 1989) 101, 103, 132	Department of Transport
South African National Roads Agency Limited and National Roads Act	(Act 7 of 1998)	Department of Transport
Animal Protection Act	(Act 71 of 1962) 2, 5	Department of Agriculture
Animal Diseases Act	(Act 35 of 1984) 17, 31	Department of Agriculture
Abattoir Hygiene Act	(Act 121of 1992) 17, 24	Department of Agriculture
Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies Act	(Act 36 of 1947)	Department of Agriculture
Sectional Titles Act	(Act 95 of 1986) 28	Department of Public Works
Regulations in terms of the Sectional Titles Act	Section 2, 7	Department of Public Works
Housing Act	(Act 107 of 1997) 9	Department of Health
REGULATIONS		
Hazardous Substances Act Government Notice R453 GG 5467 of 25/3/77 Government Notice R73 of 11/1/85 Government Notice R2920 of 23/10/92 Government Notice R247 of 26/2/93		Department of Minerals and Energy
Environment Conservation Act Government Notice R1182 GG18261 of 5/9/97 Government Notice R1183 of 5/9/97 Government Notice R1184 of 5/9/97		Department of Environmental Affairs and Tourism
Sectional Titles Act Regulations		Department of Public Works
Minerals Act Government Notice R801 of 25/6/99		Department of Minerals and Energy
Development Facilitation Act		Department of Land Affairs
LOCAL GOVERNMENT BY-LAWS		
Builder's Refuse		Johannesburg Metro
Special Industrial, Hazardous, Medical and Infectious Refuse		Johannesburg Metro
Disposal Sites		Johannesburg Metro
Littering, Dumping and Ancillary Matters		Johannesburg Metro

Source: Lombard and Widmer (2005)

ANNEXURE D

Letter of information and consent:

No 11 Roof Garden Mansions 03 May 2014
259 Sydenham Road
Durban
4001

To whom it may concern

Letter of information and consent:

Title of the Research Study: The Management of electronic waste - a case study of the Umbogintwini Industrial Complex and Southgate Business Park in Kwa-Zulu Natal.

Principal researcher: Mr. Krishna Govender

Supervisor: Dr Soobramoney Chetty at Durban University of Technology

Brief Introduction and Purpose of the Study:
The *Constitution of the Republic of South Africa* says that everyone has a right to an environment, which is not harmful to his or her health or wellbeing, however, many businesses by their operational nature generate electronic waste; although their individual environmental impacts are small, their cumulative impacts are highly significant.

In cognisance of this, this study attempts to ascertain the nature and extent to which the organisations located within the Umbogintwini Industrial Complex (UIC) are managing their electronic waste (e-waste). It is envisaged that an e-waste recycling business model will be developed for adoption by the management of the industrial complex, thereby minimising the impact of the e-waste generated at the complex on the environment, and ultimately, on one's health.

Outline of the Procedures:

This is an exploratory study. The target population will comprise of all companies located within the Umbogintwini Industrial Complex.
The Managing Director of the Umbogintwini Industrial Complex is aware of the study and supports the research study. Contact made with companies was is either personally or via email. A survey questionnaire is used to collect the data from the companies.
The time taken for each participant to complete his questionnaire is approximately fifteen (15) minutes. The study should take 12 months to be finished.

Risks or Discomforts to the Subject:
Participation is voluntary and that non-participation will not result in any penalty. There is no risk or discomforts during the course of this study. The study has an ethical approval.

Benefits:
The benefits to the study are twofold. Firstly, it attempts to quantify the amount of electronic waste generated within the industrial complex. Secondly, it offers a management model for the handling of electronic waste within the industrial complex.

Reason/s why the Participant May Be Withdrawn from the Study:
There will be no adverse consequences for the subject and no participant will be withdrawn from the study.

Remuneration:
Due to financial constraints, the participants will not receive any monetary or other types of remuneration during the study.

Costs of the Study:
The participants do not cover any costs towards the study.

Confidentiality:
All information submitted is treated with the highest level of confidentiality and no names and details of the participants are divulged to a third party. Additionally, the findings of the study will be made available to them once they have been concluded.

Research-related Injury:
There will be no research-related injury or adverse reaction during the course of the study and no compensation paid to any participant during the study

Persons to Contact in the Event of Any Problems or Queries:
Supervisor: Dr Soobramoney Chetty at Durban University of Technology
Tel No : 084 659 2200 Email: chettys@dut.ac.za

Researcher: Mr Krishna Govender
Tel No. : 082877817 Email: krish.govender@lindon.co.za

Research Ethics administrator on 031 373 2900.

Statement of Agreement to Participate in the Research Study:

I,…………………………….. (subject's full name) ………………….(ID number), have read this document in its entirety and understand its contents.
Where I have had any questions or queries, Mr Krishna Govender has explained these to me to my satisfaction.
Furthermore, I fully understand that I may withdraw from this study at any stage without any adverse consequences and my future health care will not be compromised. I, therefore, voluntarily agree to participate in this study.

Subject's name (print) ……………………………………….…
Subject's signature:……………………………………..….. Date:……………...…
Researcher's name (print) signature: …………………….………...
Researcher's signature:………………………………...…..Date:..........................
Witness name (print) signature: ……………………………………...
Witness signature: ………………………….....................Date:………………….

ANNEXURE E

Letter of informed consent from the Managing Director of Umbogintwini Industrial Complex

HEARTLAND
Leasing (Pty) Ltd.

08 May 2013

TO WHOM IT MAY CONCERN

From my initial interview with Krish Govender, we think that his research study on E-waste management will benefit not only the Umbogintwini Industrial Complex but the greater Durban area. We also have a waste management strategy in place and feel that the findings from this study can be used to update our waste management strategy.

We will support him in his research and wish him everything of the best.

