AN INVESTIGATION OF THE GREENHOUSE GAS EMISSION SAVINGS AND LANDFILL SPACE SAVINGS FROM VOLUNTARY RECYCLING ACTIVITIES BY DURBAN SOLID WASTE IN THE ETHEKWINI MUNICIPALITY FOR 2009-2014

by

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ABSTRACT

This study investigated the greenhouse gas emission savings and landfill space savings of voluntary recycling activities by Durban Solid Waste in the eThekwini Municipality for the period from 2009 to 2014. The study investigates recycling practices and quantifies greenhouse gas emission savings and landfill space savings due to voluntary recycling of mainline recyclables in eThekwini Municipality. The mainline recyclables selected for this study due to the availability of comprehensive historical recycling data are defined as paper, plastics, glass and cans, which were collected at recycling centres within the municipal footprint. This study is important because reduced greenhouse gas emissions mitigate against global warming and recycling extends the lifespan of existing landfills which benefits the environment. The literature review provided context to municipal waste management based on previous research conducted in South Africa and other world regions.

South African greenhouse gas emission factors were used to calculate emission savings and the Environmental Benefits of Recycling Calculator method was used to calculate the landfill space savings. Descriptive statistics were used to interpret recycling data patterns across the mainline recyclables. Regression analysis was used to generate predictive regression models to forecast future mainline recyclables. Furthermore, the forecasted recycling data was used to predict future greenhouse gas emission savings and landfill space savings. Mainline recyclables data from 2009 to 2014 for voluntary recycling in eThekwini Municipality was made available for this study by Durban Solid Waste. The mainline recyclables diverted from landfills during this period amounted to 97 953 tonnes. This generated greenhouse gas emission savings and landfill space savings amounting to 66 708 tonnesCO_2e and 383 591m^3 respectively. These greenhouse gas emission savings represent approximately 11% of annual emissions in eThekwini and the landfill space savings represent approximately a two-year extension to the lifespan of Mariannhill landfill site. Further research opportunities would involve the investigative study of local greenhouse gas emission factors and local landfill space savings factors for other recyclable materials.

PREFACE

I, Jackson N. Marange, declare that:

(i) The research reported in this dissertation, except where otherwise indicated, is my original work.

(ii) This dissertation has not been submitted for any degree or examination at any other university.

(iii) This dissertation does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

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………J.N. Marange……………………… …………...14-05-2020……

Jackson Ngonidzashe Marange Date

As the candidate's supervisor, I have approved this dissertation for submission.

……… N. Matete ……… 14/05/2020

Dr. N. Matete (Supervisor) Date

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List of Abbreviations

CBC- Community Based Contractors

CDM- Clean Development Mechanism

CSIR- Council for Scientific and Industrial Research

DEA- Department of Environmental Affairs

DEAT- Department of Environmental Affairs and Tourism

DECWA- Department of Environment and Conservation of Western Australia

DSW- Durban Solid Waste

DWAF- Department of Water Affairs and Forestry

EBRC- Environmental Benefits of Recycling Calculator

EC- European Community

EEA- European Economic Area

EIA- Environmental Impact Assessment

EMIs- Environmental Management Inspectors

EMS- Environmental Management Systems

EPA- Environmental Protection Agency

EU- European Union

GHG- Greenhouse Gases

GJ- Gigajoules

IDP- Integrated Development Plan

IEA- International Energy Agency

IndWMPs- Industrial Waste Management Plans

IPCC- Intergovernmental Panel for Climate Change

IP&WM- Integrated Pollution and Waste Management

ISWA- International Solid Waste Association

IWMP- Integrated Waste Management Plans

IWMSA- Institute of Waste Management of Southern Africa

KZN- KwaZulu-Natal

LCA- Life Cycle Assessment

LSS- Landfill Space Savings

MCPP- Municipal Climate Protection Programme

MDG- Millennium Development Goals

MRFs- Material Recovery Facilities

n.d- no date

NEMA- National Environmental Management Act

NSW- New South Wales

NWIBR- National Waste Information Baseline Report

NWMS- National Waste Management Strategy

PRASA- Paper Recycling Association of South Africa

SAWIC- South African Waste Information Centre

SAWIS- South African Waste Information System

SD- Standard Deviation

SMEs- Small and Medium Enterprises

SMMEs- Small, Medium and Micro Enterprises

SPSS- Statistical Package for Social Sciences

Stats SA- Statistics South Africa

UK- United Kingdom

UNCED- United Nations Conference on Environment and Development

UNEP- United Nations Environment Programme

USA- United States of America

US EPA- United States Environmental Protection Agency

WARM- Waste Reduction Model

WIS- Waste Information System

WRAP- Waste and Resources Action Programme

WRATE- Waste and Resources Assessment Tool for the Environment

ZWIA- Zero Waste International Alliance

CHAPTER 1

1. INTRODUCTION

1.1 General Overview

South Africa has the largest gross domestic product among African countries south of the Sahara, and is also the leading polluter on the African continent with regards to GHG emissions (Seymore et al., 2014). According to Lee et al. (2016), the volume of waste produced in urban settlements in the world is projected to increase by 0.9 billion tonnes between 2009 and 2025 to reach 2.2 billion tonnes per annum in 2025. According to Minghua et al. (2009), population, economic growth and affluence are the leading factors behind the increased generation of municipal waste in developing nations.

Population growth is also having a bearing on South Africa's urbanisation, waste production and waste management (DEA, 2016). A World Bank survey concluded that approximately two out of every three South Africans live in urban settlements (South African Institute of Race Relations, 2013). Ezeah et al. (2013), Sentime (2011), and Simatele and Etambakonga (2015) agreed that urban population growth has adversely affected South African municipal waste management services.

Most cities in Africa, South Africa included, lack the requisite infrastructure and organisational structures to provide sustainable waste management services (Simatele and Etambakonga, 2015). Most African countries also lack comprehensive policies and legislative frameworks which support investment in recycling and waste management (Simelane and Mohee, 2015). The promotion of recycling activities in these countries would assist with establishment of sustainable municipal waste management services and socio-economic service delivery.

Climate change and global warming are very significant environmental problems facing mankind today; some studies have researched the interrelationship between greenhouse gas emissions and increased generation of waste (Kennedy et al., 2009; Gentil et al., 2009; Friedrich and Trois, 2010). Numerous studies have suggested that the implementation of zero waste and waste diversion strategies could result in significant greenhouse gas and carbon reductions (Couth and Trois, 2010; cited in Jagath, 2010). According to Friedrich and Trois (2016), reduced waste generation gives rise to lesser GHG emissions and the lifespan extension of landfill sites. For Mariannhill landfill site, there are additional environmental paybacks given that residual waste is landfilled at a site with greenhouse gas extraction and electricity generation capabilities (Friedrich and Trois, 2016).

It is important to always monitor, quantify and strive for the reduction of greenhouse gases in waste management processes. Approximately 3% of GHG emissions in the world are accredited to waste handling, with waste related activities accounting for up to 18% of global methane emissions (Bogner et al., 2008). South Africa exhibits similar trends with 2% of greenhouse gases accredited to waste handling, and 12% of methane gas accredited to related waste management activities (DEAT, 2009b). Despite the relatively minor GHG emission percentage credited to the waste sector, it is imperative to investigate this, bearing in mind that waste streams are uniquely placed to shift from minor sources of greenhouse gases to key emission savers (UNEP, 2010). Increases in waste streams and greenhouse gas emissions, and restricted capacity of landfill sites dictate the necessity to adopt sustainable waste management strategies like waste reduction, reuse and recycling.

According to Fakir (2009), recycling benefits go beyond the reduction in environmental costs with some of its cost-benefits listed hereunder:

- Energy savings from reduced dependence on production from virgin sources
- Landfill space savings and related costs of constructing new landfill sites
- Reduced costs of environmental and health externalities through waste disposal reduction
- Employment creation, particularly in developing countries
- Savings on the exploitation of mineral ores and other virgin materials

1.2 Motivation of the Research

The South African government responded to the challenge of waste management by enacting the National Environmental Management: Waste Act (Act No. 59 of 2008). This law integrated and consolidated existing waste laws into one effective waste statute. Subsequently, the National Waste Management Strategy (NWMS) was constituted as a legislative requirement of the Waste Act, with the aim of attaining the objects of the Waste Act. The key target of the NWMS which proposed a diversion of 25% of recyclables from landfill sites by 2016 primarily motivated me to embark on this study; with specific focus on recycling in eThekwini Municipality. The Waste Act and the NWMS were borne out of the overarching vision of the Polokwane Declaration on Waste Management of 2001, which proposed the reduction of waste production by half and waste disposal by a quarter by 2012, and preparation of Zero Waste plans by the year 2022. Though the

Polokwane Declaration targets were overly optimistic, they did provide an inspirational vision which resulted in the enactment of the Waste Act and the NWMS, as well as setting up South Africa on a sustainable waste management trajectory and heading towards a future zero-waste society.

Climate change is triggered by GHG emissions (IPCC, 2007). According to eThekwini Municipality (eThekwini IDP, 2017/18), climate change is causing environmental challenges in eThekwini Municipality, such as increased temperatures, inclement weather patterns and ocean level rise. It is forecasted that Durban temperatures will rise by 1.5ºC-2.5ºC by 2065 and 3.0ºC-5.0ºC by 2100 (eThekwini IDP, 2017/18). Annual precipitation is projected to go up by 500mm by 2100 (eThekwini IDP, 2017/18). Ocean levels along eThekwini's coastline are currently rising by 2.7cm every decade (eThekwini IDP, 2017/18).

It is against this backdrop that this study was conducted to establish whether recycling could attest to be a worthwhile waste management strategy for eThekwini, in pursuit of the 25% waste diversion from landfills proposed by the NWMS. The study aims to investigate the key environmental benefits of greenhouse gas emission savings and landfill space savings resulting from voluntary recycling of mainline recyclables by Durban Solid Waste in eThekwini Municipality for the period from 2009 to 2014. It also seeks to establish whether the emission savings and landfill space savings due to recycling of mainline recyclables rationalises the augmentation of recycling programmes in the municipality. The mainline recyclables which are defined by paper, plastics, glass and cans were selected for this study due to the availability of comprehensive historical recycling data.

1.3 Description of the Study Area

The study is located in the eastern coastal metro of Durban in eThekwini Municipality of KZN province. The municipality lies in an important biodiversity area of diverse topography, 98kms of coastline, 18 major catchments, 16 estuaries, 4000 kms of rivers and 78 781.8 hectares of land (eThekwini IDP, 2017/18). The population of eThekwini Municipality in 2016 was 3.7 million and is predicted to reach 3.8 million in 2019 (eThekwini IDP, 2017/18).

eThekwini Municipality boundary lies on the northern town of Tongaat and the southern boundary is around Umkomaas. eThekwini covers an area of approximately 2, 297km^2 (eThekwini IWMP, 2016-21). eThekwini is currently serviced by three landfill sites namely, Buffelsdraai, Mariannhill and Lovu landfill sites. Bisasar Road Landfill Site used to be the fourth landfill site in the metro until it was decommissioned in 2014, with the bulk of waste previously destined for the landfill site now being landfilled at Buffelsdraai Landfill Site (Kolekar et. al., 2016). eThekwini Municipality is split into four main waste management regions namely, Central, West, North and South (eThekwini IWMP, 2016-21). Figure 1.1 below presents the waste management regions in eThekwini Municipality.

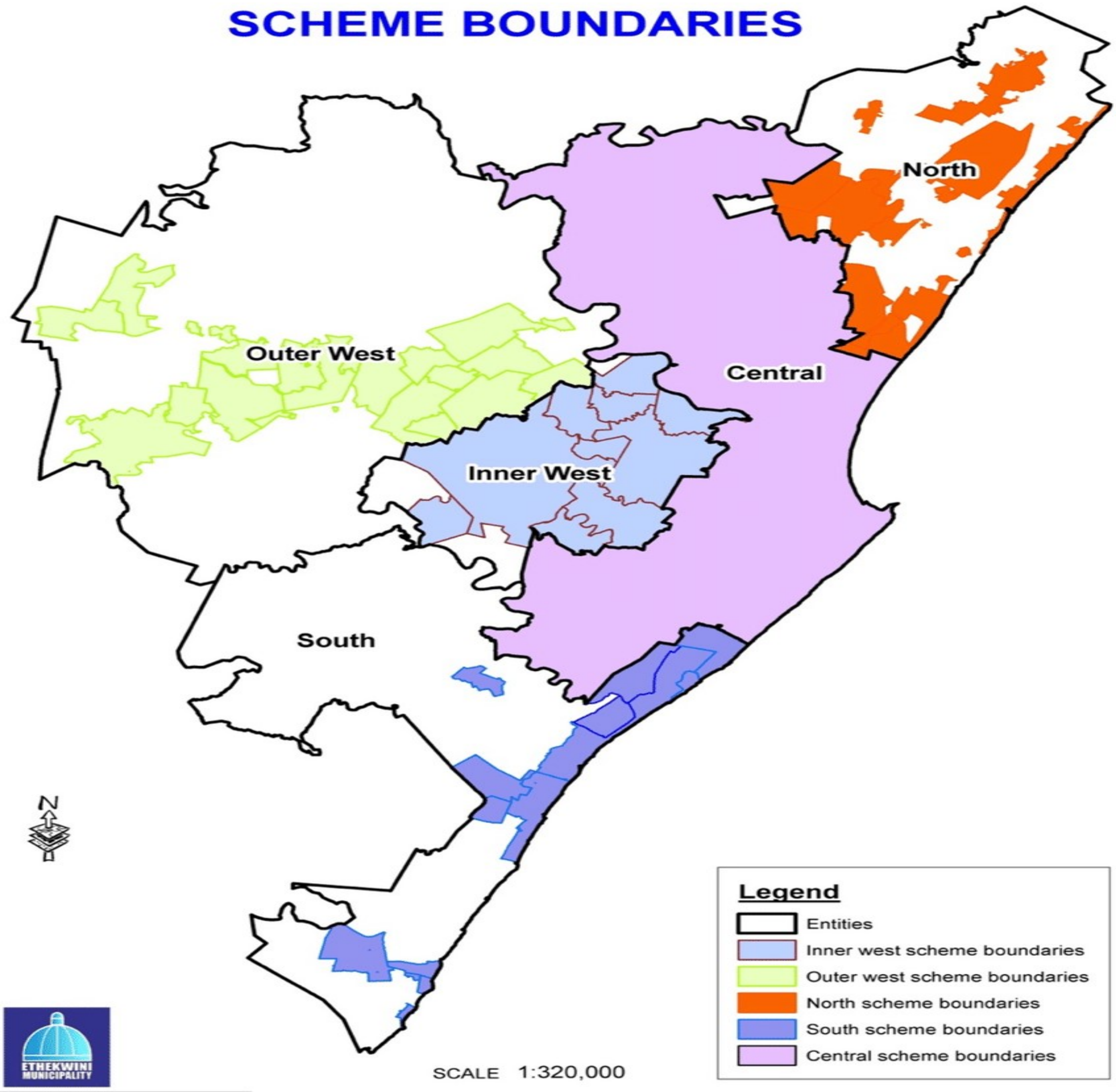

Figure 1.1: Map of Showing eThekwini Municipality Waste Management Regions (Davids et al, 2018)

1.4 Background of the Study

The leading factors behind increased municipal waste generation are economic and population growth (Minghua et al., 2009). Existing environmental infrastructure and budgetary allocations are inadequate to serve the ever-growing waste streams in developing nations like South Africa. According to DEAT (2000), waste hierarchy forms the bedrock of waste management in local municipalities. The waste hierarchy model is founded on the concepts of waste prevention and reduction, re-use, recycling, recovery and composting (DEA, 2011).

According to Oelofse and Strydom (2010), monetary incentives are the key recycling drivers in industry with environmental considerations aided by convenience having a major bearing on household recycling in South Africa.

Recycling diverted 10% of South African waste, with landfilling accounting for 90% in 2011 (DEA, 2012b). According to the CSIR (2011), an estimated 25% of municipal waste consisted of recyclables; namely, paper, plastics, cans and glass. The most viable strategy which can meaningfully alleviate pressure on landfill air space is a decrease in waste streams going to landfills through waste minimisation and recycling (CSIR, 2011).

Kwazulu-Natal province generated approximately 9% of the South African waste in 2011, amounting to 9.7 million tonnes (SAWIC, 2014). Approximately 1,4% of South African waste was generated in eThekwini Municipality, and the municipality is currently attaining a waste recycling rate of approximately 7,6% (SAWIC, 2014). Recycling in eThekwini Municipality is the responsibility of DSW. It is implemented through various mechanisms namely; drop-off centres, buy-back centres, business sites, garden sites, and orange and clear bag kerbside recycling schemes (eThekwini IWMP, 2016-21).

DSW is the waste management unit of eThekwini Municipality. It operates four landfill sites, namely, Mariannhill landfill site (western region), Buffelsdraai landfill site (northern region), Bisasar Road landfill site (north central region) and Lovu Road landfill site (southern region) (eThekwini IWMP, 2016-21). DSW also operates seven major transfer stations, fourteen garden refuse transfer stations, seven buyback centres, two landfill gas to energy plants and two leachate treatment plants (eThekwini IWMP, 2016-21). The biggest of the four landfill sites, Bisasar Road, was decommissioned in 2014 (Kolekar et al., 2016). The bulk of the waste previously destined for that landfill site is now being taken for compaction to Electron Road transfer station in Durban, and then transported for landfilling to Buffelsdraai landfill site (eThekwini IWMP, 2016-21).

eThekwini Municipality's commitment to waste minimisation and recycling is demonstrated by its Integrated Waste Management Policy which is informed by the Waste Hierarchy (DSW's Essentially Better, n.d). Waste Hierarchy promotes the prioritisation of waste reduction, re-use and recycling (Waste Act, 2008). It gives priority to recycling from municipal waste streams, thus categorising waste as a resource which can be used as inputs in manufacturing processes (DEA, 2010). According to Lemmer

(2012), South Africa landfills roughly 90% of locally produced waste. Landfilling should be used for 5% of waste streams, with 95% being recycled or treated by waste treatment technology (Lemmer, 2012). Although landfilling remains the main waste disposal method in South African municipalities, the government is devoted to greenhouse gas mitigation in all spheres of society (DEAT, 2009a).

1.5 The Research Question, Aim and Objectives of the Study

1.5.1 Research Question

The research question to be answered in this study is;

- What are the greenhouse gas emission savings and landfill space savings resulting from voluntary recycling of mainline recyclables (paper, plastics, glass and cans) by Durban Solid Waste in eThekwini Municipality from 2009 to 2014?

1.5.2 Aim of the Study:

The study aims to investigate the greenhouse gas emission savings and landfill space savings resulting from voluntary recycling of mainline recyclables (paper, plastics, glass and cans) by Durban Solid Waste in eThekwini Municipality for the period from 2009 to 2014.

1.5.3 Objectives of the Study:

The objectives of the study are;

- To investigate the GHG emission savings resulting from recycling of mainline recyclables by DSW in eThekwini Municipality.
- To investigate the LSS generated as a result of recycling of mainline recyclables by DSW in eThekwini Municipality.
- To develop predictive regression models for forecasting the amounts of mainline recyclables generated in eThekwini Municipality.

