DESIGN OF A WASTE-TO-LANDFILL MINIMISATION MODEL FOR SOUTH AFRICA'S MINING TOWNS

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DECLARATION

I, LEON RODNEY KENNY (Student number: 18035345), hereby declare that this thesis entitled "A Design of a waste-to-landfill minimisation model for South Africa's mining towns" is my own original work. Unless specifically stated, all references listed have been consulted. The thesis is submitted in fulfilment of the requirements for the degree of PhD in Environmental Science & Management, at the North-West University, Mafikeng Campus, Rep`10ublic of South Africa. I further declare that this work has not previously been submitted by me for a degree at any other university.

Signed:..

LEON RODNEY KENNY

Date: 25 November 2016

This thesis has been submitted with my approval as a university supervisor and I certify that the requirements for the applicable PhD degree rules and regulations have been fulfilled.

Signed: ....

PROFESSOR T.M. RUHIIGA

Date: 25/11/16

DEDICATION

This work is dedicated to my mother (Daphne Kenny), my brother and sister (Odette Kenny and Jonathan Kenny), to my dearest Jamie Stephanie Kenny and to my handsome son Lermaine Ja-Leon Kenny and daughter Tiffany Jennifer Kenny. Last but not least this work is also dedicated to all those who seek to improve their livelihoods through the development of sustainable waste minimisation efforts and a love and care for their surroundings and the environment. After all we inherited the environment from our children.

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ABSTRACT

The study was carried out in order to design a waste to landfill minimisation model for South Africa's mining towns. The study area covered four provinces and for each province a single local municipality with a major mining town was selected. Focusing on Klerksdorp, Carletonville, Witbank and Welkom as major mining towns, interest centred on waste generation rates, storage, treatment, directorates and reduction programmes. Built on a quantitative survey research design, primary data was collected through observation and secondary statistics accessed from official sources. Initial data processing used Excel™ to generate descriptive statistics. Inferential statistics made use of correlation and linear regression techniques. The key findings were that there are very few programmes implemented for waste minimisation programmes in place, in addition to the inherent problems of organisational design within the waste management systems, poor waste management structures, the dominance of waste disposal by land filling, run down and dilapidated vehicles and equipment, lack of proper waste management data, low priority for waste stream analysis-recycling and waste minimisation, and low levels of awareness of waste minimisation in the general public. An integrated waste process model was then constructed based on a series of linear regression equations. The novelty of waste minimisation modelling developed here centres on the ability to minimise waste at stages along the waste chain from generation to final disposal.

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DEFINITION OF KEY CONCEPTS

Backlogs: Means the accumulation of waste streams to such an extent that the delivery of waste services cannot be achieved efficiently.

Building waste: Includes all waste produced during the construction, alteration, repair or demolition of any structure, and includes building rubble, earth, vegetation and rock displaced during such construction, alteration, repair or demolition.

By-law: Means legislation passed by the municipality's council which is binding on persons who resides within, visiting the area of authority of the municipality or using municipal services.

By-product: Means a substance that is produced as part of a process that is primarily intended to produce another substance or product and that has the characteristics of an equivalent virgin product or material.

Garden waste: Means organic waste which emanates from gardening or landscaping activities at residential, business or industrial premises. It includes but is not limited to grass cuttings, leaves, and branches and any biodegradable material but excludes waste products of animal origin and bulky waste.

General waste: Includes domestic waste, building waste and demolition waste that is not a hazard to the environment and poses no immediate threat to health and life.

Hazardous waste: Means any waste that contains organic or inorganic elements or compounds that owing to the inherent physical, chemical or toxicological characteristics of that waste, may have a detrimental impact on health and the environment.

Inert waste: Means any waste that does not undergo any significant physical, chemical or biological transformation after disposal and which does not burn, react physically or chemically biodegrade or otherwise and which does not impact negatively on the environment because of its pollutant nature.

Litter: Means waste, excluding hazardous waste, arising from activities in public areas that have not been disposed of in a public litter container.

Municipal: Usually means an urban administrative division having corporate status and usually powers of self-government.

Receptacle: Means an approved container having a capacity for temporary storage of waste in terms of the applicable by-laws.

Secondary cities: Those cities which at present are not classified as metropolitan in RSA (RSA< 2000) but which have a population, as of end of 2012, falling within the range from 100 000 to 500 000 inhabitants.