Yours faithfully

[redacted]

R BHIKUM
MANAGING DIRECTOR
for HEARTLAND LEASING (PTY) LIMITED

Heartland Leasing (Pty) Ltd Reg. No. 1947/026269/07

Member of the AECI Group

Telephone: (031) 949 2111
Fax: (031) 904 1484
1 Dickens Road
Umbogintwini 4126
Private Bag X501
Umbogintwini 4120

ANNEXURE F

Letter of informed consent from the Operations Manager of the Southgate Manufacturing Park

SOUTHGATE
BUSINESS PARK

OWNERS ASSOCIATION

08 May 2013

To whom it may concern

Research on Electronic Waste: Krishna Govender

We acknowledge and support the current Research program that Mr. Krishna Govender is undertaking within the Southgate Business Park.

Projecting and maintaining a safe and clean environment is one of our key priorities and this study will assist in managing electronic waste within the Park.

Yours sincerely

[redacted]

Park Manager
Southgate Business Park

P O Box 278, Amanzimtoti, 4125 • Telephone 031-914 2458 • Fax 031-914 2458

ANNEXURE G

Covering letter to the Questionaire

Dear Sir/Madam

I am a registered Master's student in the Department of Entrepreneurial Studies & Management at the Durban University of Technology. I am conducting a survey on the management of electronic waste (e-waste) in the Umbogintwini Industrial Complex and The Southgate Business Park. In order to successfully complete my studies, I need to administer a questionnaire, and your organisation has been identified as one of the respondents.

Official permission and support for the study has been granted by the management of both The Umbogintwini Industrial Complex and The Southgate Business Park. Your co-operation in assisting me with this important component of my study is highly appreciated, and I look forward to the completed questionnaire.

Your permission is hereby requested to complete the questionnaire and return it to the researcher. This will be explained in the questionnaire that follows.

Rest assured that your responses will be treated with the utmost confidentiality and will not be divulged to any third party. On completion of this research project, if requested, a report on the findings will be e-mailed or posted to you.
Thank you for your anticipated response and cooperation.

Regards

Krish Govender

Tel: 031 904 1050

ANNEXURE H

RESEARCH QUESTIONNAIRE

Section A: Quantifying the amount of e-waste generated

Please answer the following questions by marking an “X” in the appropriate box

1. What is your organisation’s core business activity?

1.1	Agriculture, forestry and fishing	☐	1.9	Clothing, footwear, and textiles	☐
1.2	Chemicals; rubber & plastic products	☐	1.10	Construction & Building materials	☐
1.3	Educational services	☐	1.11	Electronic & electrical equipment	☐
1.4	Engineering	☐	1.12	Transport, communication & storage	☐
1.5	Food producers & processors	☐	1.13	Health services	☐
1.6	Leisure, hotels & catering services	☐	1.14	Paper, printing & Publishing	☐
1.7	Personal & household services	☐	1.15	Retail trade	☐
1.8	Financing, insurance, real estate & business services	☐	1.16	Wholesale trade	☐
			1.17	Other (please specify):	☐

2. Number of desktop/laptop computers in your organisation (If unsure, estimate):

		a. Currently in use	b. Obsolete/redundant
2.1	Less than 5	☐	☐
2.2	5 - 10	☐	☐
2.3	11 - 15	☐	☐
2.4	16 - 20	☐	☐
2.5	21 - 25	☐	☐
2.6	26 - 30	☐	☐
2.7	More than 30	☐	☐
2.8	No computers	☐	☐

3. Total number of printers/photocopiers/scanners/ fax machines (If unsure, estimate):

		a. Currently in use	b. Obsolete/redundant
3.1	Less than 5	☐	☐
3.2	5 - 10	☐	☐
3.3	11 - 15	☐	☐
3.4	16 - 20	☐	☐
3.5	21 - 25	☐	☐
3.6	26 - 30	☐	☐
3.7	More than 30	☐	☐
3.8	No printers/ photocopiers/ scanners/fax machines	☐	☐

4. Total number of computer screens/security monitors/televisions(If unsure, estimate):

		a. Currently in use	b. Obsolete/redundant
4.1	Less than 5	☐	☐
4.2	5 – 10	☐	☐
4.3	11 – 15	☐	☐
4.4	16 – 20	☐	☐
4.5	21 – 25	☐	☐
4.6	26 – 30	☐	☐
4.7	More than 30	☐	☐
4.8	screens/ security monitors/ televisions	☐	☐

5. Total number of air-conditioning units in your organisation (If unsure, estimate):

		a. Currently in use	b. Obsolete/redundant
5.1	Less than 10	☐	☐
5.2	11 – 20	☐	☐
5.3	21 – 30	☐	☐
5.4	More than 30	☐	☐
5.5	No air-conditioning units	☐	☐

6. Total number of electrical industrial equipment (such as: electronic tools, security scanners, timers, drills and cutting machines, welding machines, presses, sewing and trimming machines, cash registers, control boards, etc.) in your organisation. If you are uncertain, please give an estimate.

		a. Currently in use	b. Obsolete/redundant
6.1	Less than 10	☐	☐
6.2	10 – 20	☐	☐
6.3	21 – 30	☐	☐
6.4	31 – 40	☐	☐
6.5	41 – 50	☐	☐
6.6	More than 50	☐	☐
6.7	No electrical industrial equipment	☐	☐

7. To what extent do you agree or disagree with this statement: **"our company has the potential to generate a large volume of e-waste**"?

Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
☐	☐	☐	☐	☐

Section B: Management of e-waste

8. To what extent do you agree or disagree with the statement that **"there is limited information available on e-waste recycling in the Umbogintwini Industrial Complex and Southgate Business Park?"**

Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
☐	☐	☐	☐	☐

9. If the equipment in question 5 and question 6 malfunctions, what does your organisation do?

9.1	Completely replace with new equipment	☐
9.2	Repair the obsolete/redundant equipment	☐
9.3	Replace if cannot be repaired	☐

10. Does your organisation currently store or gets rid of obsolete/redundant electronic and electrical equipment?

Store	Gets rid of e-waste	Not sure
☐	☐	☐

11. If your company does not get rid of the obsolete/redundant electronic and electrical equipment, where does your company store this obsolete/redundant electronic equipment?