1.6 Chapters Layout

This dissertation consists of five chapters. Chapter 1 serves to introduce the research study. Chapter 2 presents a literature review which establishes the research context. Chapter 3 describes the methodology employed to realise the research outcomes and the assumptions and delimitations of the study. Chapter 4 focuses on data presentation, data analysis and discussion of the results. Chapter 5 outlines the Conclusions as derived from the study findings and recommendations for further research.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Waste Management Overview

This chapter provides a contextual background to waste management in eThekwini Municipality, South Africa and other regions of the world. It explores the concept of sustainable waste management, whilst placing strong emphasis on recycling which is the key subject of study in this research. In developing nations like South Africa, municipal waste has developed into a serious environmental threat. Minghua et al. (2009) indicated that population and economic growth are the principal factors causing increased waste production in both developing and developed nations. Existing environmental infrastructure and budgetary allocations are inadequate to serve the ever-growing population and waste streams in developing nations like South Africa (Pilusa and Muzenda, 2013). According to the CSIR (2011), the challenges affecting local municipal solid waste management are equipment, labour management, financial management and lack of planning.

Generation of waste is associated with populace, community living standards and urbanisation (Bogner et al., 2008). Increased generation of waste is an inadvertent by-product of economic growth, with key drivers of waste production being growing economies, increased product manufacturing and population growth (DEA, 2012a). However, it should also be noted that waste minimisation and recycling initiatives can assist in decoupling the notion that economic development is interlinked with waste generation. According to Friedrich and Trois (2011), developing countries also face challenges when it comes to the collation, accounting and reporting of ever-increasing amounts of greenhouse gas emissions from waste at municipal level. However, promotion of recycling as the cornerstone of eThekwini Municipality's waste management strategy will result in substantial GHG emission savings (DSW's Essentially Better, n.d).

Waste management legislation serves to monitor and control waste management activities, whilst promoting waste minimisation and sustainability (Austin and Gets, 2009; cited in Jagath, 2010). According to eThekwini Municipality (eThekwini IDP, 2017/18), there has been advancement in environmental statutes which focus on promoting environmentally sustainable waste practices by both the government and private citizens. The key law and regulations which govern waste management in

South Africa, namely, National Environmental Management: Waste Act (Act No. 59 of 2008) and National Waste Management Strategy (2011), are discussed in the next two sections. The National Environmental Management: Waste Act, 2008 prescribes the increased diversion of waste away from landfills towards re-use, recycling and recovery. Through the regulations to the Waste Act, the National Waste Management Strategy (NWMS), the South African government set a target of 25% diversion of recyclables from landfills for re-use, recycling and recovery (DEA, 2011); which happens to be the key motivator for this study with respect to eThekwini Municipality. Further to the recycling investigative study in eThekwini, the study also seeks to establish if recycling in eThekwini is in alignment with the national average recycling rate of 10% and the waste diversion rate of 25% as prescribed in the NWMS; if not, concrete proposals would be recommended to enhance and augment recycling in the municipality.

2.1.1 National Environmental Management: Waste Act

The National Environmental Management: Waste Act (Act No. 59 of 2008) was enacted in 2009.The Act reforms and integrates old discrete waste laws into one consolidated, coordinated and effective legislation (DEA, 2008). The Act defines the laws and regulations governing waste management processes, with many of them applicable to eThekwini Municipality (eThekwini IWMP, 2016-21). In fulfilment of the rights vested in Section 24 of the South African Constitution, the Waste Act further establishes a general duty of the State to “put in place uniform measures that seek to reduce the amount of waste that is generated and, where waste is generated, to ensure that waste is reused, recycled and recovered in an environmentally sound manner before being safely treated and disposed of” (Waste Act, 2008).

According to the National Environmental Management: Waste Act (2008), “waste means any substance, whether or not that substance can be reduced, re-used, recycled and recovered.” The Act states that a “waste disposal facility means any site or premise used for the accumulation of waste with the purpose of disposing of that waste at that site or on that premise” (Waste Act, 2008). Disposal is defined as “the burial, deposit, discharge, abandoning, dumping, placing or release of any waste into, or onto, any land (Waste Act, 2008). According to the National Environmental Management: Waste Act (2008), waste minimisation is “the avoidance of the amount and toxicity of waste that is generated and, in the event where waste is generated, the reduction of the amount and toxicity of waste that is disposed of”. Recycling is a “process where waste is reclaimed for further use, which process involves the separation of waste from a waste stream for further use and the processing of that separated material as a product or raw material" (Waste Act, 2008). The Waste Act (2008) defines reuse as a process meant to "utilise articles from the waste stream again for a similar or different purpose without changing the form or properties of the articles".

The Objects of the National Environmental Management: Waste Act (2008) are listed hereunder;

(a) "to protect health, well-being and the environment by providing reasonable measures;
(b) to ensure that people are aware of the impact of waste on their health, well-being and the environment;
(c) to provide for compliance with the measures set out in paragraph (a); and
(d) generally, to give effect to Section 24 of the Constitution in order to secure an environment that is not harmful to health and well-being:" (Waste Act, 2008).

The National Environmental Management: Waste Act (2008) places significant importance on the preparation of IWMP by government entities, municipalities and identified industrial sectors. Prior to the Waste Act (2008), waste management was administrated by various legislations which were administered by different government departments. This disjointed methodology to waste management resulted in ineffective and uncoordinated waste practices. The Waste Act (2008) consolidated and restructured the country's waste management legislation.

2.1.2 National Waste Management Strategy (NWMS)

The National Waste Management Strategy (NWMS) is a legislative requirement of the National Environmental Management: Waste Act (Act No. 59 of 2008). The aim of the NWMS is to attain the objects of the Waste Act (DEA, 2011). The strategy is used to spearhead the implementation of the Waste Act, as well as enabling a coordinated waste management approach in both the public and private sectors, and the wider community (DEA, 2011). The key target of the NWMS which motivated for this study proposed a diversion of 25% of recyclables from landfill sites by 2016.

The Waste Hierarchy approach is the foundation upon which the NWWS is structured (DEA, 2011). The Objects of the Waste Act (2008) are organised based on the Waste Hierarchy, which is the over-arching waste management strategy in South Africa. The NWMS is organised around a comprehensive list of eight goals (DEA, 2011). The strategy has an action plan which spells out how the goals, proposed indicators and targets will be fulfilled, and highlights the roles and responsibilities of the government, private sector and wider society (DEA, 2011). The South African government is responsible for compliance monitoring of the Waste Act and its regulations, with the private sector and wider society encouraged to actively participate in sensitising the public to the objectives of the NWMS, as well as creating a conducive compliance culture and reporting of compliance violations (DEA, 2011).

Tools which will be employed when implementing the NWMS include, inter-alia, waste classification and management system, norms and standards, licensing, industry waste management plans, extended producer responsibility, priority wastes and economic instruments (DEA, 2011). According to the National Waste Management Strategy (DEA, 2011), the waste management measures which constitute the toolbox are summarised hereunder;

- ✓ "Waste Classification and Management System- provides a methodology for the classification of waste and provides standards for the assessment and disposal of waste for landfill disposal.
- ✓ Norms and Standards- establishes baseline regulatory standards for managing waste at each stage of the waste management hierarchy.
- ✓ Licensing- lists activities that require licences (with conditions) and those that do not if undertaken according to conditions or guidelines.
- ✓ Industry Waste Management Plans- enables collective planning by industry to manage their products once they become waste and to collectively set targets for waste reduction, recycling and re-use.
- ✓ Extended Producer Responsibility- regulates that industry is responsible beyond point of sale for particular products that have toxic constituents or pose waste management challenges, particularly where voluntary waste measures have failed.
- ✓ Priority Wastes- identifies categories of waste that, due their risks to human health and the environment, require special waste management measures, particularly where a solution requires the involvement of multiple role-players.
- ✓ Economic Instruments- encourages or discourages particular behaviour and augments other regulatory instruments" (DEA, 2011).

Table 2.1 presents a summary of the goals, proposed indicators and targets upon which the National Waste Management Strategy is based.

Table 2.1: Summary of Goals, Objectives, Proposed Indicators and 2016 Targets for the NWMS (DEA, 2011).

GOALS	DESCRIPTION	PROPOSED INDICATORS	TARGETS (2016)
Goal 1	Promote waste minimisation, re-use, recycling and recovery of waste	-% recyclables diverted from landfill sites for re-use, recycling and recovery. -No. of municipalities in which separation of waste at source initiatives are being implemented. -Targets and measures for waste minimisation in the paper and packaging industry, pesticide industry, lighting industry and waste tyre industry's IndWMPs.	-25% of recyclables diverted from landfill sites for re-use, recycling or recovery. -All metropolitan municipalities, secondary cities and large towns have initiated separation at source programmes. -Achievement of waste reduction and recycling targets set in IndWMPs for paper and packaging, pesticides, lighting and tyres industries.
Goal 2	Ensure effective and efficient delivery of waste services	-% of households receiving basic waste collection services. -% of licenced waste disposal sites.	-95% of urban households and 75% of rural households have access to adequate levels of waste collection services. -80% of waste disposal sites have permits.
Goal 3	Grow the contribution of the waste sector to the green economy	-No. of new jobs created in the waste sector. -No. of additional SMEs and cooperatives participating in waste service delivery and recycling.	-69 000 new jobs created in the waste sector. -2 600 additional SMEs and cooperatives participating in waste service delivery and recycling.
Goal 4	Ensure that people are aware of the impact of waste on their health, well-being and the environment	-% of municipalities running local awareness campaigns. -% of schools implementing waste awareness programmes.	-80% of municipalities running local awareness campaigns. -80% of schools implementing waste awareness programmes.
Goal 5	Achieve integrated waste management planning	-The % of municipalities that have integrated their IWMPs into their IDPs. -The % of waste management facilities with waste with waste quantification services -The % of municipalities that have met the targets set in IWMPs.	-All municipalities have integrated their IWMPs with their IDPs, and have met the targets set in IWMPs. -All waste management facilities required to report to SAWIS have waste quantification systems that report information to WIS.
Goal 6	Ensure sound budgeting and financial management for waste services	-% of municipalities that provide waste services that have conducted full-cost accounting for waste services. -% of municipalities that provide waste services that have implemented cost reflective tariffs.	-All municipalities that provide waste services have conducted full-cost accounting for waste services and have implemented cost reflective tariffs.

Goal 7	Provide measures to remediate contaminated land	-The % of sites reported to the contaminated land register which have site assessments performed. -The % of confirmed contaminated sites with approved remediation plans.	-Assessment complete for 80% of sites reported to the contaminated land register. -Remediation plans approved for 50% of confirmed contaminated sites.
Goal 8	Establish effective compliance with and enforcement of the Waste Act	-% of successful enforcement actions against non-compliant facilities. -Number of EMIs dealing with Waste Act at local, provincial and national level.	-50% increase in the number of successful enforcement actions against non-compliant activities. -800 EMS appointed in the three spheres of government to enforce the Waste Act.

The National Waste Management Strategy (NWMS) is currently undergoing a comprehensive review process and a draft version was recently released for public comment by the Department of Environmental Affairs (DEA). The 2011 NWMS is being reviewed in accordance with Section 8.6 (5) of the National Environmental Management: Waste Act (2008), which stipulates that the NWMS must be reviewed at intervals of not more than 5 years (DEA, 2019). “This strategy takes into account progress, challenges and lessons learned from the implementation of the 2011 NWMS, as well as new social, environmental and economic developments, and pressures affecting the waste sector” (DEA, 2019). The ongoing review process has revealed that the key target of the 2011 NWMS of diverting 25% of recyclables from landfill sites by 2016 has been met with limited progress (DEA, 2019). The proposed key target of the draft 2018 NWMS prescribes for the prevention of waste, and where waste prevention is not feasible, 50% of waste should be diverted from landfills within 5 years, 65% within 10 years, and at least 80% of waste within 15 years through reuse, recycling and recovery (DEA, 2019).

2.2 Waste Hierarchy

According to DEA (2009a), South African waste management challenges are largely due to ineffective data collection techniques, lack of waste management information, exorbitant waste management operational costs and absence of incentives for waste reduction, reuse and recycling. As part of its National Waste Management Strategy, South Africa implemented the Waste Hierarchy concept which prioritises waste reduction, re-use and recycling (DEA, 2011). Source based separation of mainline recyclables is vital for the success of this strategy since it will provide higher quality recyclables for the recycling industry (CSIR, 2011).

The Waste Hierarchy is the overarching approach that informs and guides waste management in South Africa (DEA, 2011). According to DEA (2011), applying the Waste

Hierarchy in waste management decision making is a statutory requirement for all stakeholders in the waste sector. Waste Hierarchy offers an all-inclusive methodology to waste management, sequentially implementing the concepts of waste avoidance, reuse, recycling, recovery and treatment (DEA, 2011). Responsibility lies with the manufacturer to guarantee that product packaging is designed in such a way that enables waste reduction, re-use or recycling (DEA, 2011). This represents considerable advancement from the previously adopted “cradle to grave”, which only made the manufacturer liable for the product life cycle until landfill disposal. The NWMS affirms the significance of IWMP through the co-ordination of waste activities within the waste hierarchy (DEA, 2011).

The Waste Hierarchy concept outlines the various stages that ought to be followed to reduce landfill waste disposal. The first stage encourages producers to minimise waste generation through the use of clean production technology that results in more efficient raw material usage. The next stage encourages re-using waste materials which can be washed or repaired, and then reused to achieve the same purpose that they were originally intended for. With this approach waste materials are diverted from landfill disposal and sustainably reused in society. Subsequent to this, recyclable materials remaining in the waste stream can be removed and used to manufacture new raw materials. Organic waste can also be recycled from the waste stream and used to make compost.

Waste hierarchy aims to maximise the benefits to be derived from waste materials and forms the bedrock of eThekwini Municipality’s integrated waste management approach which is communicated through the ‘Triple Rs’ of reduction, re-use and recycling (DSW’s Essentially Better, n.d). eThekwini’s integrated waste management approach promotes all techniques in the waste hierarchy recognised by the NWMS (DSW’s Essentially Better, n.d). This study focuses mainly on recycling which is a very crucial component of the waste hierarchy. The highly desirable options of the hierarchy are waste avoidance and waste reduction. Waste avoidance and source reduction results in higher GHG emission savings for most products because of the elimination of emissions linked to manufacturing. According to Acuff and Kaffine (2013), an increase in recycling only results in GHG emission savings equivalent to the emissions variance between manufacturing from virgin sources and manufacturing from recyclables. The next most desirable states in the waste hierarchy are waste re-use and recycling, which aim to recoup waste materials from the waste stream. Lastly, the least favourable options of the Waste Hierarchy; namely, energy recovery, waste treatment and disposal, can be adopted if the most favourable options are not feasible. Figure 2.1 presents a diagrammatic illustration of the Waste Hierarchy.

Figure 2.1: Waste Hierarchy (Wood, 2018)

2.3 Zero Waste

According to the Zero Waste International Alliance (ZWIA, 2013), “zero waste is a goal that is both pragmatic and visionary, to guide people to emulate sustainable natural cycles, where all discarded materials are resources for others to use. Zero waste means designing and managing products and processes to reduce the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them. Implementing zero waste will eliminate all discharges to land, water, or air that may be a threat to planetary, human, animal or plant health.” Apart from promoting recycling, zero waste also intends to modernise the design principles, manufacturing and distribution systems to avoid waste generation (ZWIA, 2013).

According to Zaman and Lehman (2013), “zero waste design principles go beyond recycling to focus firstly on avoidance and reduction of waste by innovative product design and then recycling and composting the rest.” Waste policies are progressively shifting from waste prevention to sustainability approaches which recognise waste as a potential resource (Silva et al., 2017). Environmental laws and material scarceness generate awareness of eco-design benefits by using recycled waste materials as inputs to previous manufacturing processes (EEA, 2014; UNEP, 2011). According to Mazzanti and Montini (2014) and Ghisellini et al. (2016), circular economy programs have proved that “closed loop systems” can deliver many environmental and economic benefits when applied using a bottom-up approach to production processes.

The zero waste concept encourages industrial systems and society to simulate nature and change from being essentially linear to being cyclic (Trois et al., 2007). This results in the effective use of each material resource to enable it to return to a natural environmental cycle or stay viable in the manufacturing sector. According to Matete and Trois (2008), zero waste prioritises waste minimisation and recycling, whilst guaranteeing that products are manufactured for re-use and recycling. Theoretically, the zero waste concept must render landfilling obsolete, even though in reality residual waste which cannot be recycled, re-used or treated will ultimately get disposed at landfills (Jagath, 2010).

As indicated by Jagath (2010), waste management activities that aim to attain waste diversion from landfills can be classified as zero waste strategies. The goals of zero waste are achievable; however, there are economic, legislative and institutional factors that inhibit the implementation of zero waste strategies (Matete, 2009). Zero waste programmes in South Africa are sustainable relative to environmental and social viability; though institutional viability is a constraint because most municipalities lack the financial and infrastructural capacity required to implement zero waste strategies (Matete, 2009).

Educational awareness programmes are critical to the success of any reduce, re-use, recycle and composting initiatives which enable the attainment of zero waste. Pilusa and Muzenda (2013) suggested that South African municipalities ought to evaluate socio-economic conditions existing in their communities when planning waste management programmes. Monetary incentives such as pay-as-you-discharge charges can be implemented to encourage waste minimisation, alongside environmental awareness campaigns meant to encourage recycling behaviour among consumers. This will assist in reducing the prevalence of environmentally unfriendly practises such as illegal dumping of waste. In comparison with other developing nations, South Africa boosts a recognised recycling sector which implements various recycling methods, namely, drop-off centres, buy-back centres and organised scavenging (Matete and Trois, 2008).

2.4 Recycling

Recycling is a resource recovery practice, which according to Acuff and Kaffine (2013), entails collecting and treating goods for use as inputs in manufacturing identical or related goods. It involves the breaking down of a product or commodity into raw materials used to produce new items (Acuff and Kaffine, 2013). Recycling is also a key component of the waste hierarchy. Recyclable materials, among others, include plastics, glass, paper and cardboard, cans, textiles and rubber. Recycling does contribute towards greenhouse gas emissions; albeit to a much lesser scale than if natural resources were used. According to Acuff and Kaffine (2013), recycling only generates emission savings equal to the emissions difference between virgin production and recycled inputs. It reduces greenhouse gas emission savings due to reduced exploitation of virgin materials. For instance, recycling a can of aluminium saves approximately 97% of energy needed for production from virgin aluminium ore (Letcher and Shiel, 1986). The GHG emissions related to the manufacturing of aluminium cans from virgin resources largely emanate from the energy expended during the electrolytic smelting process used in extracting pure aluminium metal from aluminium oxide (Acuff and Kaffine, 2013).

Recycling also offers employment and empowerment opportunities, economic growth and a cleaner environment. Processing of recyclables is labour-intensive work which generates work, learnership and business opportunities that require training and skills development as opposed to waste collection and disposal. According to Oelofse and Strydom (2010), financial incentives for the industrial sector play a keynote part in formal recycling growth in South Africa, while as the informal recycling is motivated by high rates of indigence and unemployment.