Service provider or contractor: Means the person, firm or company who's tender or quotation has been accepted by or on behalf of the municipality and includes the contractor's heirs, executors, administrators, trustees, judicial managers or liquidators, as the case may be.

Systems analysis: A systematic examination and evaluation of data, by breaking it into its component parts to uncover their interrelationships. It can also be described as the process of breaking a complex topic or substance into smaller parts to gain a better understanding of it.

Tariff: Means the prescribed charge determined by the municipality in terms of any applicable legislation for any service rendered by the municipality in terms of the respective local municipality by-laws.

Waste management: Can be referred to the interwoven collection, transport, processing or disposal, managing and monitoring of waste materials. The term usually relates to materials produced by human activity, and the process generally undertaken to reduce their effect on health, the environment or aesthetics.

Waste minimisation model: Means the process and the policy of reducing the amount of waste produced by a person or society.

ABBREVIATIONS

ANOVA	Analysis of Variance
APE	Alternative Press Expo
AZT	Azidothymidine
CBO	Community-Based Organisations
CDM	Clean Development Mechanism
CEO	Chief Executive Officer
CER's	Certified Emission Reductions
CH^4	Methane
CO^2	Carbon Dioxide
CPU	Central Processing Unit
CRT	Cathode Ray Tube
DANIDA	Danish International Development Agency
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DEPA	Danish Environmental protection Agency
DMR	Department of Mineral Resources
DO	Dissolved Oxygen
DPLG	Department of Provincial and Local Government
DTI	Department of Trade and Industry
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EA	Environmental Affair
EIA	Environmental Impact Assessment
EMCAs	Environmental Management Corporate Agreements
EMI	Environmental Management Inspector
EPA	Environmental Protection Agency
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
ESAs	External Support Agencies

EWM	European Waste Minimisation
GDP	Gross Domestic Product
GHG	Greenhouse Gasses
GIS	Geographic Information Systems
GNI	Gross National Index
GPS	Global Positioning System
GSA	Government of South Africa
HDPE	High Density Poly-Ethylene
HR	Human Resource
IDP	Integrated Development Planning
IndWMP	Industry Waste Management Plan
IP&WM	Integrated Pollution and Waste Management
ISWA	International Solid Waste Association
IWEX	Integrated Waste Exchange
IWM	Integrated Waste Management
IWMP	Integrated Waste Management Plan
KPA	Key Performance Areas
LDPE	Low Density Poly-Ethylene
LFG	Landfill Gas Collection
MBT	Mechanical and biological treatment
MOU	Memorandum of Understanding
MRFs	Material Recovery Facilities
MSWM	Municipal Solid Waste Management
MW	Megawatts
NECSA	National Energy Consortium of South Africa
NEM	National Environmental Management Act
NGO	Non-Governmental Organisation
NJDEP	New Jersey Department of Environmental Protection
NMBM	Nelson Mandela Bay Municipality
NWMS	National Waste Management Strategy
NWMSI	National Waste Management Strategy Implementation

PET	Poly-Ethylene Terephthalate
POP	Persistent Organic Pollutant
PP	Poly-Propylene
PPA	Power Purchase Agreement
PPE	Personal Protective Equipment
PPP	Public Private Partnership
PS	Poly-Styrene
PST	Product Stewardship
PVC	Poly-Vinyl Chloride
SALGA	South African Local Government Association
SANS	Standards South Africa
SATMC	South African Tyre Manufacturing Conference
SAWIC	South African Waste Information Centre
SAWIS	South African Waste Information System
SMEs	Small and Medium Enterprises
SPSS	Statistical Package for the Social Sciences
UN	United Nations
UNFCCC	United Nations Convention on Climate Change
US EPA	United States Environmental Protection Agency
USA	United States of America
WIS	Waste Information System
WMin	Waste Minimisation
WPS	Waste Planning System
WtE	Waste to Energy
WX	Waste Exchange