11.1	On Site	☐
11.2	Off Site	☐
11.3	Both on and off site	☐
11.4	Not sure	☐

12. Which of the following can be a reason for not disposing obsolete/redundant electronic equipment?

12.1	We are not aware of any authorised agent that will recycle our e-waste	☐
12.2	We have not yet given it thought	☐
12.3	We do not think we generate enough e-waste that needs disposal	☐
12.4	Other (please specify)	☐

13. How does your organisation dispose of its obsolete/redundant electronic and electrical equipment?

13.1	Treat it as ordinary office bin/municipal waste	☐
13.2	Dump it in specifically marked bins for Electronic Waste	☐
13.3	Dismantle and recycle it in-house	☐
13.4	Donate old electronic and electrical equipment	☐
13.5	Ask a recycling company to pick it up	☐
13.6	Supplier comes and takes it back	☐
13.7	Don't know	☐

14. To what extent do you agree or disagree with the statement that "**it is important for organisations to have a strategy for the management of obsolete/redundant electronic and electrical equipment**"?

Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
☐	☐	☐	☐	☐

Section C: Importance of e-waste recycling

15. Are you aware of any legislation that deals with the disposal of obsolete/redundant electronic and electrical equipment?

Yes	No	Not sure
☐	☐	☐

16. To what extent do you agree or disagree with the statement that "**obsolete/redundant electronic and electrical equipment contains harmful substances to the environment**"?

Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
☐	☐	☐	☐	☐

17. To what extent do you agree or disagree with the statement that **“obsolete/redundant electronic and electrical equipment contains no value”?**

Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
☐	☐	☐	☐	☐

18. To what extent do you agree or disagree with the statement that “**there is a serious e-waste problem in Durban**?

Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
☐	☐	☐	☐	☐

19. Would your organisation consider supporting an e-waste recycling plant in this area?

Yes	No	Not sure
☐	☐	☐

20. Any other comments you wish to make:

If you want a copy of the findings of the study, please provide the following contact details:

Name of Contact person	Telephone	E-mail

Thank you for filling out this questionnaire.

ANNEXURE I

Frequency tables

What is your organisation's core business activity?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Chemicals; chemical, rubber & plastic products	10	12.8	12.8	12.8
	Educational services	1	1.3	1.3	14.1
	Engineering	5	6.4	6.4	20.5
	Food producers & processors	3	3.8	3.8	24.4
	Leisure, hotels & catering services	1	1.3	1.3	25.6
	Financing, insurance, real estate & business services	2	2.6	2.6	28.2
	Clothing, footwear, and textiles	2	2.6	2.6	30.8
	Construction & Building materials	8	10.3	10.3	41.0
	Electronic & electrical equipment	7	9.0	9.0	50.0
	Transport, communication & storage	4	5.1	5.1	55.1
	Health services	4	5.1	5.1	60.3
	Paper, Printing & Publishing	2	2.6	2.6	62.8
	Retail trade	2	2.6	2.6	65.4
	Wholesale trade	1	1.3	1.3	66.7
	Other	26	33.3	33.3	100.0
	Total	78	100.0	100.0	

Number of desktop/laptop computers in your organisation currently in use					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 5	47	60.3	61.8	61.8
	5 - 10	17	21.8	22.4	84.2
	11 - 15	2	2.6	2.6	86.8
	16 - 20	2	2.6	2.6	89.5
	21 - 25	2	2.6	2.6	92.1
	More than 30	6	7.7	7.9	100.0
	Total	76	97.4	100.0	
Missing	System	2	2.6		
Total		78	100.0		

Number of desktop/laptop computers in your organisation that are broken					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 5	15	19.2	62.5	62.5
	5 - 10	5	6.4	20.8	83.3
	11 - 15	2	2.6	8.3	91.7
	16 - 20	1	1.3	4.2	95.8
	More than 30	1	1.3	4.2	100.0
	Total	24	30.8	100.0	
Missing	System	54	69.2		
Total		78	100.0		

Total number of printers/photocopiers/scanners/ fax machines currently in use					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 5	62	79.5	82.7	82.7
	5 - 10	9	11.5	12.0	94.7
	11 - 15	2	2.6	2.7	97.3
	16 - 20	1	1.3	1.3	98.7
	21-25	0	0.0	0.0	0.0
	26 - 30	1	1.3	1.3	100.0
	more than 30	0	0.0	0.0	0.0
	Total	75	96.2	100.0	
Missing	System	3	3.8		
Total		78	100.0		

Total number of printers/photocopiers/scanners/ fax machines that are broken					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 5	19	24.4	90.5	90.5
	5 - 10	1	1.3	4.8	95.2
	16 - 20	1	1.3	4.8	100.0
	Total	21	26.9	100.0	
Missing	System	57	73.1		
Total		78	100.0		

Total number of computer screens/security monitors/televisions currently in use					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 5	50	64.1	64.9	64.9
	5 - 10	13	16.7	16.9	81.8
	11 - 15	4	5.1	5.2	87.0
	16 - 20	1	1.3	1.3	88.3
	21 - 25	3	3.8	3.9	92.2
	More than 30	6	7.7	7.8	100.0
	Total	77	98.7	100.0	
Missing	System	1	1.3		
Total		78	100.0		

Total number of computer screens/security monitors/televisions that are broken					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 5	16	20.5	69.6	69.6
	5 - 10	6	7.7	26.1	95.7
	11 - 15	1	1.3	4.3	100.0
	Total	23	29.5	100.0	
Missing	System	55	70.5		
Total		78	100.0		

Total number of air-conditioning units in your organisation currently in use					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 10	63	80.8	87.5	87.5
	11 - 20	5	6.4	6.9	94.4
	21 – 30	1	1.3	1.4	95.8
	More than 30	3	3.8	4.2	100.0
	Total	72	92.3	100.0	
Missing	System	6	7.7		
Total		78	100.0		