According to Fakir (2009), some of the cost-benefits of recycling have been identified as energy savings in manufacturing processes, landfill air space savings, local employment creation and savings on the use of scarce and expensive mineral ores and other virgin materials. There are also various disadvantages of recycling worth noting. According to Couth and Trois (2010), the notable disadvantages of recycling are that the long haulage distances between recyclable generation points and the industrial markets for processing such materials can result in prohibitive transportation costs and high GHG emissions by waste vehicles, thus confounding the feasibility of recycling initiatives. One disadvantage of plastic recycling is that different plastic materials must be separated before reprocessing which increases complexities to the recycling process (Friedrich and Trois, 2013).

Recycling programmes tend to be dependent on high levels of community participation, examples being the kerbside collection programme, at source separation of waste, drop off and buy back centres all relying on high participation and compliance rates (Matete, 2009). Recycling programmes are also subjected to the constraints posed by market factors, product demand and price instability (Matete, 2009). According to Jagath (2010), the establishment of recycling centres, educational awareness and recycling promotional initiatives require high capital investments and resource allocations which cannot be afforded by most South African municipalities.

According to Sevigné-Itoiz et al. (2014), GHG emission savings from recycling activities are greater in countries which depend on carbon intensive energy sources. In South Africa, recycling results in greater GHG emission savings compared to other nations due to the country's high dependency on coal energy (Friedrich and Trois, 2013). The greenhouse gas emission levels of energy generation systems vary between different nations as a result of energy mix variations (Turner et al., 2015).

Approximately 4.75 million tonnes of South African waste produced in 2011 consisted of glass, paper, cans and plastics (DEA, 2011). The waste stream composition for mainline recyclables for the cities of Tshwane and Johannesburg is approximately 25% and 29% respectively (General Waste Minimisation Plan Report for Gauteng, 2009). The recycling rates for municipal waste in Cape Town ranged from 4 to 14% between 2009 and 2011, with an average recycling rate of 9.2% (State of Environment Outlook Report for the Western Cape Province, 2013). According to the South African Waste Information Centre (SAWIC, 2014), eThekwini Municipality generated approximately 1,4% of the South African total waste stream in 2014 and attained an overall recycling rate of approximately 7,6%.

2.5 Environmental Benefits of Recycling

According to King and Gutberlet (2013), waste management is a key driver of climate change. According to Lee et al. (2016), the annual global gross domestic product is projected to contract by between 5% and 20% if there is no decline in GHG emissions. Waste recycling and recovery can significantly reduce greenhouse gas emissions. Several research studies have revealed that waste recycling results in net GHG emission savings (Franchetti and Kilaru, 2012; Manfredi et al., 2011 and WRAP 2010a; quoted in Turner at al., 2015). The use of recycled materials to produce new products replaces virgin source production which normally requires the use of substantial energy and raw material inputs. (Turner at al., 2015).

During the previous century there was unparalleled growth in urban populations across the world, alongside the rise of material consumption culture and waste disposal (Population Reference Bureau, 2011). According to Schor (2010), the world is experiencing serious environmental challenges as a consequence of people using more resources than the natural environment can regenerate and sustainably deal with resultant waste. The high levels of population growth and waste generation are a key challenge for most South African municipalities (DEA, 2016). Waste generation frequently exceeds the economic and human resource capacity of municipalities, the available landfill air spaces and waste integration capacity of the environment (Karak et al., 2012).

The key GHG produced from waste processes are carbon dioxide, methane and nitrous oxide (Gentil et al., 2009 and Machado et al., 2009). Upstream GHG emissions are life cycle emissions of a product up to the point of sale, while as downstream GHG emissions occur after point of sale. Typical examples of upstream emissions are raw material extraction and product processing, and downstream emissions include distribution, storage and product use. Both downstream and upstream waste management activities result in the release of GHG (US EPA, 2006). Without recycling, upstream greenhouse gas emissions arise primarily from virgin raw material processing which requires more energy than recycling (Bogner et al., 2008 and Mohareb et al., 2008; cited by King and Gutberlet, 2013). Downstream greenhouse gas emissions arise due to several waste management practices like landfilling and incineration, but also to a lesser extent during recycling and composting activities.

The USA made a pledge to decrease its 2005 GHG emission levels by 26-28% by the year 2025, whilst China pledged to acquire 20% of its energy requirements from clean energy by 2030 (White House, 2014). The EU pledged to implement a 20% reduction of its 1990 emission levels by 2020 (EC, 2009) and a 40% drop by 2030 (EC, 2014). The United Kingdom (UK) also pledged to an 80% reduction of its 1990 emission levels by 2050 (HMSO, 2008). According to Elia et al. (2015), the European Waste Directive prescribed to pay as you throw initiatives (EC, 2008). Seventeen EU countries are implementing this directive at municipal level (EC, 2012).

Country specific GHG emission factors must be established to be able to accurately calculate and account for GHG emission savings from recycling. Several countries in the industrialised world have developed GHG emission factors for recyclable materials for use by local municipalities in support of decision making and accounting for GHG. The Waste and Resources Action Programme (WRAP) created a technique to assist the Scottish Government in assessing the greenhouse gas effects of waste management (Pratt, 2014 and Pratt et al., 2013). WRAP produced some of the GHG emission factors for recyclables, and also produced a version of the methodology suitable for England (WRAP, 2012). The US EPA prepared a Waste Reduction Model (WARM) for quantifying GHG emanating from waste management (US EPA, 2015). The WARM has GHG emission factors for 39 recyclable materials and the model is presented in the form of an internet-based calculator and spreadsheet.

Changing society's consumption trends and reducing waste generation significantly contributes to mitigation against environmental degradation. Waste must be perceived to be valuable resource, and to see and rate it as such (Gutberlet, 2012a; cited in King and Gutberlet, 2013). In relation to GHG emissions, recycling is a more sustainable environmental practice than landfilling, and in the majority of scenarios it is also more environmentally friendly than incineration (Chen and Lin, 2008 and Mohareb et al., 2008). One of the key socio-economic benefits of recycling is the creation of job opportunities ranging from collection of recyclables to remanufacturing of products, thereby improving the standard of living in developing countries (Fehr and Santos, 2009; cited by King and Gutberlet, 2013).

Municipalities and governments ought to do more to plan and implement policies focussing on recycling and resource recovery, instead of merely directing funding to landfilling and waste-to-energy projects. The environmental and socio-economic outcomes of this sustainable approach are aligned with the United Nations MDG, which place greater emphasis on alleviating indigence and inequality (United Nations, 2011). The Kyoto Protocol came into effect at the Rio Earth Summit in1992 (United Nations, 1992, 1997). South Africa is signed up to the United Nations Framework Convention on Climate Change 1992 and the Kyoto Protocol 1997 (United Nations, 1992). Non-Annex countries like South Africa and most of the developing world do not have mandatory targets for GHG reductions (United Nations, 1992). The Kyoto Protocol was meant to cut global emissions, thus mitigating against climate change. It also introduced the Clean Development Mechanism (CDM) which allowed developing nations like South Africa to take part in carbon trading for environmental and economic benefit (Couth and Trois (2010).

2.6 Case Study: Recycling of Mainline Recyclables in South Africa

2.6.1 Mainline Recyclables

Paper, plastics, glass and cans were selected as the mainline recyclables to be investigated in this study. Recycling of municipal waste gives rise to significant greenhouse gas emission savings, with recyclables which replace virgin resources in the manufacturing process attaining the largest emission savings (ISWA, 2009 and Scheutz et al., 2009; cited in Friedrich and Trois, 2013). This is more pronounced in developing nations like South Africa which mostly rely on energy generation from coal. Table 2.2 presents the recycling trends in urban households across municipalities in South Africa between 2005 and 2016. Table 2.2 shows that there was a decline of 1.3% in household recycling rates between 2005 and 2007. After that the household recycling percentage increased to 5.3% in 2008 before declining again, and then progressively increasing up to 6.8% in 2012, before declining again to 2.5% in 2015. No explanation was given for the recurring annual variations in household recycling participation rates. The fluctuations might have been a consequence of inconsistent household recycling patterns due to lack of public awareness and education of the benefits of recycling.

Table 2.2: Percentage of Urban Households That Collected Waste for Recycling in South Africa, 2005-2016 (after Statistics South Africa, 2018)

Year	Estimate of Municipal Households Recycling Waste (%)
2005	3.8
2006	2.7
2007	2.5
2008	5.3
2009	3.8
2010	4.4
2011	5.8
2012	6.8
2013	5.8
2014	3.3
2015	2.5

According to Friedrich and Trois (2013), a carbon balance based on an LCA was carried out in South Africa to establish GHG emission factors for mainline recyclables. When calculating emission factors, the emissions per given unit are accounted over the product life cycle or part of it depending on the limitations of the study (Friedrich and Trois, 2013). LCA is also used for comparative assessments of environmental benefits derived from different waste management processes.

Paper

Recycling of paper and cardboard has long been established in South Africa. As pointed out by Friedrich and Trois (2013), paper constitutes approximately 18% of South African municipal waste. PRASA coordinates paper recycling in South Africa (PRASA, 2011). It encourages paper recycling and supports waste management and environmental sustainability. The paper mills in KwaZulu-Natal are Nampak, Mondi, Sappi, Natal Waste Paper and SA Paper Mills (Grant, 2011).

According to PRASA (2011), 1 804 582 tonnes of paper materials were recycled in 2011 in South Africa, giving rise to a recycling rate of 59%. 62.1% of 1 882 480 tonnes of recoverable paper were recycled in South Africa in 2013, equating to 1 169 296 tonnes (PRASA, 2013). However, 713 184 tonnes were still not recovered and ended up in landfill sites (PRASA, 2013). Paper and cardboard recovery from waste streams results in high water savings, primarily because the wood pulping process which produces virgin fibres is a water intensive process (NSW, 2005). Compared with recycled paper production, virgin paper production uses more energy, more water and generates more air pollution (NSW, 2005).

Plastics

12% of South African waste is made up of plastic products (Friedrich and Trois, 2013). According to Packaging SA (2011), the main plastic types are polyethylene, polyethylene terephthalate, polypropylene, polystyrene and polyvinyl chloride. According to Plastics SA (2011), the plastics recycling sector is fully established in South Africa, and particularly within eThekwini Municipality. Approximately 22% of all plastic recyclers in South Africa are located within KwaZulu-Natal, and of these 81% are located within eThekwini Municipality (Plastics SA, 2014).

According to Plastics SA (2014), 1 400 000 tonnes of plastics were used in this country in 2014, and 315 600 tonnes were diverted from landfills. The diversion rate from landfills was 22.5%, increasing from 20.0% in 2013 (Plastics SA, 2014). Recycling rates continue to increase in South Africa, with 352 000 tonnes of plastics being recycled in 2018, representing a recycling rate of 46.3% (Plastics SA, 2018).

According to Plastics SA (2011), 4 840 full time jobs and 34 500 informal sector jobs were generated from plastics recycling in 2009. In 2018, the employment creation statistics in the plastics recycling sector increased to 58 470 informal sector jobs and 7 892 full time formal jobs (Plastics SA, 2018). Recycling of plastics in South Africa saved 246 000 tonnes of greenhouse gas emissions in 2018, which is equivalent to greenhouse gas emissions from 51 200 cars (Plastics SA, 2018).

Glass

Glass constitutes 7% of waste generated in South African municipalities (Friedrich and Trois, 2013). DEA (2012b) states that glass waste streams consist of bottles, sheet glass, jars, window glass and drinking glasses. However, glass recycling largely relates to bottles which can either be re-used or recycled by crushing them to make new glass (DEA, 2012b).

According to the Glass Recycling Company (2015), glass is 100% recyclable and is non-biodegradable, with each recycled glass tonne saving 1.2 tonnes of virgin resources. A tonne of recycled glass saves 1.52 cubic meters of LSS (IWMSA, 2011). 14.1GJ/tonne of energy is needed to manufacture glass from natural resources as opposed to

9.23GJ/tonne to recycle glass (Matete, 2009). The recycling rate of South African glass packaging went up from 18% in 2005-06 to 40.6% in 2012-13 (DEA, 2012b). All recyclable glass collected within eThekwini Municipality is sent to Nampak and Consol, both based in Gauteng and Consol in Cape Town (DEA, 2012b).

Cans

According to Friedrich and Trois (2013), approximately 4% of South African municipal waste is made up of metals. Steel and aluminium cans consist of aluminium, aerosol, beverage oil, food and paint cans. The most recovered metals are aluminium and steel beverage cans. Metal recycling amounted to approximately 147 000 tonnes (55.8% rate of recycling) in 2009 and further improved to 59.9% in 2011 (Packaging SA, 2011 and Marthinusen, 2013).

Collect-a-Can (2014) reported that the rate of recycling for steel and aluminium cans in South Africa is approximately 70%. According to Waste Online (2004), aluminium production from virgin sources requires 95% more energy compared to recycling production. Damgaard et. al. (2009) also states that compared with production from virgin sources aluminium recycling is much less energy intensive and uses only 5% of virgin production energy requirements. Recycling a steel tonne preserves 1.5 tonnes of iron ore, with the recycling process using 60% less water and 75% of the total energy input required for virgin production (Waste Online, 2004).

Collect-a-Can is a recycling firm that recycles metal cans in South Africa. This is a joint venture initiative between ArcelorMittal and Nampak (Collect-a-Can, 2014). The cans are sold to steel or aluminium foundries which manufacture steel and aluminium products such as ArcelorMittal in Newcastle or Hulamin in Pietermaritzburg (Collect-a-Can, 2014).

2.7 Case Study: Waste Management in eThekwini Municipality

The following case study focuses on municipal waste services and processes, and waste infrastructure in eThekwini Municipality. According to the eThekwini Municipality IWMP (2016-21), the “desired end state for waste management in the eThekwini Metropolitan area is:

- Provision of efficient and affective waste collection services.
- Minimisation of waste disposed to landfill.
- Provision of waste management services that significantly contribute to a healthy and safe environment for the residents within the eThekwini metropolitan area.”

The figure 2.2 below presents the location of eThekwini Municipality within the spatial context of Kwazulu-Natal province.

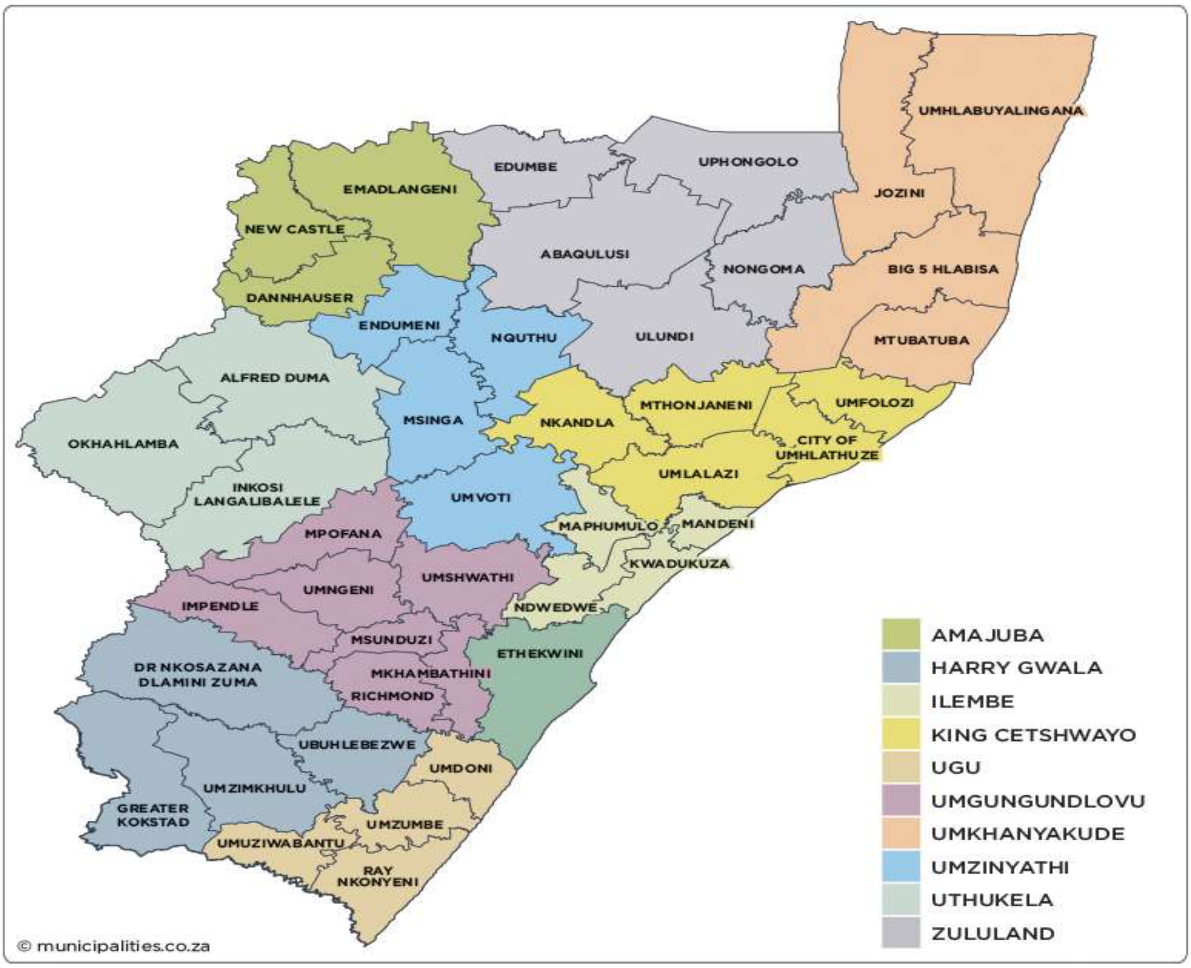

Figure 2.2: Map of KwaZulu-Natal Province Showing the Location of eThekwini Municipality (eThekwini Municipality maps)

eThekwini's Clean Development Mechanism (CDM) project which converts landfill gas to electrical energy was the first one of its kind to be registered and confirmed on the African continent (Couth et al., 2011). The CDM permits registered emerging nations to implement environmentally friendly projects that decrease anthropogenic emissions on behalf of accredited developed countries. According to Couth and Trois (2010), the objectives of CDM are to support developing nations that play host to CDM projects to attain sustainable development. This approach offers developed nations opportunities to meet their GHG emission quotas by claiming emission savings emanating from the projects they sponsor in emerging nations (Couth and Trois, 2010).

According to eThekwini Municipality's State of Local Innovation Report (2011), more than 25% of eThekwini Municipality's GHG emissions are credited to landfill sites. The municipality is promoting the fight against global warming through the operation of the Mariannhill CDM project (State of Local Innovation Report, 2011). GHG emissions attributed to waste management in developing nations are forecasted to escalate in the future. Most of these countries have challenges in GHG monitoring and reporting largely due to the absence of coherent structural frameworks for accounting and management at municipal level (Friedrich and Trois, 2011).

According to DEAT (2009a), South Africa committed to multi-sectorial greenhouse gas mitigation which includes the waste sector. eThekwini Municipality records its annual GHG emissions as prescribed by the National Climate Change Response White Paper (DEA, 2011). The GHG emissions in eThekwini Municipality in 2013 and 2014 were 28 741 558 tonnesCO_2e and 29 092 003 tonnesCO_2e respectively (eThekwini IWMP, 2016-21). The average GHG emissions in the municipality between 2010 and 2014 was 28 381 928 tonnesCO_2e. The 2010 GHG emission level for eThekwini is used as the baseline inventory because the data collection and reporting methodology was standardised for that period (eThekwini IWMP, 2016-21). Apart from 2013, there was continual annual increase in GHG emissions in the municipality. This pattern is mainly due to increased energy usage and carbon intensive processes in the municipality (eThekwini IWMP, 2016-21). The 2.1% decrease in GHG emissions in 2013 compared to 2012 was unexplained in existing literature. Table 2.3 presents the GHG emissions data for eThekwini Municipality between 2010 and 2014.