CHAPTER 1: INTRODUCTION

1.1 Background

In South Africa, 566 million tons off rubbish gets thrown away each year (Oelofse, 2012), much of which ends up dumped in landfill sites. The rubbish that gets added to landfill sites daily is compacted down to reduce its volume and increase the life of the landfill site. Therefore at the end of each day the waste is covered with soil to prevent further contact with the air, thus keeping it relatively dry and discouraging animals from going through it. Some landfill sites generally only accept non-hazardous waste, with some special sites taking hazardous waste (Nahman and Godfrey 2010). The local municipalities responsible for the general waste service delivery are faced with increasing challenges impacting on both the presence and quality of such services (Butler and Zacharat, 2012). Many landfill sites in South Africa have shown a decline in operating standards and levels of legal compliance over the past few years. The low priority attached by local municipality to waste does little to mitigate this current problem with the potential impacts on human health and the environment. In 1998, waste generation in South Africa amounted to 533 million tonne per annum of which the majority comprised mining waste (Godfrey and Scott, 2012). Domestic and trade waste represented 1.5% and sewage sludge 0.1%. Municipal waste generation per capita differs noticeably across income groups, with low, middle and high income groups generating 0.41, 0.74 and 1.29 kg per day respectively. However failing waste services is a reality in South Africa (Hovde et al, 2010). With indications of a strong correlation between a country's gross domestic product and waste generation, further economic growth in South Africa will lead to increased consumption of goods and services and consequently an increase in waste, which will require collection, treatment and disposal (Zurbrugg and Aristani, 2011).

The generation of waste in South Africa is expected to increase as a result of population and economic growth at a predicted rate of 2-3% per annum (SAWIS, 2013). The General Household Survey (StatsSA, 2012) revealed that 39% of households or 50% of the South African population, are not receiving a regular municipal waste collection service, with municipal waste collection having only improved by 2.7% between 2006 and 2010 (Oelofse, 2012), whereas a government study in 2007 revealed that 54% of the national backlog in waste service delivery can be found in metropolitan and secondary municipalities (Miranda et al, 2011). Figure 1 represents the legal landfill sites in South Africa and from the figure it can be seen that the Gauteng province has the highest number of legal landfill sites and the North West province the least number.

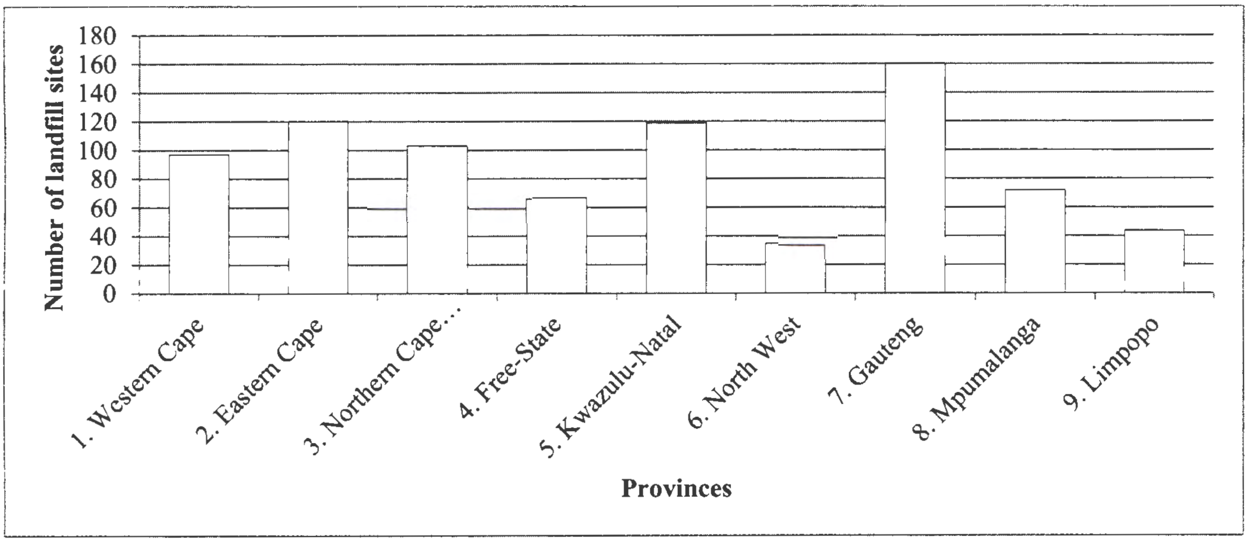


Figure 1. Legal landfill sites by province: South Africa (DEA, 2012)

While it is accepted that there are many well operated sanitary landfill sites in South Africa in line with international best practice, only 817 out of 1496 known landfill sites are authorised through permits and of those authorised, compliance with permit conditions is seldom audited. Of the unauthorised landfill sites, more than 90% are thought to be municipal landfills (Nahman, 2010). The biggest offender in terms of compliance of landfill sites would therefore appear to be municipalities. Table 1 represents the number of permitted waste management facilities in South Africa. Hazardous waste facilities have the highest percentage of permit status, whereas recycling and health care waste facilities have the least permitted status.