Total number of air-conditioning units in your organisation that are broken					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 10	16	20.5	94.1	94.1
	11 - 20	1	1.3	5.9	100.0
	Total	17	21.8	100.0	
Missing	System	61	78.2		
Total		78	100.0		

Total number of electrical equipment currently in use					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 10	38	48.7	52.1	52.1
	10 – 20	18	23.1	24.7	76.7
	21 – 30	8	10.3	11.0	87.7
	31 – 40	4	5.1	5.5	93.2
	41 – 50	1	1.3	1.4	94.5
	More than 50	4	5.1	5.5	100.0
	Total	73	93.6	100.0	
Missing	System	5	6.4		
Total		78	100.0		

Total number of electrical equipment that are broken					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 10	21	26.9	95.5	95.5
	10 – 20	1	1.3	4.5	100.0
	Total	22	28.2	100.0	
Missing	System	56	71.8		
Total		78	100.0		

To what extent do you agree or disagree with this statement: "our company has the potential to generate a large volume of e-waste"?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	18	23.1	23.1	23.1
	Disagree	33	42.3	42.3	65.4
	Neither disagree or agree	16	20.5	20.5	85.9
	Agree	11	14.1	14.1	100.0
	Strongly agree	0	0.0	0.0	0.0
	Total	78	100.0	100.0	

To what extent do you agree or disagree with the statement that "there is limited information available on e-waste recycling in this area"?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	2	2.6	2.6	2.6
	Disagree	3	3.8	3.9	6.6
	Neither disagree or agree	13	16.7	17.1	23.7
	Agree	44	56.4	57.9	81.6
	Strongly agree	14	17.9	18.4	100.0
	Total	76	97.4	100.0	
Missing	System	2	2.6		
Total		78	100.0		

If the equipment, as described in 5 and 6 above malfunctions, what does your organisation do?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Completely replace with new equipment	5	6.4	6.6	6.6
	Repair the broken equipment	28	35.9	36.8	43.4
	Replace if cannot be repaired	43	55.1	56.6	100.0
	Total	76	97.4	100.0	
Missing	System	2	2.6		
Total		78	100.0		

Does your organisation currently store or gets rid of broken, obsolete/ redundant electronic and electrical equipment?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Store	23	29.5	30.3	30.3
	Gets rid of e-waste	51	65.4	67.1	97.4
	Not sure	2	2.6	2.6	100.0
	Total	76	97.4	100.0	
Missing	System	2	2.6		
Total		78	100.0		

If your company does not get rid of the broken/redundant electronic and electrical equipment, where does your company store this broken/ redundant electronic equipment?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	On Site	25	32.1	49.0	49.0
	Off Site	8	10.3	15.7	64.7
	Both on and off site	4	5.1	7.8	72.5
	Not sure	14	17.9	27.5	100.0
	Total	51	65.4	100.0	
Missing	System	27	34.6		
Total		78	100.0		

Which of the following can be a reason for not disposing broken/redundant electronic equipment?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	We are not aware of any authorised agent that will recycle our e-waste	12	15.4	18.2	18.2
	We have not yet given it thought	14	17.9	21.2	39.4
	We do not think we generate enough e-waste that needs disposal	28	35.9	42.4	81.8
	Other	12	15.4	18.2	100.0
	Total	66	84.6	100.0	
Missing	System	12	15.4		
Total		78	100.0		

How does your organisation currently dispose of its obsolete/redundant electronic and electrical equipment?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Treat it as ordinary office bin/municipal waste	9	11.5	13.0	13.0
	Dump it in specifically marked bins for Electronic Waste	6	7.7	8.7	21.7
	Dismantle and recycle it in-house	9	11.5	13.0	34.8
	Donate old electronic and electrical equipment	16	20.5	23.2	58.0
	Ask a recycling company to pick it up	7	9.0	10.1	68.1
	Supplier comes and takes it back	7	9.0	10.1	78.3
	Don’t know	15	19.2	21.7	100.0
	Total	69	88.5	100.0	
Missing	System	9	11.5		
Total		78	100.0		

To what extent do you agree or disagree with the statement that “it is important for organisations to have a strategy for the management of redundant/obsolete electronic and electrical equipment”?.					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neither disagree or agree	8	10.3	10.3	10.3
	Agree	50	64.1	64.1	74.4
	Strongly agree	20	25.6	25.6	100.0
	Total	78	100.0	100.0	

Are you aware of any legislation that deals with the disposal of obsolete/ redundant electronic and electrical equipment?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	11	14.1	14.3	14.3
	No	49	62.8	63.6	77.9
	Not sure	17	21.8	22.1	100.0
	Total	77	98.7	100.0	
Missing	System	1	1.3		
Total		78	100.0		

To what extent do you agree or disagree with the statement that “broken/redundant electronic and electrical equipment contains harmful substances to the environment”?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neither disagree or agree	12	15.4	15.4	15.4
	Agree	51	65.4	65.4	80.8
	Strongly agree	15	19.2	19.2	100.0
	Total	78	100.0	100.0	

To what extent do you agree or disagree with the statement that “broken/redundant electronic and electrical equipment contains no value”?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	4	5.1	5.1	5.1
	Disagree	34	43.6	43.6	48.7
	Neither disagree or agree	21	26.9	26.9	75.6
	Agree	18	23.1	23.1	98.7
	Strongly agree	1	1.3	1.3	100.0
	Total	78	100.0	100.0	

To what extent do you agree or disagree with the statement that “there is a serious e-waste problem in Durban?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	3	3.8	3.9	3.9
	Neither disagree or agree	41	52.6	53.9	57.9
	Agree	26	33.3	34.2	92.1
	Strongly agree	6	7.7	7.9	100.0
	Total	76	97.4	100.0	
Missing	System	2	2.6		
Total		78	100.0		