Table 2.3: Greenhouse Gas Emissions Data for eThekwini Municipality Between 2010 and 2014 (after eThekwini IWMP, 2016-21).

YEAR	TOTAL GHG EMISSIONS	% CHANGE	% CHANGE FROM 2010 BASELINE
2010	27 066 285	20.1	
2011	27 649 400	2.2	2.2
2012	29 360 395	6.2	8.3
2013	28 741 558	-2.1	6.2
2014	29 092 003	1.2	7.5

Recycling based GHG emission savings are expected to be higher in developing countries like South Africa, largely due to their predominant reliance on energy generation capacity from coal (Friedrich, 2013). Coal fired power stations are a major source of greenhouse gas emissions and air pollution due to the high carbon content in coal. As the local energy matrix is transformed in the future by the rolling out of renewable energy infrastructure, the local GHG emission factors must be reviewed to align them with that paradigm shift. Presently there are very few GHG emission factors available for developing nations (Friedrich and Trois, 2011). According to Friedrich (2013), South Africa developed its own local GHG emission factors for mainline recyclables. Greenhouse gas emission factors developed in South Africa for different recyclable materials show emission factors ranging from -290kgCO_2e (glass) to -19 111kgCO_2e (metals- aluminium) per tonne of recyclables (Friedrich and Trois, 2013). Recycling also increases landfill space savings and prolongs landfill lifespans (Chester et al., 2008). According to Blight and Mussane (2007), municipalities must not expect to generate huge incomes from recycling activities; the most significant benefit should be the lifespan extension of existing landfill sites and GHG emission savings.

2.7.1 Recycling in eThekwini Municipality

According to DEA (2012b), KwaZulu-Natal province (KZN) generates approximately 9% of South African municipal waste, which amounted to 9.7 million tonnes in 2011. In comparison with other provinces in South Africa, KZN generated the fifth largest amount of waste (DEA, 2012b). eThekwini Municipality landfilled approximately 1.41 million tonnes of waste in 2014, amounting to 1,4% of South African municipal waste and 7.6% recycling rate (SAWIC, 2014). This recycling rate is slightly below the national average of around 10% (SAWIC, 2014). According to DSW Waste Statistics (2014), the municipal waste stream disposed at eThekwini landfills, excluding builders' rubble, amounted to 1 512 466 tonnes (2012), 1 495 436 tonnes (2013) and 1 451 863 tonnes (2014). This gave rise to recycling rates, excluding builders' rubble, of approximately 1.3% (2012), 1.2% (2013) and 1.3% (2014).

In eThekwini Municipality, recycling is carried out through kerbside collection, drop-off centres, buy-back centres, business sites and garden refuse sites (eThekwini IWMP, 2016-21). The drop off centres mainly target high income areas, whereas buy back centres primarily target indigent communities (Kolekar et al., 2016). The municipality provides weekly refuse collection to its residents. 86.1% of households in eThekwini Municipality have their domestic refuse collected by DSW or a private company at least once a week, while as 13.9% of the households do not receive a regular waste collection service (eThekwini IWMP, 2016-21).

In formal areas the waste collection service consists of a kerbside service which requires householders to place waste bags on kerbs on prearranged collection days. As for waste collection in informal settlements which have limited road access and safety constraints, DSW utilises local private contractors known as Community Based Contractors (CBC) (eThekwini IWMP, 2016-21). According to eThekwini Municipality (eThekwini IWMP, 2016-21), these CBC utilise their garbage trucks to haul waste to local landfills. Commercial and industrial areas receive a minimum of one weekly collection service provided by DSW or private waste collectors (eThekwini IWMP, 2016-21).

Garden refuse blue bags are provided by DSW at a cost to homeowners or procured at retail outlets, with refuse collection taking place on domestic waste collection days. The orange bag kerbside recycling scheme is a weekly collection service for paper, cardboard and plastics, with the orange bags supplied to homeowners by eThekwini Municipality (eThekwini IWMP, 2016-21). Through the clear bag kerbside recycling scheme DSW conducts household collection of glass bottles and cans. The Glass Recycling Company operates 185 glass recycling banks in eThekwini (eThekwini IWMP, 2016-21).

According to eThekwini Municipality’s State of Local Innovation Report (2011), the orange bag scheme is part of a separation at source waste collection mechanism for plastics, paper and cardboard. Recycling bags for the source separation of recyclables programme are normally provided by recyclers and are also available for purchase in local retail shops. eThekwini Municipality has 956 713 households (Stats. SA Census, 2011; quoted in eThekwini IWMP, 2016-21). The recycling programme collects an average of 900 tonnes of monthly paper, plastic and cardboard (eThekwini IWMP, 2016-21). At-source separation of recyclables generates high yields of uncontaminated recyclables; however, attaining high levels of household participation and compliance with such recycling strategies is challenging (Jagath, 2010).

Informal recyclers also play a pivotal role in the waste sector in South Africa. According to WISA (2019), it is estimated that waste pickers recycle up to 90% of plastic and packaging waste in South Africa; saving the public purse up to R750m. It is estimated that there are approximately 90, 000 informal recyclers in South Africa who provide an essential service to local authorities (WISA, 2019). Informal recyclers are waste pickers who engage in the collection and sorting of recyclable materials from landfill sites, dump sites and in communities and industrial areas, which they proceed to sell for a living. According to (WISA, 2019), waste pickers’ work is beneficial to the environment and public health because they reduce waste stream volumes at landfill sites and public spaces by reclaiming discarded waste and reintroducing it into value chain systems at no cost to municipalities.

2.7.2 Landfilling in eThekwini Municipality

Landfills are the most commonly used waste disposal method by municipalities in developing nations. According to DEAT (2009a), landfills are also the most common South African waste disposal method. Landfilling entails the deposition of waste into landfill cells, with the cells being covered by soil and compacted to hold the waste in place, thus preventing infestation of parasites, controlling odours and ingress of water (Tchobanoglous et al., 1993). The three categories to consider in the classification of landfills are the waste type classification, anticipated waste stream volumes and leachate generation potential at the landfill (Tchobanoglous et al., 1977).

Landfilling is not an environmentally friendly waste disposal method. This, according to Bogner et al. (2008), is because landfilling and subsequent waste decomposition gives rise to significant GHG emissions. According to DEAT (2000c), waste disposal at landfills is a very cost-effective waste management strategy. However, Stotko (2006); cited by Matete and Trois (2008), disputes this notion by arguing that it is not necessarily factual since the costs of landfilling do not take external costs into account. When external costs such as GHG emissions, leachate pollution and global warming are considered, the landfilling option would be less economical than the other waste management alternatives such as recycling (Stotko, 2006; cited by Matete and Trois, 2008).

Waste collection service levels in eThekwini Municipality vary between different areas. In formal areas, weekly collections are provided for household waste with residents paying for the service. For informal settlements, there is a limited collection service provided free of charge at designated collection points (Friedrich and Trois, 2010). According to eThekwini (eThekwini IWMP, 2016-21), the municipality is divided into four waste regions, namely, West, Central, South and North. The municipality has seven strategically located waste transfer stations, namely, Hammarsdale, Mount Edgecombe, Chatsworth, Flower Road, Umlazi, Amanzimtoti and Electron Road (eThekwini IWMP, 2016-21). Municipal waste is taken to the waste transfer stations by collection vehicles for compaction prior to being transported by long haul vehicles to landfills, thus significantly reducing transportation costs and the transportation carbon footprint (eThekwini IWMP, 2016-21).

Electron Road Waste Transfer Station which was commissioned in 2014 is eThekwini's largest waste transfer station, with most of its compacted waste delivered to Buffelsdraai

Landfill Site for disposal (eThekwini IWMP, 2016-21). eThekwini Municipality has three landfill sites operated by DSW which are strategically situated in different waste regions. These are the Mariannhill landfill site (western region), Buffelsdraai landfill site (northern region), and Lovu landfill site (southern region) which was recently commissioned in July 2014 (eThekwini IWMP, 2016-21). Each of these landfill sites has a weighbridge which registers the waste tonnage delivered by waste vehicles (eThekwini IWMP, 2016-21). Bisasar Road landfill site (north central region) which is located close to Durban Central was decommissioned in 2014 (eThekwini IWMP, 2016-21).

Mariannhill landfill site lies within the proximity of Pinetown. The landfill site was commissioned in 1997 (Couth et al, 2010). It receives between 550 and 700 tonnes of waste every day (Jagath, 2010). The landfill site covers 33 hectares of land, with landfill space of approximately 5 million m^3, and is scheduled for decommissioning by 2022 (Couth and Trois, 2010). Mariannhill landfill site is a registered national conservancy and consists of a landfill, waste to energy generation plant, waste recovery facility and leachate treatment facility (Jagath, 2010). The treated leachate is utilised for suppressing dust and irrigating the rehabilitated sections of the landfill (Jagath, 2010).

Buffelsdraai landfill site is situated close to Verulam town in the northern region of eThekwini Municipality. It was commissioned in 2006 and has a lifespan of 50-70 years (Jagath, 2010). The landfill site covers an area of 100ha, and has a remaining lifespan of 65 years (eThekwini IWMP, 2016-21). 35% of waste which was previously destined for the now decommissioned Bisasar Road Landfill Site is now landfilled at Buffelsdraai Landfill Site via the Electron Road Waste Transfer Station (eThekwini IWMP, 2016-21).

2.8 Summary

The literature review chapter provided context to this research study. The objective was to identify and contextualise information and data that could be useful to the study. The chapter contextualised waste management in eThekwini Municipality, South Africa and other global regions. The aim of the study is to investigate the greenhouse gas emission savings and landfill space savings resulting from voluntary recycling of mainline recyclables by Durban Solid Waste in eThekwini Municipality for the period from 2009 to 2014.The mainline recyclables considered in the study are paper, plastics, glass and cans. The study focused on municipal waste management processes, primarily recycling, in support of the drive towards sustainable waste management. Population growth and economic development were established as some of the main drivers of waste production and global GHG emissions. The key legislative and regulatory framework which governs the South African waste management sector was discussed, namely, the National Environmental Management: Waste Act and the National Waste Management Strategy. The Waste Hierarchy which underpins the National Waste Management Strategy which motivated for the study was discussed, alongside its key concepts of waste reduction, re-use and recycling. Recycling statistics and waste management systems were discussed for eThekwini Municipality, South Africa and other global regions. The next Chapter presents the methodology utilised to realise the aim and objectives of the study, as well as a review of the studies related to the main methods of this study.

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CHAPTER 3

3. METHODOLOGY

3.1 Introduction

The methodology chapter presents the data collection method, descriptive and inferential statistical analysis methods, in addition to techniques employed in calculating greenhouse gas (GHG) emission savings and landfill space savings (LSS). It concludes by outlining the assumptions and delimitations of the study. It covers the various descriptive statistics and regression analysis methods used to analyse mainline recyclables data and generate predictive regression models for future recyclables, which would then be used to forecast GHG emission savings and LSS. SPSS Version 23 was used for statistical analysis of the recycling data.

3.2 Literature Review Overview

The preceding literature review chapter which sets the background for this methodology chapter covered waste management in eThekwini Municipality, South Africa and other global regions. It covered the waste management overview, the South African legislative and regulatory environment, waste management and waste minimisation concepts, and recycling case studies in eThekwini Municipality and South Africa. This information was obtained from research articles, journals, previous dissertations and theses, books, research websites, municipal and government publications.

3.3 Review of Studies Related to the Main Methods of the Study

Regression analysis has been used in several studies to generate predictive models to forecast waste stream and recycling volumes. Křupka et al. (2013), employed regression analysis to generate predictive regression models to forecast municipal solid waste volumes of selected waste types in the Pardubice region of the Czech Republic. The regression model results were used to assist municipalities to establish projected waste stream volumes, as well as to set the refuse collection fees for municipal households.

According to Sun and Chungpaibulpatana (2017), numerous researchers have employed regression analysis and time-series modelling to create relationships between variables and waste generation. Predictive models were developed in the study to forecast the amount of municipal solid waste likely to be generated in the future (Sun and Chungpaibulpatana, 2017). In a related study Ghinea et al. (2016); cited in Sun and Chungpaibulpatana (2017), also employed regression analysis and time series to predict municipal solid waste generation and composition in Iasi, Romania. Predictive modelling is critical for planning and development of sustainable waste management systems in local authorities, more so, in developing countries where municipal waste stream data is not readily available (Sun and Chungpaibulpatana, 2017).

Prediction of municipal waste streams is critical in understanding municipal waste distribution and planning of sustainable waste management systems (Sakawi and Gerrard, 2013). Correct predictions of municipal solid waste generation rates are crucial for the planning of efficient and cost-effective municipal waste management systems (Sakawi and Gerrard, 2013). Niessen (1977), also states that current and projected municipal waste generation data is key to the planning, design and implementation of waste management systems. Regression analysis was used to generate predictive models for establishing waste composition and generation rates in Malaysia (Sakawi and Gerrard, 2013).

According to Friedrich and Trois (2010), regression analysis was used to develop predictive models which were used to forecast greenhouse gas emissions from waste in eThekwini Municipality. Current municipal waste generation rates were used in the predictive models to determine the amount of waste likely to be generated in the future (Friedrich and Trois, 2010). According to Friedrich and Trois (2010), regression analysis was used to generate the predictive models because of availability of waste stream data and ease of use of method, underpinned by the assumption that past waste generation trends would persist into the future. These predictive regression models were used to assist eThekwini Municipality with planning and implementation of future waste management strategies and systems, as well as optimising existing municipal waste management infrastructure (Friedrich and Trois, 2010).

Another study conducted by Verma et al. (2019), used regression analysis to generate predictive models for municipal solid waste generation in Lucknow, India. Also, Vivekananda and Nema (2014), used regression analysis to predict municipal solid waste generation from 2010 to 2014 in New Delhi, India, and thereafter ascertained that the regression model outputs correctly predicted waste generation. Prediction of municipal solid waste streams is very important for planning of waste management systems, with regression and correlation analysis being preferred as the most suitable methods for generating predictive models (Kolekar et al., 2016). Due to complexity, unease of use and validation limitations, very few predictive models have been developed which are based on artificial intelligent systems like fuzzy logic, artificial neural network and genetic algorithms (Kolekar et al., 2016). Predictive regression models are normally preferred for forecasting purposes because they are unsophisticated and have ease of use, application and interpretation.

Descriptive statistics were also used in most of these studies to describe, interpret and establish trends and patterns in waste streams and recycling data by use of, inter-alia, means, median, variance, range, standard deviations, frequencies, percentiles, kurtosis and skewness. Appropriate graphs, tables and summary statistics, among other statistical outputs, were used to present data analysis, results and study interpretations.

3.4 Method of Data Collection

The recycling data used in the study is primary data which was collated by Durban Solid Waste (DSW) from voluntary recycling of mainline recyclables at garden refuse sites, business sites, drop-off centres, buy-back centres and kerbside collection programmes in eThekwini Municipality. The mainline recyclables selected for this study due to the availability of comprehensive historical recycling data are paper, plastics, glass and cans. The recycling data was collated by DSW between 2009 and 2014. Recycling programmes in eThekwini are implemented through various mechanisms namely, drop-off centres, buy-back centres, business sites, garden sites, and orange and clear bag kerbside recycling schemes. The recycling data was not published by DSW, they only collated and stored it. The recycling data excluded recycling activities carried out by private recyclers.

3.5 Design Methods and Procedures

3.5.1 Statistical Analysis

Mainline recyclables data was statistically analysed using the SPSS software suite. The software was used to generate summary descriptive statistics and regression analysis to generate predictive regression models. The variables in the mainline recyclables data set were paper (variable 1), plastics (variable 2), glass (variable 3) and cans (variable 4). The recycling data was checked for errors, coded and entered into a spreadsheet prior to being imported into the SPSS for analysis.

Descriptive statistics were used to interpret and describe patterns across the recycling data variables using median, mean, frequencies, standard deviation, variance, kurtosis, skewness, maximum, minimum, range and percentiles. Appropriate graphs, tables and summary statistics, among other outputs were used to present the data analysis and results. The SPSS outputs were displayed in the results chapter of the dissertation using graphs and tables. The data set trends were identified and interpreted. Regression analysis is the inferential statistical method used to analyse mainline recyclables data, thereby generating predictive regression models for forecasting future recyclables. In this study regression analysis was simplified. Adequate data was not available to use in the regression model to investigate different factors that could explain the recycling rates observed.

The regression analysis conducted was set at the type 1 error of 5% or probability, $\alpha = 0.05$. If the p value was reported in the analysis to be less than 0.05, the study would declare a statistically significant result and the null hypothesis would be rejected. This would indicate a reliable relationship which can be used to make predictions. If p value was found to be larger than 0.05, the study would declare a non-significant statistical result and the null hypothesis would not be rejected. A p-value less than 0.01 would imply a highly significant test result.

Model summary tables were used to provide R and R square statistics which were used to establish the extent to which the predicted regression model fitted the recycling data. The R square statistic shows the degree to which the total variation in the dependent variable (monthly recyclables) would be accounted for by the independent variable (time). The R value stands for the correlation coefficient that explains the degree to which the independent variable is correlated to the dependent variable. High values of R signify a high level of prediction and low R values a low level of prediction.

The null **(**H_0**)** and alternative **(**H_1**)** hypotheses that were tested when regression analysis was conducted on mainline recyclables data are presented in Table 3.1 below. The decision criteria was set at$\alpha = 0.05$. The criterion was used to decide whether to retain or reject the null hypothesis. Using regression analysis, a test statistic was computed to produce a value that was compared to the criterion. Regression analysis was done to investigate the existence of a statistically significant correlation between the amount of recyclables collected (paper, plastic, glass and cans) and the time series data (months).

Table 3.1: Null and Alternative Hypotheses to be tested in Regression Analysis.

Hypothesis 1	***H_0:***	*Statistically significant correlation does not exist between the amount of paper recycled and the time series data in months.*
	H_1:	*Statistically significant correlation exists between the amount of paper recycled and the time series data in months.*
Hypothesis 2	***H_0:***	*Statistically significant correlation does not exist between the amount of plastic recycled and the time series data in months.*
	H_1:	*Statistically significant correlation exists between the amount of plastic recycled and the time series data in months.*
Hypothesis 3	***H_0:***	*Statistically significant correlation does not exist between the amount of glass recycled and the time series data in months.*
	H_1:	*Statistically significant correlation exists between the amount of glass recycled and the time series data in months.*
Hypothesis 4	***H_0:***	*Statistically significant correlation does not exist between the amount of cans recycled and the time series data in months.*
	H_1:	*Statistically significant correlation exists between the amount of cans recycled and the time series data in months.*

The application of regression analysis is appropriate when the relationship between the variables is linear. The predictive regression models were presented in the form of linear equations as shown hereunder;

$$\boldsymbol{y = a + bx}$$

Where: $y =$ mainline recyclables in tonnes (dependent variables- paper, plastic, glass and cans recyclables)

$x =$ time- cumulative time in months (independent variable)
$\boldsymbol{a} = y -$ intercept (constant)
$\boldsymbol{b} =$ regression line slope

The regression line slope, $\boldsymbol{b}$ represents the strength and nature of the relationship between the dependent and independent variables in the regression equation. According to Hair et al. (2014), the coefficient sign denotes whether the relationship is positive or negative.