Table 1. Waste management facilities permit status

Landfill type	No. of facilities	No. of permitted facilities	Percentage of legal facilities
Inert waste	1419	776	43.56%
Hazardous waste	77	41	53.25%
Health care waste	12	4	33.33%
Recycling facilities	9	2	22.22%
Transfer stations	35	12	34.29%
Total	1552	835	

Research conducted by the CSIR in 2008 (Oelofse, 2012) shows four underlying challenges facing municipalities with regard to waste management. These include financial, equipment, human resource management and institutional behaviour. However, these should not be seen as challenges but rather the symptoms of a number of underlying constraints that need to be addressed (Watson et al, 2012). Municipalities identify the lack of adequate budget allocations as a major obstacle. It is not clear though whether the absence of investments in waste processing facilities is due to budget constraints or to the failure to appreciate the role such facilities would play in waste minimisation. Underlying constraints often include the capping of municipal budgets, the ineffective cost recovery for disposal at landfills, the delays in finalising municipal budgets, vandalism and or theft of infrastructure, reduced operational budgets and ineffective utilisation of equipment and personnel (Mudau et al, 2013). The current skills shortage specifically around waste management combined with the high turnover of staff within municipalities provide further challenges to sustainable waste management (Achillas and Banians, 2011). Waste has direct and indirect impacts on human and ecosystem health including the contamination of surface and ground waters. In addition, methane emissions from waste contributes an estimated 2% of the greenhouse gas emissions profile of South Africa. These impacts could be significantly reduced with improved waste management practices (Oelofse, 2012).

The different phases of the waste management hierarchy (WMH) are the foundations of the cradle-to-grave waste management and this approach seeks to re-use or recycle a product when it reaches the end of its life span. In this way, it becomes inputs for new products and materials. This cycle repeats itself until as small a portion as possible of the original product eventually enters the next level of the waste stream. Recovery involves reclaiming particular components and materials, or using the waste as a fuel. As a last resort, waste enters the lowest level of the hierarchy to be treated and disposed of depending on the safest manner for its final disposal. Where the quantity of waste cannot be reduced during production, the purpose of implementing the waste model hierarchy is to use waste as a resource and divert these potential resources from land filling (Barlaz, 2010). Although land filling is widely considered the most affordable way to manage waste, this view does not take into account the environmental impacts of landfills, the costs of developing and maintaining additional landfill capacity to accommodate the increasing rate of waste disposal and the cost of closing and remediating the landfill (Elena and Tross, 2011). In South Africa, the official position is that all municipalities across the country are aware of the basic principles of the WMH and that strategies are in place to ensure waste minimisation from points of generation to the final disposal. In practice however, and in spite of an impressive array of environmental White Papers and Acts, there is little evidence today to suggest that there is indeed a general movement towards achieving the long term goals of waste minimisation (Oelofse, 2012).

Such an integrated model should meet future demand by decreasing the volume of waste streams that find their way into landfill sites, thus increasing the life span of the landfill. There is also a growing pressure on out-dated waste management infrastructure with declining levels of capital investment and maintenance (Bilitewski, 2008). Waste management suffers from a pervasive under-pricing, which means that the costs of waste management are not fully appreciated by consumers and industry, and waste disposal is preferred over other options. Few waste treatment options are available to manage waste and so they are more expensive than landfill costs. There are also too few adequately compliant landfills and hazardous waste management facilities, which hinders the safe disposal of all waste streams (Mudau et al, 2013). Due to the complex nature of many waste minimisation programmes, including all or several aspects of the integrated WMH at the same time with an emphasis on waste prevention and the traditional role of municipalities to merely provide an end-of-pipe waste management and treatment services for the benefit of generating revenue, local government bodies rarely have extensive waste minimisation experience nor do they provide sufficient human resources capacity and skills in this regard. In particular when waste management programmes are geared towards industry and commerce, municipalities do not typically have the human resources or skills in place that are required to go beyond a traditional "pollution control" e.g. through law enforcement and tariffs for the waste removal role (CSIR, 2011).