Would your organisation consider supporting an e-waste recycling plant in this area?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	50	64.1	64.1	64.1
	No	4	5.1	5.1	69.2
	Not sure	24	30.8	30.8	100.0
	Total	78	100.0	100.0	

Any other comments you wish to make?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Supportive comment	2	2.6	2.6	2.6
	Neutral comment	2	2.6	2.6	5.1
	No comment	74	94.9	94.9	100.0
	Total	78	100.0	100.0	

ANNEXURE J

Quantity of e-waste generated

Table J1: Number of desktop/laptop computers in use

No	Number of devices	Actual % of companies in this range	No of companies from total of 313	Average weight (kg)	Median	Estimated quantity of e-waste (kg)
2.1	Less than 5	60.3	189	25	3	14 145.19
2.2	05 - 10	21.8	68	25	7	11 938.14
2.3	11 - 15	2.6	8	25	13	2 608.33
2.4	16 - 20	2.6	8	25	18	3 611.54
2.5	21 - 25	2.6	8	25	23	4 614.74
2.6	26 - 30	0.0	0	25	28	-
2.7	More than 30	7.7	24	25	30	18 057.69
	No desktop computers	2.6	8	0	-	-
		100.0	313		**TOTAL**	**54 975.64**

Table J2: Number of obsolete/redundant desktop/laptop computers

No	Number of devices	Actual % of companies in this range	No of companies from total of 313	Average weight (kg)	Median	Estimated quantity of e-waste (kg)
2.1	Less than 5	19.2	60	25	3	4 514.42
2.2	05 - 10	6.4	20	25	7	3 511.22
2.3	11 - 15	2.6	8	25	13	2 608.33
2.4	16 - 20	1.3	4	25	18	1 805.77
2.5	21 - 25	1.3	4	25	23	2 307.37
2.6	26 - 30	0.0	0	25	28	-
2.7	More than 30	0.0	0	25	30	-
	No broken desktop computers	69.2	217	0	-	-
		100.0	313.0		**TOTAL**	**14 747.12**

Table J3: Number of printers/photocopiers/scanners/ fax machines

No	Number of devices	Actual % of companies in this range	No of companies from total of 313	Average weight (kg)	Median	Estimated quantity of e-waste (kg)
3.1	Less than 5	79.5	249	60	3	44 783.08
3.2	05 - 10	11.5	36	60	7	15 168.46
3.3	11 - 15	2.6	8	60	13	6 260.00
3.4	16 - 20	1.3	4	60	18	4 333.85
3.5	21 - 25	0.0	0	60	23	-
3.6	26 - 30	1.3	4	60	28	6 741.54
3.7	More than 30	0.0	0	60	31	-
3.8	No printers/photocopiers	3.8	12	0	-	-
		100.0	313		**TOTAL**	**77 286.92**

Table J4: Number of obsolete/redundant printers/photocopiers/scanners/ fax machines

No	Number of devices	Actual % of companies in this range	No of companies from total of 313	Average weight (kg)	Median	Estimated quantity of e-waste (kg)
3.1	Less than 5	24.4	76	60	3	13 723.85
3.2	05 - 10	1.3	4	60	7	1 685.38
3.3	11 - 15	1.3	4	60	13	3 130.00
3.4	16 - 20	0.0	0	60	18	-
3.5	21 - 25	0.0	0	60	23	-
3.6	26 - 30	0.0	0	60	28	-
3.7	More than 30	0.0	0	60	31	-
3.8	No broken printers/photocopiers	73.1	229	0	32	-
		100.0	313		**TOTAL**	**18 539.23**

Table J5: Number of computer screens/security monitors/televisions

No	Number of devices	Actual % of companies in this range	No of companies from total of 313	Averag e weight (kg)	Median	Estimated quantity of e-waste (kg)
4.1	Less than 5	64.1	201	30	3	18 057.69
4.2	05 - 10	16.7	52	30	7	10 955.00
4.3	11 - 15	5.1	16	30	13	6 260.00
4.4	16 - 20	1.3	4	30	18	2 166.92
4.5	21 - 25	3.8	12	30	23	8 306.54
4.6	26 - 30	0.0	0	30	28	-
4.7	More than 30	7.7	24	30	31	22 391.54
4.8	No screens/securit y monitors	1	4	0	-	-
		100	313		**TOTAL**	**68 137.69**

***Table J6**: Number of obsolete/redundant computer screens/security monitors/televisions*

No	Number of devices	Actual % of companies in this range	No of companies from total of 313	Average weight (kg)	Median	Estimated quantity of e-waste (kg)
4.1	Less than 5	20.5	64	30	3	5 778.46
4.2	05 - 10	7.7	24	30	7	5 056.15
4.3	11 - 15	1.3	4	30	13	1 565.00
4.4	16 - 20	0.0	0	30	18	-
4.5	21 - 25	0.0	0	30	23	-
4.6	26 - 30	0.0	0	30	28	-
4.7	More than 30	0.0	0	30	31	-
4.8	No broken screens/security monitors	70.5	221	0	-	-
		100	313		**TOTAL**	**12 399.62**

Table J7: Number of air-conditioning units in your organisation

No	Number of devices	Actual % of companies in this range	No of companies from total of 313	Average weight (kg)	Median	Estimated quantity of e-waste (kg)
5.1	Less than 10	80.8	253	55	5	69 522.12
5.2	11 - 20	6.4	20	55	15	16 552.88
5.3	21 – 30	1.3	4	55	25	5 517.63
5.4	More than 30	3.8	12	55	31	20 525.58
5.5	No air-conditioning	7.7	24	0	-	-
		100	313		**TOTAL**	**112 118.21**

Table J8:: Number of obsolete/redundant air-conditioning units in your organisation

No	Number of devices	Actual % of companies in this range	No of companies from total of 313	Average weight (kg)	Median	Estimated quantity of e-waste (kg)
5.1	Less than 10	20.5	64	55	5	17 656.41
5.2	11 - 20	1.3	4	55	15	3 310.58
5.3	21 – 30	0.0	0	55	25	-
5.4	More than 30	0.0	0	55	31	-
5.5	No broken air-conditioning	78.2	245	0	-	-
		100	313		**TOTAL**	**20 966.99**