Forecasting waste generation is important for municipal planning purposes, with most prediction models founded on correlation and regression (Kolekar, et al., 2016). The modelling of GHG emission savings and LSS for future scenarios was based on forecasted amounts of mainline recyclables being diverted from eThekwini landfills.

These recyclable amounts were calculated using regression analysis based on the amounts diverted from landfills in the period from 2009 to 2014. In a related study by Friedrich and Trois (2016), they used regression analysis to model GHG for possible future situations on the basis of forecasted waste streams. The selected regression method was preferred because of data suitability and ease of use (Friedrich and Trois, 2016).

3.5.2 Greenhouse Gas Emission Savings

GHG emission factors which were used to calculate emission savings for mainline recyclables diverted from eThekwini landfills were based on emission factors developed for local South African conditions (Friedrich, 2013). Greenhouse gas emission factors from Europe and the USA are routinely used in calculating greenhouse gas emissions in developing countries, giving rise to under-estimation or over-estimation of generated emissions (Chen and Lin, 2008). This study utilises locally developed emission factors for calculating emission savings. The masses of mainline recyclables diverted from landfills were multiplied by their respective local emission factors to establish the emission savings. Table 3.2 presents the local GHG emission factors used for mainline recyclables.

Table 3.2: Greenhouse Gas Emission Factors for Mainline Recyclables in South Africa (Friedrich, 2013).

Waste Fraction/Material	**South African GHG Emission Factors ($kgCO_2e$/tonne of recyclable)**
Paper- mixed	-568.5
Plastics- mixed	-980
Glass	-290.1
Steel Cans	-2 586.9
Aluminium Cans	-19 110.7

The amounts of waste materials (tonnes) diverted for recycling are entered into a spreadsheet interface for evaluation. The GHG emission savings are then automatically generated and shown on the output screen in tonnes of carbon dioxide equivalents ($tonnesCO_2e$). The greenhouse gas (GHG) emission savings or reductions are calculated by the following equation:

GHG Emission Savings = GHG Emission Factor ($tonnesCO_2e$/tonne) * Quantity of Recycled Waste (tonnes)

3.5.3 Landfill Space Savings

The Environmental Benefits of Recycling Calculator (EBRC) method was used to calculate the LSS derived from recycling initiatives by DSW in eThekwini Municipality. It is used for estimating the environmental benefits of recycling programmes. The methodology is based on empirical parameters. It is presented in a Microsoft Excel spreadsheet interface which was developed by the Department of Environment and Conservation of Western Australia (NSW, 2006). The EBRC method allows users to input quantities of recycled materials on a spreadsheet for data analysis. The LSS are determined by multiplying the recycled material quantities diverted from landfill disposal by the respective LSS factor to obtain the total landfill space savings. According to DECWA (NSW, 2006), the EBRC method is founded on a scientific, transparent and international best practice LCA methodology which evaluates environmental benefits of recycling.

The EBRC method calculates LSS by multiplying the respective LSS factors with volumetric quantities of recyclables diverted from landfills. Table 3.3 below presents the LSS factors used in the study.

Table 3.3: Landfill Space Saving Factors (NSW, 2008)

Recyclables	**Land Space Savings Factor (m^3/ton)**
Paper and cardboard	2.84
Glass	4.36
PET	6.39
HDPE	5.47
PVC	10.77
PP	10.77
Plastics (mixed)	8.35
Al	4.93
Steel	2.15

The volumes of recyclables (m^3) diverted for recycling are entered into a spreadsheet interface for evaluation. The LSS (m^3) are then automatically generated and shown on the output screen. The landfill space savings (LSS) are calculated by the following equation:

$$\text{LSS} = \text{LSS Factor } (m^3/\text{tonne}) * \text{Quantity of Recycled Waste (tonnes)}$$

3.6 Assumptions and Delimitations of the Study

The assumptions and delimitations which were noted during the study are listed hereunder;

a. When calculating LSS for plastics, the average LSS factor for mixed plastics was used. Also, when calculating GHG emission savings for plastics, the average GHG emission factor for mixed plastics was used.
b. According to Friedrich (2013), European data on plastic production was greatly relied upon in calculating GHG emission factors, thereby resulting in an under-estimation of the South African emissions. Unlike in Europe, South African energy generation is largely dependent on coal which has a very high carbon content.
c. The reliability of recycling projections is dependent on assuming that current waste generation and recycling trends will persist into the future.
d. The study is delimited to eThekwini Municipality in KwaZulu-Natal province. It is also delimited to the investigation of four mainline recyclables (paper, plastics, glass and cans) collected through voluntary recycling by DSW within eThekwini Municipality between 2009 and 2014.

3.7 Summary

This chapter provided a methodological framework upon which this research is constructed. It also presented a review of other studies related to the main methods of this study. Regression analysis and descriptive statistical analysis methods used to generate predictive regression models and to interpret recycling data patterns were discussed in this chapter. Analysis of the methodologies and procedures used to establish GHG emission savings and LSS in eThekwini Municipality were presented. The discussion of the research methodology gave a contextual framework to the next chapter which presents the results and discussion of the study.

CHAPTER 4

4. RESULTS AND DISCUSSION

4.1 Introduction

The results chapter provides data analysis and presentation of results. It covers descriptive statistics and inferential statistical methods used to analyse mainline recyclables data (paper, plastics, glass and cans) and generate predictive regression models for the recyclables collected by DSW through voluntary recycling in eThekwini Municipality. Current and projected greenhouse gas emission savings and landfill space savings due to voluntary recycling programmes implemented by DSW in eThekwini were also quantified. The study used time series data for the period between 2009 and 2014. Statistical analysis of the recycling data was done using the SPSS Version 23.

4.2 Descriptive Statistical Analysis

4.2.1 Statistical Analysis of Variable 1- Paper Recyclables

Figure 4.1 presents the paper recyclable tonnes (variable 1) collected through voluntary recycling in eThekwini Municipality between 2009 and 2014. Recyclable paper collected ranged from 7 038 tonnes (2009) to 14 372 tonnes (2012), with total paper recyclables collected between 2009 and 2014 amounting to 74 255 tonnes. Generally, paper recycling increased year on year over the time series data period. The study aims to promote recycling which mitigates against environmental impacts of waste management by reducing greenhouse gas emissions and generating landfill space savings at landfill sites.

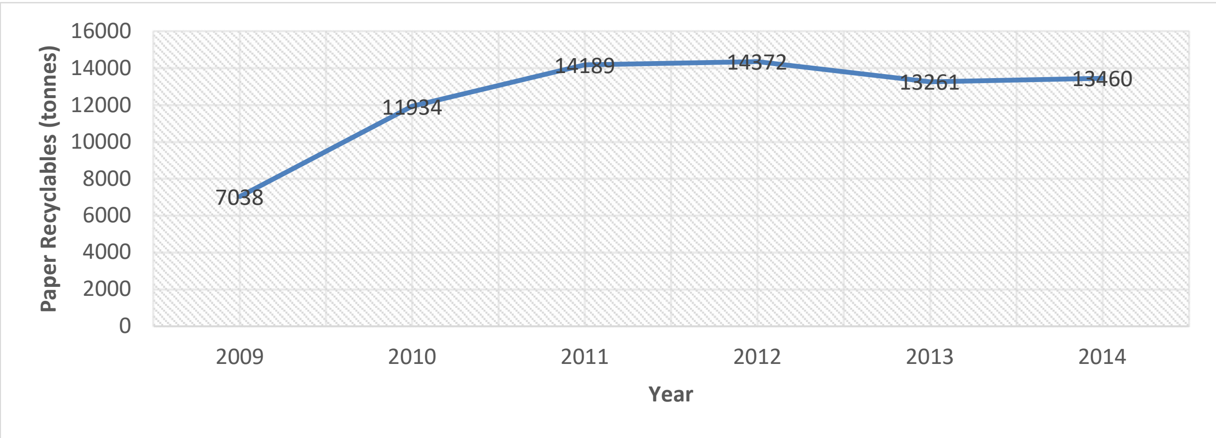

Figure 4.1: Graph of Paper Recyclables (tonnes) Collected Through Voluntary Recycling in eThekwini Municipality Between 2009 and 2014.

4.2.1.1 Summary Statistics of Results for Paper Recyclables

Table 4.1 presents the descriptive statistical analysis results for monthly paper recyclables (Mean= 1031.32; Standard Deviation= 270.48). The mean (1 031.32) and median (1 069.55) are almost the same, implying that the distribution is highly likely to be symmetric. The minimum and maximum amounts of monthly paper recyclables are 297.30 tonnes (February 2009) and 1 569.40 tonnes (December 2011) respectively. Skewness and kurtosis are defined by deviations from distribution symmetry and relative flatness respectively. The values of skewness (-0.85) and kurtosis (1.03) are close to zero and three respectively, indicating that the data approximates a normal distribution. Values close to zero signify the skewness of a normal distribution, while as values close to three signify the kurtosis of a normal distribution.

Table 4.1: Summary of Descriptive Statistical Analysis Results for Monthly Paper Recyclables

Descriptive Statistics	Statistical Value
Mean	1031.32
95% Confidence Interval for Mean: Lower Bound	967.76
Upper Bound	1094.88
Median	1069.55
Standard Deviation	270.48
Minimum	297.30
Maximum	1569.40
Skewness	-.85
Kurtosis	1.03

4.2.2 Statistical Analysis of Variable 2 (Plastics), Variable 3 (Glass) and Variable 4 (Cans)

Figures 4.3, 4.4 and 4.5 present plastics (variable 2), glass (variable 3) and cans (variable 4) recyclables, respectively, collected through voluntary recycling in eThekwini Municipality between 2009 and 2014. The plastic recyclables ranged from 1 546 tonnes (2009) to 4 050 tonnes (2014), with total plastic recyclables collected over the six-year period amounting to 17 785 tonnes. Plastic recycling generally increased year on year over the time series data period. Figure 4.2 presents the plastic recyclable tonnes (variable 2) collected through voluntary recycling in eThekwini Municipality between 2009 and 2014.

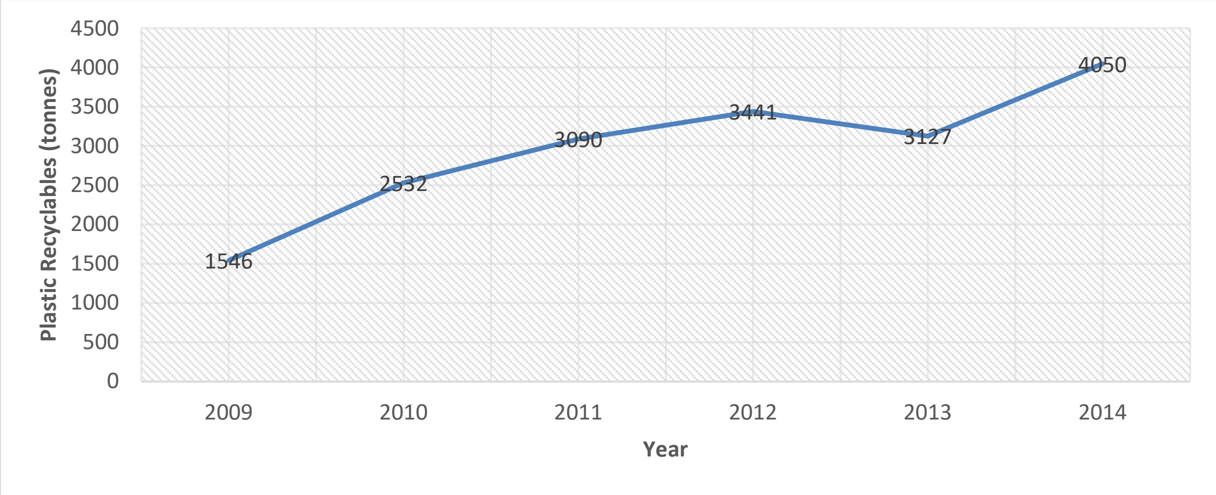

Figure 4.2: Graph of Plastic Recyclables (tonnes) Collected Through Voluntary Recycling in eThekwini Municipality Between 2009 and 2014.

Glass recyclables ranged from 352 tonnes (2009) to 1 316 tonnes (2014), with the total for the six-year period amounting to 4 958 tonnes. Glass recycling generally increased year on year, with some spikes observed over the time series data period. At the beginning of the time series data period there was no widespread municipal coverage of the clear bag kerbside recycling scheme due to delays in expanding the kerbside recycling programme to townships (eThekwini IWMP, 2016-21). As a consequence of this, glass recycling had much lower recycling participation rates than paper or plastics, which happened to have more established recycling streams. Figure 4.3 presents the glass recyclable tonnes (variable 3) collected through voluntary recycling in eThekwini Municipality between 2009 and 2014.

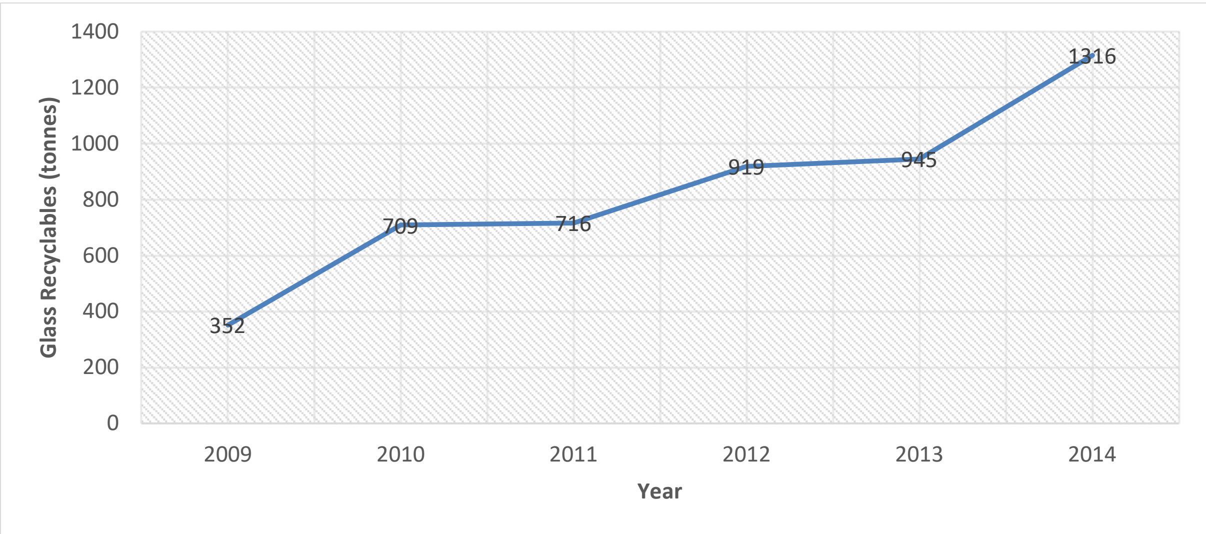

Figure 4.3: Graph of Glass Recyclables (tonnes) Collected through Voluntary Recycling in eThekwini Municipality Between 2009 and 2014.

Cans recyclables ranged from 37 tonnes (2010) to 356 tonnes (2014), for a total amount of 955 tonnes between 2009 and 2014. Recycling of cans generally increased year on year, with some spikes observed over the time series data period. Initially there was no extensive coverage of the clear bag recycling programme because of delays in implementing the recycling scheme in townships (eThekwini IWMP, 2016-21). However, municipal recycling coverage generally increased resulting in spikes in 2013 and 2014.

Cans recycling had much lower recycling participation rates than paper or plastics, which had more established recycling streams. Figure 4.4 presents the cans recyclable tonnes (variable 4) collected through voluntary recycling in eThekwini Municipality between 2009 and 2014.

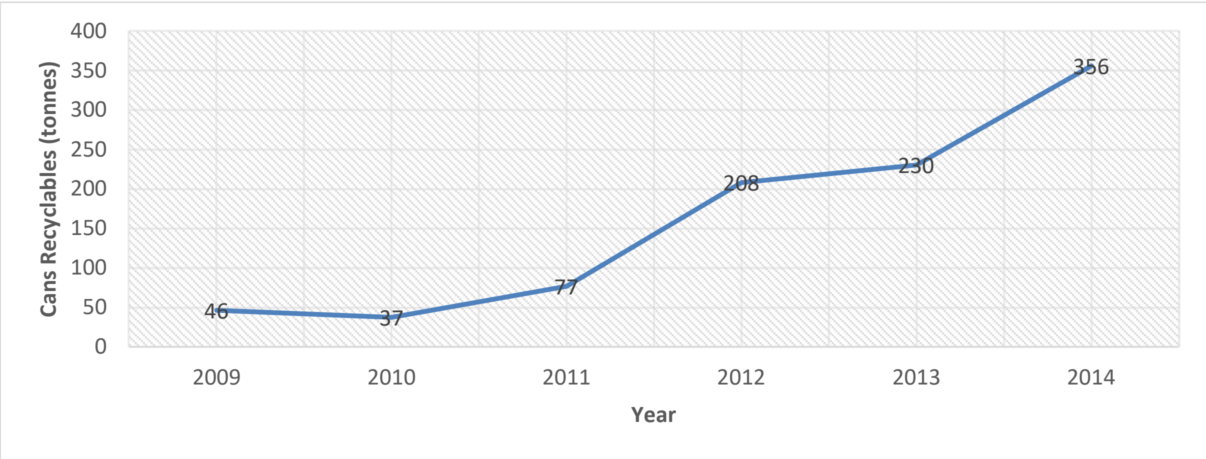

Figure 4.4: Graph of Cans Recyclables (tonnes) Collected Through Voluntary Recycling in eThekwini Municipality Between 2009 and 2014.

4.2.2.1 Summary Statistics of Results for Plastics, Glass and Cans

Table 4.2 presents the descriptive statistical analysis results for monthly plastic recyclables (Mean= 247.02; Standard Deviation= 76.98), monthly glass recyclables (Mean= 68.87; Standard Deviation= 40.27) and monthly cans recyclables (Mean= 13.26; Standard Deviation= 11.81) As presented in the table, the mean and median for plastic and glass recyclables are nearly the same, indicating that the distributions are highly likely to be symmetric. The mean and median for cans recyclables are relatively different, implying that the distribution might be asymmetric.

Plastic recyclables exhibited the highest statistical values for median, mean, variance, standard deviation, range and interquartile range, followed by glass recyclables. Cans recyclables have the lowest descriptive statistical values. The values of skewness and kurtosis for plastic recyclables are close to zero and three respectively, indicating that the data approximates a normal distribution. There is a linear relationship in the data which allows linear regression analysis to generate good regression models. For glass and cans recyclables these values tended to deviate away from normality. This limited linear relationship in the recycling data would not produce perfect regression models.

Table 4.2: Summary of Descriptive Statistical Analysis Results for Monthly Plastics, Glass and Cans Recyclables.