High income countries revealed that solid waste management is primarily driven by five factors. The first and second drivers of solid waste management are public health and the environment. These two factors are covered in the constitution of South Africa, No 108 of 1996. Section 24 makes reference to the need to promote the protection of present and future generations. The third driver is resource scarcity which influences policy makers to establish legal frameworks that protect the environment from exploitation. Climate change as the fourth driver brought concerns around the world on waste that has significant impact on the natural environment. Public concern and education about environmental management play a major role in waste management efficiency and therefore strategies that support waste hierarchy principles require behavioural changes (Marshal et al, 2013).

Public health legislation continues to drive waste management forward in this day and age. The first priority of municipalities is to collect and remove waste from the immediate vicinity of residential areas (Wilson, 2007). Once the waste had been removed from underfoot, priorities shift to other aspects of the waste management chain, such as the proliferation of landfills (Seadon, 2006). However disposal was for the most part regulated and controlled, consisting of dumping and burning. The focus remains on waste collection and transportation from the residential areas to the disposal site (Ehrenfeld and Gertler, 2007).

After the Second World War, landfilling was still the principal waste disposal method and rapid growth in consumption from 1960 onwards resulted in a larger municipal waste stream with a higher plastics content (Wolsink, 2010). Finally, the environmental movement of the 1960s and 1970s brought waste disposal onto the political agenda in industrialized countries (Wilson, 2010) which created a significant shift in policymakers' perspectives on how to approach SWM. New legislation addressing water pollution and SWM emerged, initially targeting the elimination of uncontrolled disposal and subsequent SWM legislation increasingly raised environmental standards to reduce the contamination of land, air and water (Bingemer and Crutzen, 2011). The environmental movement acted as a primary driver of the policy stages from the 1970s onwards. SWM policy from the 1970s to mid-1980s focused on waste control, and was therefore characterized by measures such as the daily covering and compacting of landfills and retrofitting incinerators for dust control. In the 1990s, integrative policy gained much attention because it had become evident that advocating for ever-increasing environmental protection was not enough - an integrative regulatory approach was needed that encompassed not only the technical and environmental but also the political, social, financial, economic, and institutional elements of waste management if environmental protection were to be realized (McDougall et al., 2011).

In pre-industrial times, resources were relatively scarce. Anything vendible in the waste stream was scavenged and consumer goods were reused and repaired rather than tossed into the waste stream. As cities grew in size during the industrial revolution, the resource value of waste rose again, and waste pickers collected, used, and sold materials from the waste stream - an activity that continues today in many developing countries. However, recycling rates plummeted from the high levels of pre-industrial times to single digits (Wilson, 2007), as this was a period of immense increase in consumption, strong marketing of commodities, and little regard for resource utilisation. Thus, the availability of land and its value as a resource somewhat acted as a driver for the move away from landfilling, though land scarcity primarily led to new treatment options, such as incineration. The waste hierarchy sparked a massive transition from end-of-pipe to preventative thinking, which emerged with a multitude of new terms and phrases.

Climate change has acted as an environmental driver since the early 1990s, leading to a shift away from landfilling biodegradable waste, which is a major source of methane emissions, and a strengthened focus on energy recovery from waste (Oelofse, 2012). This driver was brought on by the global concern about climate change issues, which led to pressure and advocacy around the world. This driver led to a policy stage focused on waste prevention and target achievements characterized by a series of preventative policy measures, including laws and targets for compost and recycling goals, diversion from landfill, extended producer responsibility, and landfill bans for recyclable materials (Wilson, 2007). Policies such as the EU Landfill Directive require reductions in levels of biodegradable material sent to landfill as a method to recover valuable materials and reduce methane emissions. This has further increased recycling and composting rates which is on the rise in cities that are modernising their waste systems. However, since climate change measures can only have significant impact if most countries adhere to this objective, there is no immediate national gain from reducing greenhouse gas emissions. This is the primary weakness of this driver and one of the primary reasons it is so difficult to gain consensus for a post-2012 convention for reducing carbon dioxide levels.