Table J9: Number of electrical industrial equipment

No	Number of devices	Actual % of companies in this range	No of companies from total of 313	Average weight (kg)	Median	Estimated quantity of e-waste (kg)
6.1	Less than 10	48.7	152	60	5	45 746.15
6.2	10 – 20	23.1	72	60	15	65 007.69
6.3	21 – 30	10.3	32	60	25	48 153.85
6.4	31 – 40	5.1	16	60	35	33 707.69
6.5	41 – 50	1.3	4	60	45	10 834.62
6.6	More than 50	5.1	16	60	51	49 116.92
6.7	No electrical equipment	6.4	20			
		100.0	313		**TOTAL**	**252 566.92**

Table J10: Number of obsolete/redundant electrical industrial equipment

No	Number of devices	Actual % of companies in this range	No of companies from total of 313	Average weight (kg)	Median	Estimated quantity of e-waste (kg)
6.1	Less than 10	27	84	60	5	25 280.77
6.2	10 – 20	1	4	60	15	3 611.54
6.3	21 – 30	0	0	60	25	-
6.4	31 – 40	0	0	60	35	-
6.5	41 – 50	0	0	60	45	-
6.6	More than 50	0	0	60	51	-
6.7	No electrical equipment	72	225			
		100.0	313		**TOTAL**	**28 892.31**

ANNEXURE K

Table of Wilcoxon test *p*-values

Test Statistics[a]

	Number of desktop/laptop computers in your organisation that are obsolete/redundant - Number of desktop/laptop computers in your organisation currently in use	Total number of printers/photocopiers/scanners/ fax machines that are obsolete/redundant - Total number of printers/photocopiers/scanners/ fax machines currently in use	Total number of computer screens/security monitors/televisions that are obsolete/redundant - Total number of computer screens/security monitors/televisions currently in use	Total number of air-conditioning units in your organisation that are obsolete/redundant - Total number of air-conditioning units in your organisation currently in use	Total number of electrical equipment that are obsolete/redundant - Total number of electrical equipment currently in use
Z	-1.946[b]	-1.580[b]	-2.444[b]	-1.604[b]	-3.316[b]
Asymp. Sig. (2-tailed)	.052	.114	.015	.109	.001

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

ANNEXURE L

One-Sample Kolmogorov-Smirnov Test

		Number of desktop/laptop computers in your organisation currently in use	Number of desktop/laptop computers in your organisation that are obsolete/redundant	Total number of printers/photocopiers/scanners / fax machines currently in use	Total number of printers/photocopiers/scanners/ fax machines that are obsolete/redundant	Total number of computer screens/security monitors/televisions currently in use	Total number of computer screens/security monitors/televisions that are obsolete/redundant	Total number of air-conditioning units in your organisation currently in use	Total number of air-conditioning units in your organisation that are obsolete/redundant	Total number of electrical equipment currently in use	Total number of electrical equipment that are obsolete/redundant
N		76	24	75	21	77	23	72	17	73	22
Normal Parameters[a,b]	Mean	1.93	1.75	1.28	1.19	1.94	1.35	1.22	1.06	1.96	1.05
	Std Deviation	1.731	1.391	.781	.680	1.757	.573	.676	.243	1.369	.213
Most Extreme Differences	Absolute	.327	.330	.467	.515	.352	.424	.504	.537	.279	.539
	Positive	.327	.330	.467	.515	.352	.424	.504	.537	.279	.539
	Negative	-.295	-.295	-.360	-.390	-.297	-.272	-.371	-.404	-.242	-.416
Kolmogorov-Smirnov Z		2.850	1.617	4.042	2.361	3.089	2.033	4.275	2.214	2.382	2.528
Asymp. Sig. (2-tailed)		.000	.011	0.000	.000	.000	.001	0.000	.000	.000	.000

a. Test distribution was Normal. b. Calculated from data

ANNEXURE M

The table of correlations

Spearman's rho (r_s-values)																										
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24		
Spearman's rho	C1	Correlation Coefficient	1.000																							
		Sig. (2-tailed)																								
		N	78																							
	C2	Correlation Coefficient	-.037	1.000																						
		Sig. (2-tailed)	.748																							
		N	76	76																						
	C3	Correlation Coefficient	.103	.506*	1.000																					
		Sig. (2-tailed)	.631	.012																						
		N	24	24	24																					
	C4	Correlation Coefficient	-.037	.467**	.263	1.000																				
		Sig. (2-tailed)	.756	.000	.214																					
		N	75	75	24	75																				

	C5	Correlation Coefficient	.072	.321	.451	.188	1.000																		
		Sig. (2-tailed)	.757	.155	.060	.413																			
		N	21	21	18	21	21																		
	C6	Correlation Coefficient	.010	.716**	.556**	.629**	.325	1.000																	
		Sig. (2-tailed)	.933	.000	.005	.000	.150																		
		N	77	75	24	75	21	77																	
	C7	Correlation Coefficient	.123	.686**	.904**	.259	.583*	.659**	1.000																
		Sig. (2-tailed)	.578	.000	.000	.244	.014	.001																	
		N	23	22	20	22	17	23	23																
	C8	Correlation Coefficient	-.217	.441**	.073	.663**	.253	.609**	.247	1.000															
		Sig. (2-tailed)	.067	.000	.736	.000	.269	.000	.255																
		N	72	70	24	70	21	72	23	72															
	C9	Correlation Coefficient	-.053	-.159		-.159		-.159			1.000														
		Sig. (2-tailed)	.840	.543		.542		.543																	
		N	17	17	12	17	12	17	12	14	17														