Descriptive Statistics (tonnes)	**Plastic Recyclables**	**Glass Recyclables**	**Cans Recyclables**
Mean	247.02	68.87	13.26
95% Confidence Interval for Mean			
Lower Bound	228.93	59.41	10.49
Upper Bound	265.11	78.34	16.04
Median	251.80	61.90	8.85
Standard Deviation	76.98	40.27	11.81
Minimum	74.10	.00	.80
Maximum	445.50	199.80	45.50
Skewness	-.162	1.20	.88
Kurtosis	.160	2.19	-.27

4.3 Regression Analysis

4.3.1 Regression Analysis of Model 1- Paper Recyclables

Regression analysis was used to analyse time-series data. Such data representing variations in one or more variables over time expresses the long-term trend in a regression format. It was used to generate predictive regression models for the mainline recyclables (paper, plastic, glass and cans) forecasted to be recycled by DSW in eThekwini Municipality. Model 1 represents the predictive regression model for paper recyclables. The monthly paper recyclables (variable 1) recycled by DSW in eThekwini Municipality between 2009 and 2014 are shown above in Figure 4.1. This mainline recyclables data was used in regression analysis to generate predictive regression models for paper recyclables.

4.3.1.1 Diagnostic Tests for Paper Recyclables

The first output table of regression analysis presents the model summary and overall fit statistics in Table 4.3. The table presents the R, R^2, adjusted R^2 and the standard error estimate which were used to establish the level to which the regression model predicted the dependent variable.

Table 4.3: Model Summary and Overall Fit Statistics for Paper Recyclables

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.612	.375	.366	215.33221

In relation to the effect size of the analysis conducted (M = 1031.32; SD = 270.48), the linear regression accounted for 38% of the total variability in the criterion variable as indexed by the R^2 statistic, thus 38% of the variation is accounted for by the model. The R^2 statistic shows to what extent the total variation in the dependent variable (monthly paper recyclables) could be accounted for by the independent variable (time in months). The R value stands for the correlation coefficient that shows the degree to which the independent variable is interrelated to the dependent variable. The R value equates to 0.61, which indicates a relatively high degree of correlation.

4.3.1.2 Predictive Regression Model for Paper Recyclables

Table 4.4 presents ANOVA analysis results which show the level to which the regression model predicted the dependent variable. The table demonstrates that the regression model predicts the dependent variable to a high degree.

Table 4.4: Anova Analysis Results for Paper Recyclables

Model	Sum of squares	df	Mean square	F	Sig.
Regression	1948501.493	1	1948501.493	42.023	.000
Residual	3245757.179	70	46367.960		
Total	5194258.673	71			

The regression analysis was statistically significant at p ‹ .05 significance level adopted for the statistical test as represented in the F statistic below.

$$F(1, 70) = 42.02, p < .001, \alpha = .05$$

Unstandardized coefficients shown in the table below were used to build a linear regression model for predicting the dependent variable (monthly paper recyclables) using the independent variable (cumulative time in months). The significant level, p ‹ .001 is less than α ‹ .05. This proved that the regression model statistically significantly predicted the monthly paper recyclables data (dependent variable). The linear regression equation for predicting the amount of paper recyclables likely to be recycled by DSW on a monthly basis is represented by the predictive regression model hereunder;

$$Y= 742.40 + 7.916x$$

Where: y= paper recyclables in tonnes (dependent variable)

x= cumulative time in months (independent variable, ID column on Table B-1: Appendix B)

Table 4.5 below presents the regression coefficients, significance of the coefficient and the intercept used to generate the predictive regression model stated above.

Table 4.5: Regression Coefficients for Paper Recyclables

	Unstandardized	Coefficients	Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.
Constant	742.400	51.288		14.475	.000
Time in months	7.916	1.221	.612	6.482	.000

4.3.2 Regression Analysis of Models 2 (Plastics), 3 (Glass) and 4 (Cans)

The models 2, 3 and 4 represent the predictive regression models for plastics, glass and cans respectively.

4.3.2.1 Diagnostic Tests for Plastics, Glass and Cans Recyclables

Table 4.6 below presents the model summaries and overall fit statistics of the regression analysis for plastics, glass and cans recyclables. In relation to the effect size of the plastic recyclables analysis conducted (M= 247.02; SD= 76.98), the linear regression accounted for 70% of the total variability in the criterion variable as indexed by the R^2 statistic. 70% of the total variation in monthly plastic recyclables (dependent variable) can be accounted for by the cumulative time in months (independent variable). The R statistic equates to 0.84, which indicates a high degree of correlation.

Table 4.6: Model Summary and Overall Fit Statistics for Plastic, Glass and Cans Recyclables

Recyclable Fractions	R	R Square	Adjusted R Square	Std. Error of the Estimate
Plastic	.837	.700	.696	42.45168
Glass	.623	.389	.380	31.71119
Cans	.794	.630	.625	7.23239

With regards to the effect size of the glass recyclables analysis conducted (M= 68.87; SD= 40.27), the linear regression accounted for 39% of the total variability in the criterion variable as indexed by the R^2 statistic. 39% of the total variation in monthly glass recyclables (dependent variable) is accounted for by the independent variable. The R value equates to 0.62, which shows a high degree of correlation.

In relation to the effect size of the cans recyclables analysis conducted (M= 13.26; SD= 11.81), the linear regression accounted for 33% of the total variability in the criterion variable as indexed by the R^2 statistic. 63% of the total variation in monthly cans recyclables (dependent variable) is accounted for by the independent variable. The R value equates to 0.79, which indicates a high degree of correlation.

4.3.2.2 Predictive Regression Models for Plastics, Glass and Cans Recyclables

Table 4.7 below shows the level to which the regression models predicted the dependent variables. The regression analysis for plastic recyclables was statistically significant at p ‹ .05 significance level used for this statistical test as represented in the F statistic below.

$$F(1, 70) = 163.44,\ p < .001,\ \alpha = .05$$

Table 4.7: Anova Analysis Results for Plastics, Glass and Cans Recyclables

Models	Sum of Squares	df	Mean Square	F	Sig.
Plastics Model					
Regression	294548.464	1	294548.464	163.443	.000
Residual	126150.149	70	1802.145		
Total	420698.613	71			
Glass Model					
Regression	44744.288	1	44744.288	44.495	.000
Residual	70391.972	70	1005.600		
Total	115136.260	71			
Cans Model					
Regression	6240.145	1	6240.145	119.297	.000
Residual	3661.526	70	52.308		
Total	9901.671	71			

Unstandardized coefficients shown in the table below were used to build a linear regression model for predicting the dependent variable (monthly recyclables) using the independent variable (cumulative time in months). The significant level, p ‹ .001 (plastic recyclables) was less than α ‹ .05. This proved that the regression model statistically significantly predicted monthly plastic recyclables (dependent variable).

The linear regression equation for predicting the amount of plastic recyclables likely to be recycled on a monthly basis is represented by the predictive regression model hereunder;

$$Y = 134.69 + 3.08x$$

Where: y= plastic recyclables in tonnes (dependent variable) x= cumulative time in months (independent variable, ID column on Table B-1: Appendix B)

Table 4.8 below presents the regression coefficients, significance of the coefficients and the intercepts used to generate predictive regression models for plastics, glass and cans recyclables.

Table 4.8: Regression Coefficients for Plastics, Glass and Cans Recyclables

Models	**Unstandardized Coefficients**		**Sig.**
	B	**Std. Error**	
Plastics Model			
Constant	134.687	10.111	.000
Time in months	3.078	.241	.000
Glass Model			
Constant	25.092	7.553	.001
Time in months	1.200	.180	.000
Cans Model			
Constant	-3.089	1.723	.077
Time in months	.448	.041	.000

The regression analysis of glass recyclables was statistically significant at $p < .05$ significance level as represented in the F statistic below.

$$F(1, 70) = 44.50, p < .001, \alpha = .05$$

The significance level, $p < .001$ (glass recyclables) was less than $\alpha < .05$. This proved that the regression model statistically significantly predicts monthly glass recyclables.

The linear regression equation for predicting the amount of glass recyclables likely to be recycled on a monthly basis is represented by the predictive regression model hereunder;

$$Y = 25.09 + 1.20x$$

Where:

y= glass recyclables in tonnes, x= cumulative time in months (ID column on Table B-1: Appendix B)

The regression analysis of cans recyclables was statistically significant at $p < .05$ significance level as represented in the F statistic below.

$$F\,(1,\,70) = 119.30,\; p < .001,\; \alpha = .05$$

The significance level, $p < .001$ (cans recyclables) was less than $\alpha < .05$. This proved that the regression model statistically significantly predicts monthly cans recyclables.
The linear regression equation for predicting the amount of cans recyclables likely to be recycled on a monthly basis is represented by the predictive regression model hereunder;

$$Y = -3.09 + 0.45x$$

Where: y= cans recyclables in tonnes
x= cumulative time in months (ID column on Table B-1: Appendix B)

4.4 Greenhouse Gas Emission Savings and Landfill Space Savings

4.4.1 Mainline Recyclables

GHG emission savings and LSS were calculated based on the amounts of mainline recyclables diverted for recycling by DSW in eThekwini Municipality. Table 4.9 below presents the amounts of mainline recyclables diverted from eThekwini landfills through voluntary recycling between 2009 and 2014. The mainline recyclables which were recycled ranged from 8 983 tonnes (2009) to 19 183 tonnes (2014), with total recyclables collected over the six-year period amounting to 97 953 tonnes. With the exception of 2013, in which there was a drop in collected recyclables, the consolidated totals for the recyclables diverted from eThekwini landfills increased year on year.

Table 4.9: Consolidated Recycling Data (tonnes) from Voluntary Recycling of Mainline Recyclables in eThekwini Municipality between 2009 and 2014.

Recyclables	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***TOTAL***
Paper	*7038*	*11934*	*14189*	*14372*	*13261*	*13460*	*74255*
Plastic	*1546*	*2532*	*3090*	*3441*	*3127*	*4050*	*17785*
Aluminium Cans	*9*	*7*	*15*	*42*	*46*	*71*	*191*
Steel Cans	*37*	*30*	*61*	*166*	*184*	*285*	*764*
Glass	*352*	*709*	*716*	*919*	*945*	*1316*	*4958*
TOTAL	***8983***	***15213***	***18071***	***18940***	***17563***	***19183***	***97953***

Regression analysis was used to develop predictive regression models to forecast the amounts of future recyclables likely to be collected from voluntary recycling of mainline recyclables in eThekwini Municipality between 2015 and 2025. The projected recyclables are anticipated to increase year on year for that period, which is in line with the same growth trend exhibited in the historical recyclables data shown in Table 4.9 above. Table 4.10 below presents the projected recycling data established from the predictive regression models.

Table 4.10: Projected Recycling Data (tonnes) from Voluntary Recycling of Mainline Recyclables in eThekwini Municipality between 2015 and 2025.

Main Recyclables	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***
Paper	16366	*17506*	*18646*	*19785*	*20925*	*22065*
Plastic	4518	*4961*	*5405*	*5848*	*6292*	6735
Aluminium Cans	*77*	*90*	*103*	*116*	*129*	*142*
Steel Cans	309	*361*	*413*	*465*	*517*	569
Glass	1432	*1604*	1777	1950	*2123*	*2296*
TOTAL	***22702***	***24523***	***26344***	***28165***	**29986**	**31807**

Main Recyclables	***2021***	***2022***	***2023***	**2024**	**2025**
Paper	23205	24345	25485	26625	27765
Plastic	7179	7622	8066	8509	8953
Aluminium Cans	155	168	181	194	207
Steel Cans	621	672	724	776	828
Glass	2468	2641	2814	2987	3160
TOTAL	**33628**	**35448**	**37270**	**39091**	**40913**

Figure 4.5 below presents the historical and projected recycling data from voluntary recycling in eThekwini Municipality between 2009 and 2025; with the graph exhibiting an expected upward growth trend.

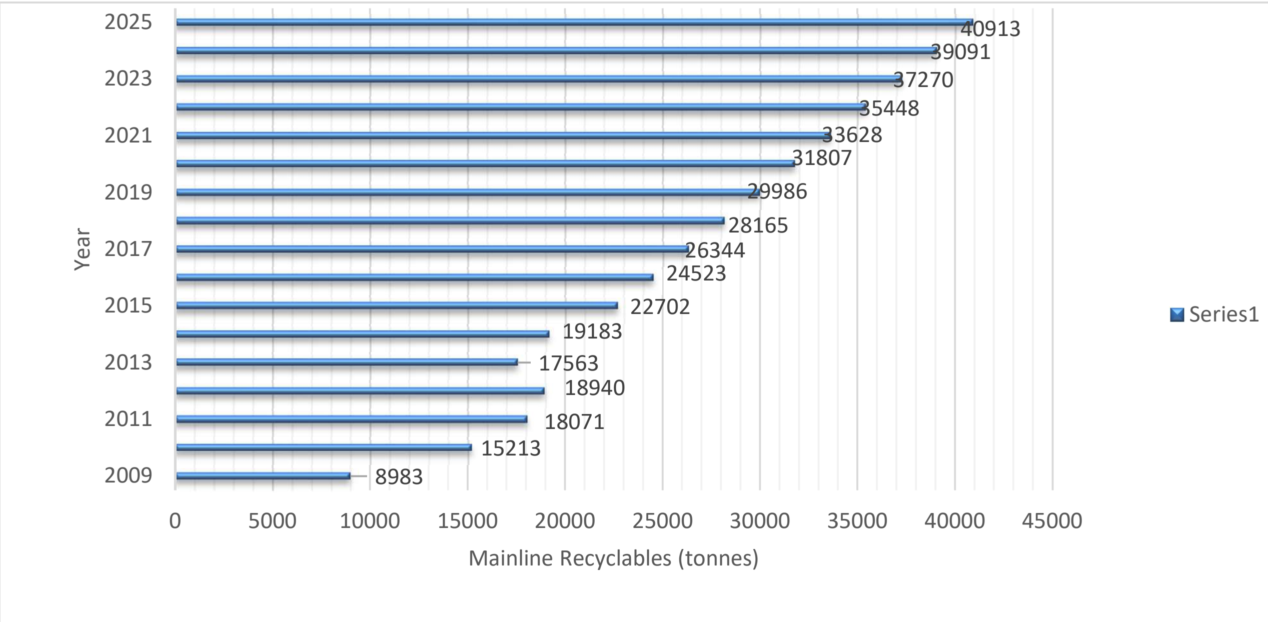

Figure 4.5: Graph of Historical and Projected Annual Recyclables from Voluntary Recycling of Mainline Recyclables in eThekwini Municipality Between 2009 and 2025.

4.4.2 Greenhouse Gas Emission Savings

GHG emission savings for eThekwini were calculated using local emission factors for South Africa (Friedrich, 2013). Table 4.11 below presents the greenhouse gas emission savings from mainline recyclables diverted from eThekwini landfills through voluntary recycling between 2009 and 2014. The GHG emission savings ranged from 5 891 tonnesCO_2e (2009) to 14 102 tonnesCO_2e (2014), with total emission savings of 66 708 tonnesCO_2e over the six-year period. Apart from the GHG emission savings drop in 2013, which was due to a reduction in collected recyclables, the consolidated totals for emission savings increased year on year.

Table 4.11: Greenhouse Gas Emission Savings (tonnesCO_2e) from Voluntary Recycling of Mainline Recyclables in eThekwini Municipality between 2009 and 2014.

Recyclables	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	**TOTAL**
Paper	*4001*	*6785*	*8066*	*8171*	*7539*	*7652*	*42214*
Plastic	*1515*	*2481*	*3028*	*3372*	*3064*	*3969*	*17429*
Aluminium Cans	*177*	*143*	*293*	*795*	*880*	*1362*	*3650*
Steel Cans	*96*	*77*	*159*	*431*	*477*	*737*	*1976*
Glass	*102*	*206*	*208*	*267*	*274*	*382*	*1438*
TOTAL	***5891***	***9692***	***11754***	***13035***	***12234***	***14102***	***66708***

Based on the projected amounts of future recyclables likely to be collected from voluntary recycling of mainline recyclables in eThekwini Municipality between 2015 and 2025; the projected amounts of greenhouse gas emission savings were calculated for the same time period. The greenhouse gas emission savings are anticipated to increase year on year, which is in line with the same growth trend exhibited in the historical greenhouse gas emissions data shown in Table 4.11 above. Table 4.12 below presents the projected greenhouse gas emissions data.

Table 4.12: Projected Greenhouse Gas Emission Savings (tonnesCO_2e) from Voluntary Recycling of Mainline Recyclables in eThekwini Municipality between 2015 and 2025.

Recyclables	***2015***	**2016**	**2017**	**2018**	**2019**	**2020**
Paper	*9304*	*9952*	*10600*	*11248*	*11896*	*12544*
Plastic	*4427*	*4862*	*5297*	*5731*	*6166*	*6600*
Aluminium	*1478*	*1726*	*1974*	*2221*	*2469*	*2718*
Steel	*800*	*935*	*1069*	*1203*	*1337*	*1471*
Glass	*415*	*465*	*516*	*566*	*616*	*666*
TOTAL	***16425***	***17940***	***19455***	***20969***	***22484***	***23999***
Recyclables	**2021**	**2022**	**2023**	**2024**	**2025**	
Paper	*13192*	*13840*	*14488*	*15136*	*15784*	
Plastic	*7035*	*7470*	*7905*	*8339*	*8774*	
Aluminium	*2966*	*3211*	*3459*	*3707*	*3956*	
Steel	*1606*	*1738*	*1873*	*2007*	*2142*	
Glass	*716*	*766*	*816*	*867*	*917*	
TOTAL	***25515***	***27025***	***28541***	***30057***	***31573***	

Figure 4.6 below presents the historical and projected greenhouse gas emission savings data from voluntary recycling in eThekwini Municipality between 2009 and 2025; with the graph exhibiting an expected upward growth trend.

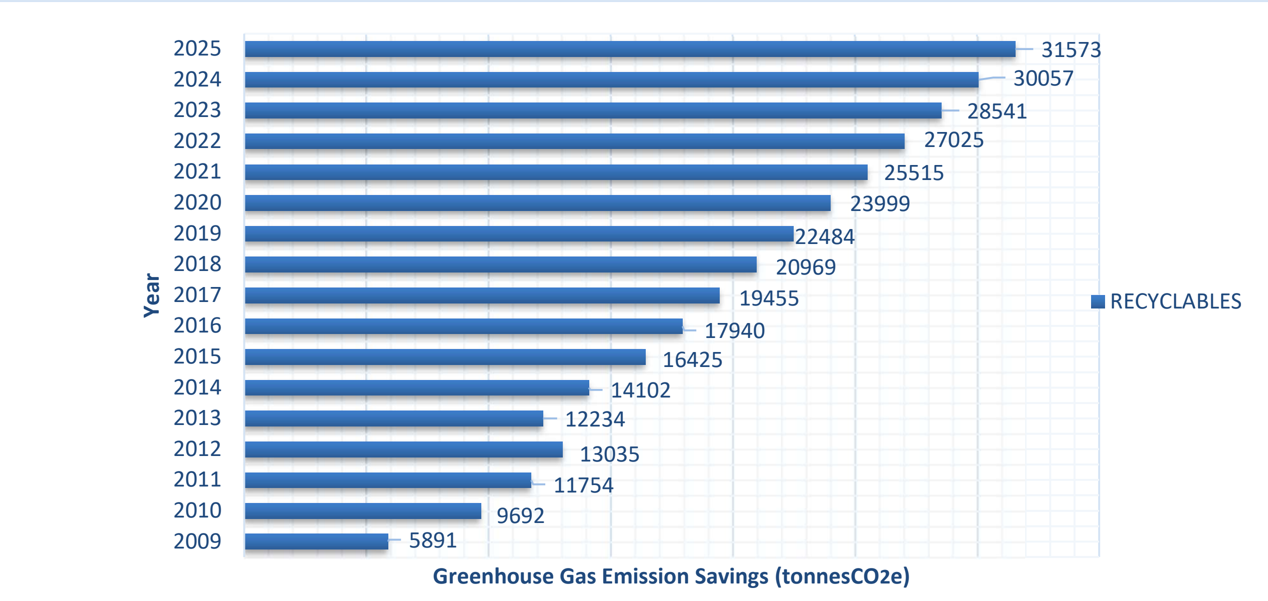

Figure 4.6: Graph of Historical and Projected Annual Greenhouse Gas Emission Savings from Voluntary Recycling of Mainline Recyclables in eThekwini Municipality Between 2009 and 2025.