Public concern and awareness have also acted as SWM drivers in high-income countries. Poor practices in the past, such as burning dumps and polluting incinerators, have left the public with negative perceptions of new SWM strategies (Wilson, 2007). In line with this, negative perceptions of past facilities have led to community opposition to proposals for any new waste management facility. Unsustainable behaviour also inhibits movement towards better SWM. Therefore, strategies that include more recycling, repair, reuse, home composting, sustainable consumption, require behavioural change (Wilson, 2007), which Jackson (2005) believes is becoming central in any sustainable development strategy. The systems that shape patterns of the public's activities create complex barriers to sustainable behaviour. Many people are unable to exercise deliberate choice because they find themselves locked into unsustainable patterns caused by habits, routines, a lack of knowledge, institutional structures, and inequalities in access, social expectations, and cultural values (Jackson, 2005).

1.2 Research Problem

Though industrialised nations generate greater amounts of per capita waste, they have developed fairly adequate facilities supported by effective approaches with competent government institutions and structures to manage their waste. South Africa is still in transition towards better waste management but currently has insufficient collection facilities and improper waste disposal methods (Manning, 2013). With a growing urban population and economy, leading to increased volumes of waste generated, this puts increasing pressure on the waste management system. There is also an increased complexity of the waste stream because of urbanisation and industrialisation. This directly affects the complexity of its management, compounded by the common practice of mixing hazardous waste with general waste.

A historical backlog of waste services is noted, especially for urban informal settlements, low-cost residential districts and the urban periphery. Although 61% of all South African households had access to kerbside domestic waste collection services in 2007, this access remains highly skewed in favour of more affluent communities (Oelofse, 2011). The inadequate waste services lead to unpleasant living conditions and a polluted unhealthy environment. There is a limited understanding of the main waste flows and national waste balance because the submission of waste data has not been mandatory until recently. Where waste data is available, it is often unreliable rending it of limited use for planning and decision making. Today, there still exists a policy and regulatory environment that does not actively promote the minimisation of waste along the waste chain (Oscar, 2012). This has limited the economic potential of the waste management sector, which has an estimated turnover of approximately R10 billion per annum (Godfrey and Scott, 2010). Both waste collection and the recycling industry make meaningful contributions to job creation and GDP, and they can expand further. Adding to this is the absence of a recycling infrastructure which would enable separation of waste at source and the diversion of waste streams to material recovery and buy back facilities. There is also mounting pressure on out-dated waste management infrastructure as a result of declining levels of capital investment and routine maintenance.

Waste management suffers from a pervasive under-pricing, which means that the costs of waste management are not fully appreciated by consumers and industry, and waste disposal is preferred over other options (Oelofse, 2012). With few waste treatment options available to manage waste, the only cheaper option is land filling. To make the problem worse there are too few adequate complaint landfill and hazardous waste management facilities. This hinders the safe disposal of all waste streams. Although estimates by the South African Local Government Association put the number of waste handling facilities at more than 2012, significant numbers of these are unpermitted (SALGA, 2013). South Africa is currently using a pipe-end approach to waste management where the end result of waste is land filling. The limitations inherent in this pipe-end approach are widely acknowledged as being inefficient and ineffective (Mudau et al, 2013). There is a need for an appropriate model that will address the issue of sustained increase in waste generation and such a model has not yet been brought forward. Through South Africa's commitment to sustainable development, South Africa aims to balance the broader economic and social challenges of a developing and unequal society while protecting its environmental resources (Oelofse, 2012). The current pipe-end approach by municipalities is not efficient as more and more waste still end up in landfills and is inappropriate in meeting the demands of waste minimisation.

Existing models such as the elimination and choice expressing reality "ELECTRE" (Saracoglu, 2015) and the Analytical Hierarchy Process (Savadogo, 2009) for waste management in use in other urban centres in South Africa, have been designed to respond to particular waste streams of those cities and cannot be easily adapted for mining towns. Models such as the technique for order preference similarity to ideal solutions" "TOPSIS Model" (Mahdavi, 2009) and the Multiple Criteria Decision-Making approach (Janowski, 2011) in use in other countries cannot be simply imported and adopted for use as they are location specific and address different socio-economic conditions. This calls for a study that takes cognisance of the patterns of urbanisation in mining towns, the character of their waste streams, and the dimensions of the waste chain and the socio-economic implications of changing costs into the design of an alternative waste minimisation model. To date, no research has been carried out in South Africa on how to develop a waste-to-landfill-minimisation model for any category of towns.

1.3 Research Purpose

The purpose of this research is to design and develop a waste-to-landfill minimisation model for South Africa's secondary mining towns.