	C10	Correlation Coefficient	-.078	.384**	.109	.418**	.094	.496**	.092	.375**	-.217	1.000														
		Sig. (2-tailed)	.510	.001	.620	.000	.687	.000	.683	.002	.420															
		N	73	71	23	70	21	72	22	67	16	73														
	C11	Correlation Coefficient	.232	.371	.421	.444*	1.000**	.358	.387	.399		.342	1.000													
		Sig. (2-tailed)	.298	.098	.082	.044		.102	.125	.066		.129														
		N	22	21	18	21	14	22	17	22	14	21	22													
	C12	Correlation Coefficient	-.129	.295**	.495*	.188	.098	.466**	.448*	.257*	-.027	.296*	-.071	1.000												
		Sig. (2-tailed)	.259	.010	.014	.107	.674	.000	.032	.029	.918	.011	.752													
		N	78	76	24	75	21	77	23	72	17	73	22	78												
	C13	Correlation Coefficient	.174	-.069	-.149	.006	-.240	-.167	-.074	-.145	-.296	-.261*	-.303	-.226*	1.000											
		Sig. (2-tailed)	.134	.556	.488	.960	.295	.152	.744	.231	.249	.028	.181	.050												
		N	76	76	24	75	21	75	22	70	17	71	21	76	76											
	C14	Correlation Coefficient	.104	-.074	-.302	.102	-.461*	.038	-.417	-.051	-.264	.164	-.433*	.040	.192	1.000										
		Sig. (2-tailed)	.371	.525	.152	.383	.036	.748	.054	.676	.305	.172	.050	.734	.097											
		N	76	76	24	75	21	75	22	70	17	71	21	76	76	76										

	C15	Correlation Coefficient	-.068	-.214	-.483*	-.166	-.205	-.244*	-.462*	-.135	.236	-.112	-.194	-.393**	-.009	-.041	1.000										
		Sig. (2-tailed)	.561	.064	.017	.156	.373	.035	.030	.264	.362	.352	.400	.000	.940	.728											
		N	76	76	24	75	21	75	22	70	17	71	21	76	76	76	76										
	C16	Correlation Coefficient	.098	-.071	-.169	-.286*	-.133	-.193	.023	-.207		-.124	-.171	-.363**	.061	-.115	.717**	1.000									
		Sig. (2-tailed)	.496	.619	.477	.042	.611	.175	.931	.154		.397	.526	.009	.671	.420	.000										
		N	51	51	20	51	17	51	17	49	12	49	16	51	51	51	51	51									
	C17	Correlation Coefficient	-.038	.093	.000	.151	.123	.177	-.125	.325**		.207	.269	-.149	-.354**	.004	.233	.155	1.000								
		Sig. (2-tailed)	.761	.460	.999	.230	.627	.157	.609	.010		.103	.279	.232	.004	.977	.060	.276									
		N	66	66	21	65	18	65	19	62	13	63	18	66	66	66	66	51	66								
	C18	Correlation Coefficient	.156	.030	.051	-.076	.036	.001	.033	.111		-.087	-.057	.081	.024	-.080	.021	.050	.083	1.000							
		Sig. (2-tailed)	.202	.808	.814	.537	.878	.993	.886	.377		.496	.805	.508	.847	.512	.861	.732	.522								
		N	69	69	24	69	21	69	22	65	16	64	21	69	69	69	69	50	61	69							
	C19	Correlation Coefficient	-.085	.055	.345	-.004	.095	.138	.334	.106	-.436	.042	-.149	-.006	.276*	.111	-.122	-.053	.048	-.071	1.000						
		Sig. (2-tailed)	.459	.634	.099	.973	.681	.232	.120	.375	.081	.727	.508	.959	.016	.338	.294	.711	.702	.564							
		N	78	76	24	75	21	77	23	72	17	73	22	78	76	76	76	51	66	69	78						

	C20	Correlation Coefficient	-.063	-.260*	-.290	-.033	-.230	-.199	-.339	.057	-.056	.087	-.059	.097	.095	.076	.053	-.041	-.048	-.025	-.117	1.000				
		Sig. (2-tailed)	.587	.025	.170	.780	.316	.084	.114	.636	.830	.464	.795	.404	.418	.514	.653	.773	.703	.840	.311					
		N	77	75	24	74	21	76	23	71	17	73	22	77	75	75	75	51	66	68	77	77				
	C21	Correlation Coefficient	-.120	.280*	.265	.094	.230	.227*	.306	.119	-.337	.054	-.020	-.042	.195	-.106	.070	-.010	.092	-.023	.660**	-.149	1.000			
		Sig. (2-tailed)	.297	.014	.210	.425	.316	.047	.156	.319	.185	.653	.931	.712	.091	.364	.551	.944	.461	.851	.000	.195				
		N	78	76	24	75	21	77	23	72	17	73	22	78	76	76	76	51	66	69	78	77	78			
	C22	Correlation Coefficient	.036	-.072	-.149	.112	-.316	-.032	-.347	-.077	-.270	.149	-.183	.038	.096	.194	.036	.182	-.188	.059	-.146	.013	-.289*	1.000		
		Sig. (2-tailed)	.755	.534	.487	.341	.163	.779	.105	.522	.295	.209	.415	.742	.410	.093	.756	.200	.130	.631	.203	.909	.010			
		N	78	76	24	75	21	77	23	72	17	73	22	78	76	76	76	51	66	69	78	77	78	78		
	C23	Correlation Coefficient	-.136	.053	.407*	.117	.413	.058	.334	.012	-.220	.023	.235	.028	.025	.249*	-.145	.008	-.096	-.138	.219	-.122	.214	.102	1.000	
		Sig. (2-tailed)	.241	.652	.049	.322	.063	.622	.120	.921	.413	.852	.293	.810	.834	.032	.218	.956	.444	.266	.057	.296	.063	.382		
		N	76	74	24	73	21	75	23	71	16	71	22	76	74	74	74	50	65	67	76	75	76	76	76	
	C24	Correlation Coefficient	.037	.013	-.023	-.036	-.205	.081	-.044	-.088	-.185	-.111	-.165	.109	-.033	-.105	.078	.084	-.063	.292*	-.276*	.067	-.174	.139	-.240*	1.000
		Sig. (2-tailed)	.747	.910	.915	.761	.373	.482	.841	.461	.478	.351	.463	.342	.777	.365	.500	.560	.613	.015	.014	.562	.127	.224	.037	
		N	78	76	24	75	21	77	23	72	17	73	22	78	76	76	76	51	66	69	78	77	78	78	76	78