4.4.3 Landfill Space Savings

The landfill space savings for eThekwini Municipality due to recycling by DSW were calculated using the Environmental Benefits of Recycling Calculator (EBRC) method. Table 4.13 below presents the landfill space savings from mainline recyclables diverted from eThekwini landfills through voluntary recycling between 2009 and 2014. The landfill space savings ranged from 34 557m^3 (2009) to 78 746m^3 (2014), with total space savings of 383 591m^3 over the six-year period. Apart from the decrease in LSS in 2013, which was due to a reduction in collected recyclables, the consolidated totals for LSS increased year on year.

Table 4.13: Landfill Space Savings (m^3) from Voluntary Recycling of Mainline Recyclables in eThekwini Municipality between 2009 and 2014.

Recyclables	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	**TOTAL**
Paper	*19989*	*33893*	*40296*	*40818*	*37661*	*38226*	*210883*
Plastic	*12907*	*21143*	*25802*	*28729*	*26108*	*33816*	*148506*
Aluminium Cans	*46*	*37*	*76*	*205*	*227*	*351*	*942*
Steel Cans	*79*	*64*	*132*	*358*	*396*	*613*	*1643*
Glass	*1536*	*3092*	*3121*	*4008*	*4121*	*5740*	*21618*
TOTAL	***34557***	***58230***	***69427***	***74118***	***68513***	***78746***	***383591***

Based on the projected amounts of future recyclables likely to be collected from voluntary recycling of mainline recyclables in eThekwini Municipality between 2015 and 2025; the projected amounts of landfill space savings were calculated for the same time period. The landfill space savings are expected to increase year on year, which is in line with the same growth trend exhibited in the historical landfill space savings data shown in Table 4.13 above. Table 4.14 below presents the projected landfill space savings data.

Table 4.14: Projected Landfill Space Savings (m^3) from Voluntary Recycling of Mainline Recyclables in eThekwini Municipality between 2015 and 2025.

Recyclables	***2015***	**2016**	**2017**	**2018**	**2019**	**2020**
Paper	*46479*	*49716*	*52953*	*56191*	*59427*	*62665*
Plastic	*37722*	*41426*	*45129*	*48832*	*52538*	*56237*
Aluminium	*381*	*445*	*509*	*573*	*637*	*701*
Steel	*665*	*777*	*888*	*1000*	*1111*	*1223*
Glass	*6241*	*6995*	*7748*	*8502*	*9256*	*10011*
TOTAL	***91489***	***99359***	***107228***	***115097***	**122970**	**130836**
Recyclables	**2021**	**2022**	**2023**	**2024**	**2025**	
Paper	*65902*	*69140*	*72377*	*75615*	*78853*	
Plastic	*59945*	*63644*	*67351*	*71050*	*74758*	
Aluminium	*765*	*828*	*892*	*956*	*1021*	
Steel	*1335*	*1445*	*1557*	*1668*	*1780*	
Glass	*10760*	*11515*	*12269*	*13023*	*13778*	
TOTAL	**138707**	**146571**	**154446**	**162313**	**170188**	

Figure 4.7 below presents the historical and projected landfill space savings data from voluntary recycling in eThekwini Municipality between 2009 and 2025; with the graph exhibiting an expected upward growth trend.

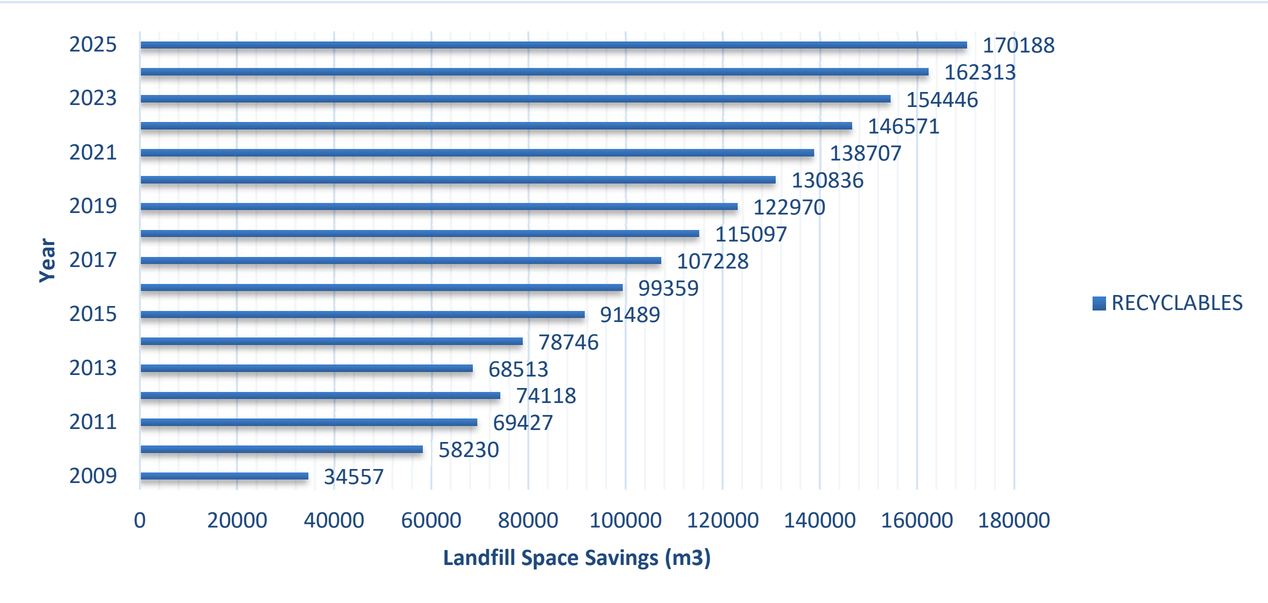

Figure 4.7: Graph of Historical and Projected Annual Landfill Space Savings from Voluntary Recycling of Mainline Recyclables in eThekwini Municipality Between 2009 and 2025.

4.5 DISCUSSION OF RESULTS

4.5.1 Introduction

Central to this research study was to explore and investigate the mainline recyclables, GHG emission savings and LSS emanating from voluntary recycling of mainline recyclables by DSW in eThekwini Municipality between 2009 and 2014. eThekwini Municipality's recycling rates for mainline recyclables ranged from 1.2% to 1.3% between 2012 and 2014. This fell short of the average national recycling rate. According to (SAWIC, 2014), the national average recycling rate is approximately 10%. eThekwini recycling rates are also below the target set in the National Waste Management Strategy for 25% waste diversion from landfills by 2016.

According to Fakir (2009), financial incentives, infrastructural development and environmental awareness are the key drivers for recycling. According to Oelofse and Strydom (2010), the key growth driver for the industrial recycling sector in South Africa is financial incentives, whilst indigency and unemployment drive the informal sector. Recycling rates can be enhanced through clear policies and incentives, market organisation and siting of suitable infrastructure that will drive recycling at household and municipal levels (Fakir, 2009). Material recovery facilities (MRFs) can also play a crucial role if strategically located to enable lower transport costs for collectors. At source separation of recyclables ought to be prioritised to prevent contamination of recyclables at landfills, which ultimately affects the quality of recyclables and makes extraction expensive (Plastics SA, 2018).

4.5.2 Extent of Mainline Recyclables in eThekwini Municipality and South Africa

From examining existing studies, it's proven that the South African paper recycling sector is fully established. Paper products present a significant amount, contributing 18% of South African municipal waste (Friedrich and Trois (2013). According to PRASA (2011), the South African paper recycling rate was 59% in 2011 and 62.1% in 2013. In eThekwini Municipality, the results showed that recyclable paper collected by DSW between 2009 and 2014 ranged from 7 038 tonnes to 14 372 tonnes, with total paper recyclables collected over the six-year period amounting to 74 255 tonnes. Paper recycling progressively increased year on year over the time series data period. Of the four mainline recyclables collected in eThekwini, paper recyclables had the highest tonnage.

According to Fakir (2009), plastic recycling rates are increasing in South Africa due to plastic legislation enacted and increased demand for plastics. Recycling is driven by market conditions and statutes in South Africa, and there is already an established local market for glass, plastics, paper and metal cans (Fakir, 2009).The increases in recycling rates for metal cans in eThekwini can also be attributed to the very high demand for scrap metal from China, as well as demand from the local South African market (Fakir, 2009). China produced 0.96 million tonnes of aluminium in 1991, and by 2004 the demand had grown by 600% (Xiao-wu, et. al, 2008). According to Willen (2008), China imports 4 billion tonnes of recycled plastic, 12 billion tonnes of recycled paper and 10 billion tonnes of scrap metal. However, in 2017 China banned the importation of plastic materials, which had a huge impact on global plastic recycling. Fortunately, South Africa wasn't adversely affected given that most of the plastic waste collected locally is used for recycling purposes within the country (Plastics SA, 2018).

Plastic products constitute approximately 12% of South African municipal waste (Friedrich and Trois, 2013). A study conducted by Packaging SA (2011) shows that South Africa and eThekwini in particular, have a well-developed plastic recycling industry. This is supported by the fact that approximately 22% of all plastic recyclers are located within KwaZulu-Natal, with 81% of them located within eThekwini Municipality (Plastics SA, 2014). The findings from this study have shown that plastic recyclables collected by DSW ranged from 1 546 tonnes (2009) to 4 050 tonnes (2014), with total plastic recyclables collected over the six-year period amounting to 17 785 tonnes. This data shows a year on year continual increase in recycled plastics in eThekwini Municipality.

Glass constitutes 7% of South African municipal waste (Friedrich and Trois, 2013). DEA (2012b) states that the South African glass recycling rate rose from 18% to 40.6% between 2005 and 2013. In eThekwini, glass recyclables collected by DSW ranged from 352 tonnes (2009) to 1 316 tonnes (2014), with a total of 4 958 tonnes over the six-year period. This represents a year on year increase in glass recyclables, with some fluctuations observed over the time series data period. These glass recycling variations are as a result of month to month discrepancies in household recycling participation levels. The relatively low collection rate maybe borne out of the fact that underprivileged households in eThekwini exchange glass bottles for cash at retail stores instead of using recycling centres where they do not normally get financial rewards. Some of the inconsistencies may be due to the fact that the implementation of the clear bag kerbside recycling scheme for collection of glass bottles and cans was still in its infancy at the time of the study, thus communities were not yet fully conscientised of the related environmental benefits.

According to Friedrich and Trois (2013), approximately 4% of the South African municipal waste stream was made up of metals. Metal recycling amounted to approximately 147 000 tonnes (55.8% rate of recycling) in 2009 and further improved to 59.9% in 2011 (Packaging SA, 2011 and Marthinusen, 2013). According to Collect-a-Can (2014), the recycling rate for steel and aluminium cans in South Africa is approximately 70%. Cans recyclables collected in eThekwini by DSW ranged from 37 tonnes (2010) to 356 tonnes (2014), with a total of 955 tonnes over the six-year period. Generally, cans recycling gradually increased year on year, with some fluctuations observed over the time series data period. These inconsistencies may be due to limited awareness and restricted municipal footprint coverage of the clear bag kerbside recycling programme which was still in its infancy at the time of the study. Cans have the lowest tonnage of the four main recyclables collected by DSW in eThekwini Municipality.

As shown in Table 4.9, the total amounts of mainline recyclables diverted from eThekwini landfills through voluntary recycling by DSW are 18 940 tonnes (2012), 17 563 tonnes (2013) and 19 183 tonnes (2014). The total municipal waste stream disposed at eThekwini landfills, excluding builders' rubble, amounted to 1 512 466 tonnes (2012), 1 495 436 tonnes (2013) and 1 451 863 tonnes (2014) (DSW Waste Statistics, 2014). This generated recycling rates, excluding builders' rubble, in eThekwini Municipality of approximately 1.3% (2012), 1.2% (2013) and 1.3% (2014).

4.5.3 Greenhouse Gas Emission Savings and Landfill Space Savings

While landfills are viewed as convenient means of waste management, they are an environmentally unfriendly waste disposal method. eThekwini is committed to remedy this environmental pollution by implementing recycling programmes which increase waste diversion from landfills (DSW's Essentially Better, n.d). This means that while eThekwini has been reliant on landfilling as a waste disposal methodology, it is cognisant that this strategy is not effective in sustainably managing waste.

GHG emission savings and LSS were calculated based on the amounts of mainline recyclables diverted from landfills due to voluntary recycling by DSW in eThekwini Municipality. The mainline recyclables which were collected between 2009 and 2014 ranged from 8 983 tonnes to 19 183 tonnes, with the total amount of recyclables over the six-year period amounting to 97 953 tonnes. As shown in Table 4.10, using developed predictive regression models, mainline recyclables likely to be collected through voluntary recycling in eThekwini Municipality were projected to gradually increase up to 40 913 tonnes by 2025. However, it was not possible at the time to obtain data to validate the projections.

The study established that GHG emission savings emanating from voluntary recycling of mainline recyclables by DSW in eThekwini ranged from 5 891 tonnesCO_2e (2009) to 14 102 tonnesCO_2e (2014). The total emission savings were 66 708 tonnesCO_2e over the six-year period from 2009 to 2014. Generally, the consolidated totals for GHG emission savings gradually increased from year to year as presented in Table 4.11. As shown in Table 4.12, the forecasted emission savings were projected to gradually increase year on year up to 31 573 tonnesCO_2e by 2025. As per Table 2.3 in the Literature Review chapter, the average GHG emissions in eThekwini Municipality between 2010 and 2014 was 28 381 928 tonnesCO_2e. The South African waste sector contributes 2% of the nation's emissions (DEAT, 2009b). Based on this premise, it would infer that approximately 567 639 tonnesCO_2e of greenhouse gases emitted per annum in eThekwini are accredited to waste management activities. With 66 708 tonnesCO_2e of greenhouse gas emission savings in eThekwini Municipality, this represents an 11% saving on annual emissions.

The study established that the LSS from voluntary recycling of mainline recyclables by DSW in eThekwini ranged from 34 557m^3 (2009) to 78 746m^3 (2014), with total space savings of 383 591m^3 over the six-year period. Generally, the consolidated totals for LSS gradually increased from year to year as presented in Table 4.13. As shown in Table 4.14, the forecasted LSS were projected to gradually increase year on year up to 170 188m^3 by 2025. LSS mitigate against the environmental impacts of landfilling by extending the lifespan of existing landfill sites as well as minimising related environmental pollution. According to Couth and Trois (2010), approximately 550-700 waste tonnes per day are disposed at Mariannhill landfill site. Adopting an average disposal rate of 625 tonnes/day, this represents 228,125 tonnes every year. Using the local compacted density for municipal solid waste of 1.2 tonnes/m^3 (Jagath, 2010), this represents 190 104m^3 of landfill space utilised per annum. This implies that for every 228 125 tonnes of waste recycled (or 190 104m^3 of landfill space saving) the landfill lifespan is extended by approximately one year. This study established that voluntary recycling of mainline recyclables by DSW in eThekwini between 2009 and 2014 generated approximately 383 591m^3 of landfill space savings. Assuming that the landfill space savings were generated at one landfill, Mariannhill landfill site, this would result in the extension of the landfill lifespan by approximately two years. This can be further augmented if eThekwini Municipality implements more recycling programmes across the entire municipal footprint which would divert more recyclables from landfills.

4.5.4 Proposed Recommendations for Improving Recycling in eThekwini Municipality

The recycling rates for eThekwini Municipality are not substantial, therefore proposals will be recommended on how to strategically enhance recycling in the municipality in order to meet the national recycling average in the interim and the NWMS recycling target over the longer term. Recycling growth can reduce unemployment, grow local small businesses, improve the livelihoods of people who work in the sector, reduce socio-economic challenges in the communities and significantly contribute towards the national fiscus. The other benefits of recycling are reduction of landfilling costs, extension of landfill lifespans, lesser environmental pollution and conservation of resources.

The growth of recycling in eThekwini can also be enhanced by the enacting of effective municipal by-laws and clear policies which incentivise the recycling sector by way of “carrot and stick approach” and facilitate the development of sustainable supply and demand local markets for recyclables. eThekwini should also aggressively expand recycling outside the mainline recyclables of paper, plastic, glass and cans, to include other recycling materials such as, e-waste, batteries, tyres and vehicle waste. Incentives ought to be offered to businesses to partake in upstream investments for the processing of these recyclables. According to Fakir (2009), the tyre levy policy which was introduced in South Africa in 2008 has substantially increased the tonnage of tyres recycled by tyre manufacturers and retailers. eThekwini should also consider offering more technical and economic support to informal recyclers to enable them to increase their recycling outputs and municipal footprint coverage. The municipality should also encourage and incentivise entrepreneurship initiatives among small and medium enterprises involved in the collection and processing of recyclables. eThekwini should also consider constructing more MRFs across the municipal footprint. The MRFs should be strategically located in areas that enable collection of more recyclables at lower transportation costs as well as driving both the supply and demand processes for the recyclables.

As per the eThekwini recycling data collected between 2009 and 2014, the recycling rate for eThekwini was between 1.2-1.3%. It would require to be increased by roughly 10-fold to be able to meet the average national recycling rate of 10%. Though not yet fully established in most wards of eThekwini, recycling is primarily conducted through the clear bag and orange bag kerbside recycling scheme. It is proposed that the expansion of the household kerbside recycling scheme should be expedited to cover most of the municipal footprint, including townships and informal settlements. This approach can significantly drive up recycling outputs, given that clean recyclables will be collected at household level throughout the municipality. It is proposed that this recycling augmentation project be incrementally implemented to enable the collection of more recyclables and potentially increase the eThekwini recycling rate to approximately 10%. In order to increase the eThekwini recycling rate to 25% as prescribed in the NWMS (DEA, 2011), it is proposed that the municipal coverage of the orange and clear bag kerbside recycling schemes be further enhanced to cover a much wider municipal footprint. The NWMS proposed a target of 25% waste diversion from landfills within a period of 5 years. The Department of Environmental Affairs (DEA) is currently reviewing the NWMS and the recently released draft review report has revealed that recycling progress has been very limited. Bearing that in mind, and the related financial constraints facing municipalities, its proposed that eThekwini should aim to increase its recycling rate by 10% every 5 years; which would take it approximately 5 years to attain a recycling rate of 10%, approximately 10 years to attain a 20% recycling rate and approximately 12.5 years to attain a recycling rate of 25%. The base year can be set as the year before this proposed recycling framework is implemented.