1.4 Research Objectives

The following objectives are advanced:

1. To describe the state of the municipal landfill sites in each of the selected study areas.
2. To evaluate resource management at each respective waste management directorate of the selected study areas.
3. To assess the current waste reduction programmes implemented by the waste directorate of each selected study area.
4. Analyse current capacity constraints in the municipal waste chain.
5. To design an improved waste minimisation model.

1.5 Hypotheses

H_1: There is a close relationship between the volume capacity of municipal landfill sites (x) and the annual volume of the waste disposed at landfill sites (y) in each study site.

H_2: There is a consistent relationship between the resident population and the totality of landfill sites in the study area.

In each of these hypotheses, the null hypothesis H_0 suggests the view that such relationships do not hold.

1.6 Rationale

Municipal solid waste management was historically a simple one way end-of-pipe approach to waste disposal. The waste was taken away and either dumped or burned somewhere in more or less controlled conditions. This guaranteed the local authorities with a permanent solution and well-known and stable costs. But the role of local authorities is changing under the pressure of public demand, legal requirements, technological processes and the rapid growth of cities (Peter and Duneel, 2013). Through the improvement in legislation and the establishment of treatment and disposal facilities typically taking 10 - 15 years, it is therefore important in the short term to put in place interim or transitional facilities to allow efficient phase out of uncontrolled dumping. There is no time to wait for detailed waste data and waste management infrastructure to be put in place before action is taken (Consonni et al, 2005).

Waste flows are becoming more complex as waste is closely linked to the increasingly changing patterns in lifestyle. These changes include the increasing quantity of waste, increasing distance between centres and calls for adequate and technology-intensive solutions (Herva and Roca, 2011). The capital costs for these transitional technologies may be relatively modest, while the long-term costs for sophisticated, high technology facilities are often beyond the resources of the public sector in developing countries. There is a need to develop facilities, support services and enforcement capabilities simultaneously with the necessary legislation and regulations. There is a need for planning the collection and treatment of certain waste flows instead of land filling high energy waste. This does not make sense while various alternative technologies are available (Robinson and Ren, 2010). Thus, local authorities need to implement complex scenarios taking the best advantage of technological possibilities and keeping in mind an unstable technological environment where technologies are being constantly improved. New waste flows call for new solutions and the development of partnerships with multiple industrial sectors including the private sectors (Mangizvo, 2010).

It is therefore important to take early action to develop a waste-to-landfill minimisation model which in the long run, will save money by preventing the problems of inadequate waste management from arising (Hellweg et al, 2009). Both waste collection and the recycling industry make meaningful contributions to job creation and GDP, and they can expand further. In most cases a carrot-and-stick approach will be needed. Although the waste hierarchy is accepted it must be emphasised that as the most common form of disposal is uncontrolled landfills, the establishment of controlled landfills is a high priority and with this the appropriate method to ensure that waste is minimised before entering such sites (Karak and Bhakta 2012).

1.7 Study Area

Figure 4 shows the cities selected in this study. The four cities selected are the City of Matlosana in the North-West Province, the City of Merafong in the Gauteng Province, the City of eMalahleni in Mpumalanga Province and the City of Matjhabeng in the Free-State Province. This selection was based on population size characteristics which fall under the category of secondary cities as they have the potential to increase in population and thus generate increased waste. They are in fact all mining towns and should in retrospect share certain common socio-economic characteristics. The greater local municipality of Matlosana incorporates the towns of Orkney, Kanana, Stilfontein, Khuma, Hartebeesfontein and Tigane to give it a population of 420 545 with a growth rate of 1.04% p.a. (StatsSA, 2016). Merafong is a gold mining town in western Gauteng and is one of the richest gold-producing areas in the world. It has a population of 214 553; with 102,624 households and encloses an area of 1,631 km^2 (StatsSA, 2016). eMalahleni is in a coal mining area with more than 22 collieries in the municipal radius and the farm land surrounding is fast being bought by investors, coal mining companies and real estate developers to accommodate the rapid growth of the city. The mining of gold and uranium as well as other industries such as agriculture and manufacturing are being promoted as further means to support the local economy (StatsSA, 2016).