KEY 1:

Question	Symbol	Question	Symbol
What is your organisation's core business activity?	C1	To what extent do you agree or disagree with the statement that "there is limited information available on e-waste recycling in this area"?	C13
Number of desktop/laptop computers in your organisation currently in use	C2	If the equipment, as described in 5 and 6 above malfunctions, what does your organisation do?	C14
Number of desktop/laptop computers in your organisation that are broken	C3	Does your organisation currently store broken, obsolete/redundant electronic and electrical equipment?	C15
Total number of printers/photocopiers/scanners/ fax machines currently in use	C4	Where does your company store your broken/redundant electronic equipment?	C16
Total number of printers/photocopiers/scanners/ fax machines that are broken	C5	Which of the following can be a reason for not disposing broken/redundant electronic equipment?	C17
Total number of computer screens/security monitors/televisions currently in use	C6	How does your organisation currently dispose of its obsolete/redundant electronic and electrical equipment?	C18
Total number of computer screens/security monitors/televisions that are broken	C7	To what extent do you agree or disagree with the statement that "it is important for organisations to have a strategy for the management of redundant/obsolete electronic and electrical equipment"?.	C19
Total number of air-conditioning units in your organisation currently in use	C8	Are you aware of any legislation that deals with the disposal of obsolete/redundant electronic and electrical equipment?	C20
Total number of air-conditioning units in your organisation that are broken	C9	To what extent do you agree or disagree with the statement that "broken/redundant electronic and electrical equipment contains harmful substances to the environment"?	C21
Total number of electrical equipment currently in use	C10	To what extent do you agree or disagree with the statement that "broken/redundant electronic and electrical equipment contains no value"?	C22
Total number of electrical equipment that are broken	C11	To what extent do you agree or disagree with the statement that "there is a serious e-waste problem in Durban?	C23
To what extent do you agree or disagree with this statement: "our company has the potential to generate a large volume of e-waste"?	C12	Would your organisation consider supporting an e-waste recycling plant in this area?	C24

KEY 2:

*	Correlation was significant at the 0.05 level (2-tailed).
**	Correlation was significant at the 0.01 level (2-tailed).
(red)	Positive values indicate a directly proportional relationship between the variables
(blue)	Negative value indicates an inverse relationship

ANNEXURE N

Chi-Square Tests

			What is your organisation's core business activity?														
			Chemicals; chemical, rubber & plastic products	Educational services	Engineering	Food producers & processors	Financing, insurance, real estate & business services	Clothing, footwear, and textiles	Construction & Building materials	Electronic & electrical equipment	Transport, communication & storage	Health services	Paper, Printing & Publishing	Retail trade	Wholesale trade	Other	Total
How does your organisation currently dispose of its obsolete/redundant electronic and electrical equipment?	Treat it as ordinary office bin/municipal waste	Count	1	0	0	0	0	0	2	1	0	0	0	0	0	5	9
		% within What is your organisation's core business activity?	11.1%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	14.3%	0.0%	0.0%	0.0%	0.0%	0.0%	21.7%	13.0%
	Dump	Count	0	1	0	2	0	0	2	0	0	0	0	0	0	1	6

	it in specifically marked bins for Electronic Waste	% within What is your organisation's core business activity?	0.0%	100.0%	0.0%	66.7%	0.0%	0.0%	25.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.3%	8.7%
	Dismantle and recycle it in-house	Count	1	0	0	1	0	1	1	2	2	0	0	0	0	1	9
		% within What is your organisation's core business activity?	11.1%	0.0%	0.0%	33.3%	0.0%	50.0%	12.5%	28.6%	50.0%	0.0%	0.0%	0.0%	0.0%	4.3%	13.0%
	Donate old electronic and electrical equipment	Count	5	0	1	0	1	0	1	0	0	1	0	0	1	6	16
		% within What is your organisation's core business activity?	55.6%	0.0%	25.0%	0.0%	100.0%	0.0%	12.5%	0.0%	0.0%	33.3%	0.0%	0.0%	100.0%	26.1%	23.2%
	Ask a	Count	2	0	0	0	0	1	0	3	0	0	0	0	0	1	7

	recycling company to pick it up	% within What is your organisation’s core business activity?	22.2%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	42.9%	0.0%	0.0%	0.0%	0.0%	0.0%	4.3%	10.1%
	Supplier comes and takes it back	Count	0	0	2	0	0	0	0	1	1	0	1	0	0	2	7
		% within What is your organisation’s core business activity?	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	14.3%	25.0%	0.0%	50.0%	0.0%	0.0%	8.7%	10.1%
	Don’t know	Count	0	0	1	0	0	0	2	0	1	2	1	1	0	7	15
		% within What is your organisation’s core business activity?	0.0%	0.0%	25.0%	0.0%	0.0%	0.0%	25.0%	0.0%	25.0%	66.7%	50.0%	100.0%	0.0%	30.4%	21.7%
Total		Count	9	1	4	3	1	2	8	7	4	3	2	1	1	23	69

	% within What is your organisation’s core business activity?	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Test

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	99.403[a]	78	.052	.	
Likelihood Ratio	89.300	78	.180	.	
Fisher's Exact Test	84.655			.018	
Linear-by-Linear Association	1.368	1	.242	.	.
N of Valid Cases	69				

a. 96 cells (98.0%) have expected count less than 5. The minimum expected count is .09.

b. Cannot be computed because there is insufficient memory.

c. Cannot be computed because the time limit has been exceeded.