The capital costs of implementing this proposed kerbside recycling augmentation programme are bound to be significant. By incrementally increasing recycling up to10-fold and 25-fold, there is likely to be an approximate 10-fold and 25-fold cost increase respectively, thereby satisfying the 10% national recycling average and 25% NWMS recycling target. Where the kerbside recycling schemes need to be implemented, the implementation costs can be obtained from the SASCOST model which was developed by the Council for Scientific and International Research (CSIR) as a decision support tool to assist municipalities in identifying the most cost-effective option for programme implementation. According to Nahman and Oelofse (n.d), the cost of implementing a kerbside recycling programme differs widely depending on the type of collection system and the type of municipality. Based on financial costing and hypothetical data, the additional cost of implementing a separate vehicle kerbside recycling system ranges from R17/household/month for Category A municipalities or metros to R60/household/month for Category B4 smaller municipalities (Nahman and Oelofse, n.d). With eThekwini Municipality falling under Category A municipalities or metros the implementation cost would be approximately R17/household/month.

With regards to landfill space savings (LSS), the voluntary recycling of mainline recyclables by DSW in eThekwini Municipality between 2009 and 2014 resulted in a potential extension of the landfill lifespan of Mariannhill by approximately 2 years. If recycling is increased by 1% by approximately doubling the current recycling rate, the landfill space savings will approximately double over a similar 6-year period. The recycling rate can potentially be doubled by doubling the number of municipal wards covered by the orange bag and clear bag kerbside recycling schemes. Based on the fact that a 6-year recycling period generated 2 years of LSS at 1% recycling rate, if eThekwini recycling rates incrementally increase to 25% upon the successful implementation of the proposed recycling recommendations that would yield approximately 8 years of annual LSS due to waste diversion from landfills.

4.5.5 Summary

Question to this research was to explore and investigate the mainline recyclables, GHG emission savings and LSS from voluntary recycling by DSW in eThekwini Municipality between 2009 and 2014. The study commenced by exploring the extent of voluntary recycling in eThekwini, focussing on mainline recyclables, namely, paper, plastics, glass and cans. Central to the findings is that, generally, there was a gradual year on year increase in collected mainline recyclables, subsequently resulting in related increases in GHG emission savings and LSS. The study established that voluntary recycling of mainline recyclables by DSW in eThekwini over the study period resulted in the potential extension of the lifespan of Mariannhill landfill site by approximately two years. With regards to GHG emission savings accrued in eThekwini over the same study period, approximately 11% of annual emission savings were realised. They can be further enhanced if recycling rates are significantly increased in line with the proposed recommendations. eThekwini recycling rates fell short of the 25% waste diversion target set in the NWMS. However, with the implementation of more effective and wide-ranging recycling strategies, this target can be attained in the future given that approximately 25% of municipal waste streams consist of recyclables. The main strategy which was discussed which can substantially increase recycling rates in eThekwini is the expansion and augmentation of the orange and clear bag kerbside recycling programme to cover the entire footprint of eThekwini Municipality.

CHAPTER 5

5. CONCLUSION

5.1 Introduction

This study aimed to investigate the mainline recyclables, GHG emission savings and LSS resulting from voluntary recycling of mainline recyclables by DSW in eThekwini Municipality for the period from 2009 to 2014.

5.2 Summary of Investigation

Descriptive statistical analysis of the four mainline recyclables (paper, plastics, glass and cans) established that recycling generally increased year on year between 2009 and 2014. The total amount of mainline recyclables which were recycled over the six-year period amounted to 97 953 tonnes. The GHG emission savings and LSS emanating from these recyclables were also quantified. Predictive regression models were developed for forecasting the future amounts of mainline recyclables likely to be recycled by DSW in eThekwini Municipality between 2015 and 2025. Expectedly, the recyclables projected to be diverted from eThekwini landfills increased year on year. Furthermore, the projected recycling data was used to forecast future GHG emission savings and LSS. The study aimed to fill this knowledge gap by using existing eThekwini primary recycling data to investigate current and projected GHG emission savings and LSS. Generally, there was continual annual increase in the amounts of recyclables, which gave rise to related increases in emission savings and landfill space savings. The study also availed information to eThekwini and other South African municipalities that can assist in appraising the feasibility and sustainability of municipal recycling programmes.

5.3 Main Conclusions

The study's main conclusions are presented in this section. The first objective was to investigate the GHG emission savings resulting from voluntary recycling of mainline recyclables by DSW in eThekwini Municipality between 2009 and 2014. The GHG emission savings generally increased year on year for the time period the recycling data was collated. Developed predictive regression models were used to show that forecasted GHG emission savings continued to increase year on year between 2015 and 2025. The current and forecasted emission savings emanating from the recyclables data were worthwhile, and would be further enhanced by an expansion of recycling programmes in eThekwini Municipality. The total GHG emission savings of 66 708 tonnesCO_2e accrued in eThekwini between 2009 and 2014 represent approximately 11% savings on annual emissions. This is a worthwhile contribution in mitigating against climate change and global warming.

The second objective was to investigate the LSS generated from voluntary recycling of mainline recyclables by DSW in eThekwini Municipality between 2009 and 2014. The LSS generally increased year on year for the time period the recycling data was collated. The developed predictive regression models were used to show that the forecasted LSS continually increased from year to year between 2015 and 2025. The current and forecasted LSS emanating from the recycling activities were worthwhile, and would be further enhanced by an expansion of recycling programmes in the municipality. The study established that the voluntary recycling of mainline recyclables by DSW in eThekwini between 2009 and 2014 generated 383 591m^3 of LSS. Assuming that these LSS were generated at one landfill, namely, Mariannhill landfill site, this would potentially result in the extension of the landfill lifespan by an additional two years.

The third objective was to develop predictive regression models to forecast the amounts of mainline recyclables likely to be collected by DSW through voluntary recycling in eThekwini Municipality. The models were developed, and upon application predicted a continual increase in forecasted mainline recyclables collected from year to year between 2015 and 2025. The current and forecasted mainline recyclables are worthwhile, and would be further optimised by expanding and augmenting recycling programmes in eThekwini. Given that the predictive regression models were developed with an underlying assumption that the existing recycling trends would continue into the future; the predictive models might require a future review if there are significant changes in waste stream and recycling trends in the municipality.

5.4 Recommendations for Future Research

The recommendations for further research identified during the study are presented below.

- South African greenhouse gas emission factors for paper, plastics, glass and cans were used in this study. The study is delimited to these four mainline recyclables. Further research would need to be done to determine the local GHG emission factors for other recycling materials, thereby facilitating a comprehensive quantification and accounting of GHG emission savings.
- The reliability of recycling projections is dependent on current waste generation and recycling trends continuing into the future. The study is delimited to the four mainline recyclables (paper, plastics, glass and cans) collected through voluntary recycling

by DSW in eThekwini Municipality between 2009 and 2014. Future studies would need to be conducted to re-establish waste streams and recycling trends, and to develop new predictive regression models to enable an accurate prediction of recyclables, GHG emission savings and LSS.

- The average GHG emission factors and average landfill space saving factors for plastics (mixed plastics) were used in this study. Future studies should incorporate the separation and quantifying of different types of plastics to enable a more accurate assessment of GHG emission savings and LSS accredited to different plastic materials.

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APPENDICES

APPENDIX A:

Table A-1: Mainline Recyclables Data

PAPER (Variable 1)	2009	2010	2011	2012	2013	2014	TOTAL
January	330	810	996	1345	1366	1148	5994
February	297	819	965	1123	970	1032	5207
March	387	861	1174	1195	1017	1029	5663
April	408	847	1090	1021	1085	1061	5512
May	408	914	1146	1154	1042	1013	5677
June	514	899	1114	1081	956	899	5463
July	578	989	1107	1168	1121	1078	6041
August	684	977	1103	1191	1007	1044	6006
September	683	1038	1288	1137	1036	1104	6286
October	797	1051	1239	1297	1331	1281	6995
November	874	1197	1397	1307	1184	1246	7205
December	1079	1533	1569	1354	1145	1526	8206
TOTAL	7038	11934	14189	14372	13261	13460	74255
PLASTIC (Variable 2)							
January	81	172	220	291	300	288	1352
February	74	169	208	235	222	294	1202
March	98	188	251	264	228	279	1309
April	103	200	220	233	252	293	1302
May	103	189	236	257	259	306	1350
June	107	200	260	250	208	296	1321
July	116	207	240	305	309	379	1556
August	133	195	252	335	261	362	1537
September	142	221	286	280	260	352	1541
October	196	228	278	301	302	348	1653
November	189	258	309	317	239	409	1722
December	202	305	330	372	287	445	1941
TOTAL	1546	2532	3090	3441	3127	4050	17785
GLASS (Variable 3)							
January	78	54	61	53	98	41	386
February	19	26	62	53	61	27	248
March	46	36	50	62	53	39	285
April	47	24	77	57	66	106	377
May	0	70	42	51	61	79	303
June	33	83	54	75	200	90	535
July	2	99	66	87	67	130	452
August	34	48	38	101	66	130	417
September	0	55	62	59	77	143	396
October	54	68	63	115	65	185	549
November	40	64	77	102	54	185	521
December	0	82	63	105	78	162	490
TOTAL	352	709	716	919	945	1316	4958

CANS (Variable 4)	2009	2010	2011	2012	2013	2014	TOTAL
January	12	2	12	15	9	42	93
February	2	2	11	7	9	32	62
March	3	2	3	8	10	27	53
April	7	3	5	46	9	23	92
May	2	2	3	4	14	25	50
June	6	4	3	6	15	23	57
July	2	4	3	21	25	30	85
August	8	5	4	22	19	28	86
September	1	1	3	22	25	33	86
October	1	3	15	23	28	30	100
November	1	4	6	20	40	31	102
December	1	5	9	14	27	32	87
TOTAL	46	37	77	208	230	356	955

APPENDIX B:

Table B-1: Mainline Recyclables Data (SPSS Regression Analysis Data)

ID	Year	Month	Type	Recyclables
1	2009	1	1 (Paper)	329.9
2	2009	2	1	297.3
3	2009	3	1	386.9
4	2009	4	1	408.5
5	2009	5	1	407.5
6	2009	6	1	514.3
7	2009	7	1	577.5
8	2009	8	1	683.8
9	2009	9	1	683.0
10	2009	10	1	796.8
11	2009	11	1	874.3
12	2009	12	1	1078.7
13	2010	1	1	809.6
14	2010	2	1	819.4
15	2010	3	1	861.2
16	2010	4	1	847.0
17	2010	5	1	914.4
18	2010	6	1	898.6
19	2010	7	1	989.0
20	2010	8	1	977.0
21	2010	9	1	1038.0
22	2010	10	1	1050.6
23	2010	11	1	1196.9
24	2010	12	1	1532.8
25	2011	1	1	995.9
26	2011	2	1	965.4
27	2011	3	1	1173.5
28	2011	4	1	1089.5
29	2011	5	1	1145.9
30	2011	6	1	1114.4
31	2011	7	1	1107.5
32	2011	8	1	1103.4
33	2011	9	1	1288.3
34	2011	10	1	1239.0
35	2011	11	1	1396.6
36	2011	12	1	1569.4
37	2012	1	1	1344.7

ID	Year	Month	Type	Recyclables
145	2009	1	3 (Glass)	77.9
146	2009	2	3	19.3
147	2009	3	3	45.8
148	2009	4	3	47.0
149	2009	5	3	0.0
150	2009	6	3	32.8
151	2009	7	3	2.2
152	2009	8	3	33.8
153	2009	9	3	0.0
154	2009	10	3	53.5
155	2009	11	3	39.9
156	2009	12	3	0.0
157	2010	1	3	54.3
158	2010	2	3	25.7
159	2010	3	3	36.3
160	2010	4	3	23.7
161	2010	5	3	70.2
162	2010	6	3	83.4
163	2010	7	3	99.0
164	2010	8	3	47.7
165	2010	9	3	54.9
166	2010	10	3	68.1
167	2010	11	3	64.2
168	2010	12	3	81.9
169	2011	1	3	61.4
170	2011	2	3	61.8
171	2011	3	3	49.8
172	2011	4	3	77.1
173	2011	5	3	42.2
174	2011	6	3	54.4
175	2011	7	3	66.0
176	2011	8	3	38.4
177	2011	9	3	62.0
178	2011	10	3	62.9
179	2011	11	3	76.6
180	2011	12	3	63.3
181	2012	1	3	53.4

38	2012	2	1	1123.4
39	2012	3	1	1195.1
40	2012	4	1	1021.0
41	2012	5	1	1154.2
42	2012	6	1	1080.9
43	2012	7	1	1167.8
44	2012	8	1	1190.8
45	2012	9	1	1136.5
46	2012	10	1	1296.7
47	2012	11	1	1307.3
48	2012	12	1	1354.0
49	2013	1	1	1365.7
50	2013	2	1	969.6
51	2013	3	1	1016.9
52	2013	4	1	1085.2
53	2013	5	1	1042.2
54	2013	6	1	956.3
55	2013	7	1	1121.2
56	2013	8	1	1007.1
57	2013	9	1	1036.2
58	2013	10	1	1330.9
59	2013	11	1	1184.0
60	2013	12	1	1145.5
61	2014	1	1	1147.9
62	2014	2	1	1031.8
63	2014	3	1	1029.2
64	2014	4	1	1061.2
65	2014	5	1	1012.6
66	2014	6	1	898.6
67	2014	7	1	1077.9
68	2014	8	1	1044.3
69	2014	9	1	1104.0
70	2014	10	1	1280.9
71	2014	11	1	1245.7
72	2014	12	1	1525.9
73	2009	1	2 (Plastic)	81.1
74	2009	2	2	74.1
75	2009	3	2	98.3
76	2009	4	2	103.1
77	2009	5	2	102.8
78	2009	6	2	107.5
79	2009	7	2	115.6
80	2009	8	2	133.3
81	2009	9	2	142.5
82	2009	10	2	195.8

182	2012	2	3	53.4
183	2012	3	3	61.8
184	2012	4	3	56.7
185	2012	5	3	50.8
186	2012	6	3	74.7
187	2012	7	3	87.3
188	2012	8	3	100.5
189	2012	9	3	59.1
190	2012	10	3	114.6
191	2012	11	3	101.7
192	2012	12	3	105.4
193	2013	1	3	97.6
194	2013	2	3	61.0
195	2013	3	3	52.6
196	2013	4	3	66.5
197	2013	5	3	61.0
198	2013	6	3	199.8
199	2013	7	3	67.2
200	2013	8	3	66.0
201	2013	9	3	77.4
202	2013	10	3	64.8
203	2013	11	3	54.0
204	2013	12	3	77.6
205	2014	1	3	40.9
206	2014	2	3	26.8
207	2014	3	3	39.2
208	2014	4	3	105.7
209	2014	5	3	78.6
210	2014	6	3	90.5
211	2014	7	3	130.2
212	2014	8	3	130.4
213	2014	9	3	143.1
214	2014	10	3	184.7
215	2014	11	3	184.9
216	2014	12	3	161.5
217	2009	1	4 (Cans)	12.1
218	2009	2	4	2.1
219	2009	3	4	3.2
220	2009	4	4	7.0
221	2009	5	4	2.0
222	2009	6	4	6.1
223	2009	7	4	1.7
224	2009	8	4	7.6
225	2009	9	4	1.4
226	2009	10	4	1.2

83	2009	11	2	189.5
84	2009	12	2	202.2
85	2010	1	2	172.2
86	2010	2	2	169.1
87	2010	3	2	187.9
88	2010	4	2	200.1
89	2010	5	2	189.3
90	2010	6	2	200.3
91	2010	7	2	207.0
92	2010	8	2	194.7
93	2010	9	2	221.1
94	2010	10	2	228.1
95	2010	11	2	257.9
96	2010	12	2	304.5
97	2011	1	2	220.0
98	2011	2	2	208.2
99	2011	3	2	251.5
100	2011	4	2	219.9
101	2011	5	2	235.9
102	2011	6	2	259.7
103	2011	7	2	239.8
104	2011	8	2	251.7
105	2011	9	2	286.2
106	2011	10	2	278.1
107	2011	11	2	309.2
108	2011	12	2	329.8
109	2012	1	2	290.6
110	2012	2	2	234.7
111	2012	3	2	264.1
112	2012	4	2	233.5
113	2012	5	2	257.3
114	2012	6	2	250.2
115	2012	7	2	305.4
116	2012	8	2	335.1
117	2012	9	2	279.6
118	2012	10	2	300.8
119	2012	11	2	317.1
120	2012	12	2	372.4
121	2013	1	2	299.9
122	2013	2	2	221.8
123	2013	3	2	228.3
124	2013	4	2	251.9
125	2013	5	2	258.9
126	2013	6	2	207.7
127	2013	7	2	309.5
128	2013	8	2	260.9
129	2013	9	2	260.4
227	2009	11	4	0.8
228	2009	12	4	1.0
229	2010	1	4	2.4
230	2010	2	4	1.9
231	2010	3	4	2.5
232	2010	4	4	2.7
233	2010	5	4	2.3
234	2010	6	4	3.6
235	2010	7	4	4.1
236	2010	8	4	5.0
237	2010	9	4	1.5
238	2010	10	4	2.6
239	2010	11	4	4.0
240	2010	12	4	4.7
241	2011	1	4	12.1
242	2011	2	4	10.8
243	2011	3	4	3.2
244	2011	4	4	5.0
245	2011	5	4	2.7
246	2011	6	4	2.8
247	2011	7	4	3.4
248	2011	8	4	3.9
249	2011	9	4	2.7
250	2011	10	4	15.4
251	2011	11	4	5.7
252	2011	12	4	9.0
253	2012	1	4	15.2
254	2012	2	4	6.6
255	2012	3	4	7.7
256	2012	4	4	45.5
257	2012	5	4	4.2
258	2012	6	4	6.4
259	2012	7	4	21.4
260	2012	8	4	21.7
261	2012	9	4	22.2
262	2012	10	4	22.9
263	2012	11	4	20.1
264	2012	12	4	14.1
265	2013	1	4	8.7
266	2013	2	4	9.1
267	2013	3	4	9.6
268	2013	4	4	9.3
269	2013	5	4	14.2
270	2013	6	4	15.1
271	2013	7	4	24.9
272	2013	8	4	18.9
273	2013	9	4	24.9

130	2013	10	2	302.1	274	2013	10	4	28.3
131	2013	11	2	238.9	275	2013	11	4	40.3
132	2013	12	2	286.5	276	2013	12	4	26.9
133	2014	1	2	288.2	277	2014	1	4	42.3
134	2014	2	2	293.7	278	2014	2	4	32.0
135	2014	3	2	279.2	279	2014	3	4	27.2
136	2014	4	2	293.2	280	2014	4	4	22.7
137	2014	5	2	305.7	281	2014	5	4	24.6
138	2014	6	2	295.5	282	2014	6	4	23.1
139	2014	7	2	378.5	283	2014	7	4	30.0
140	2014	8	2	361.7	284	2014	8	4	28.5
141	2014	9	2	351.5	285	2014	9	4	33.2
142	2014	10	2	348.1	286	2014	10	4	29.9
143	2014	11	2	409.0	287	2014	11	4	31.3
144	2014	12	2	445.5	288	2014	12	4	31.6