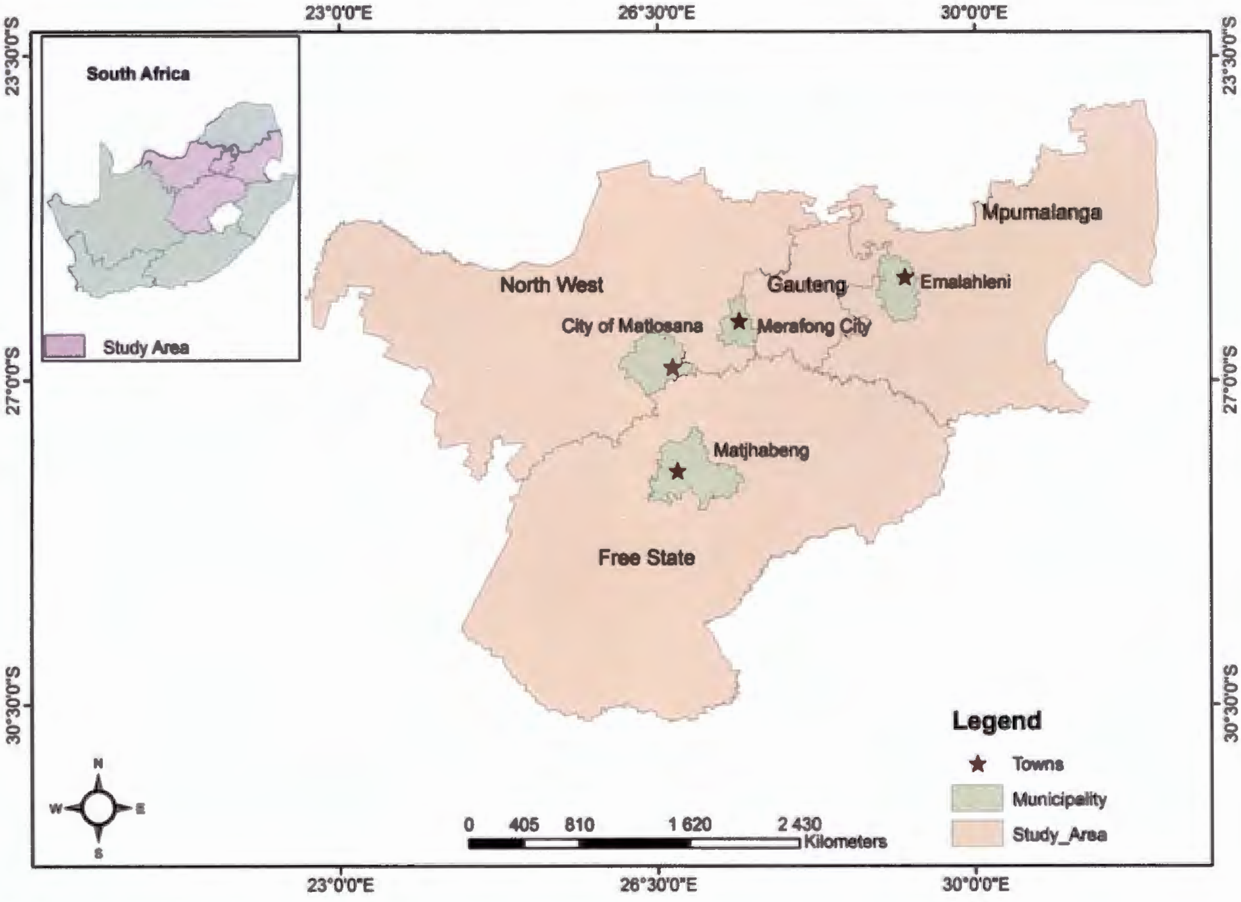


Figure 2. Selected study area

Sustained growth of the commercial areas and suburbs in eMalahleni has presented significant challenges to the municipal government specifically potable water supplies, sewage treatment, electricity distribution, refuse collection and road maintenance are particularly adversely affected, raising sustained levels of dissatisfaction with service delivery amongst the local residents. The total population is approximately 416 625 (StatsSA, 2016). Matjhabeng is a city in the Free State province of South Africa with a population of approximately 427 640 and total households of 194

336. It covers a total area of 89.51 Km^2 and is located 160 kilometres northeast of the provincial capital Bloemfontein.

1.8 Scope of the Study

The focus of this study is waste-to-landfill minimisation modelling. This is a process of elimination that involves reducing the amount of waste produced along the waste chain and helps eliminate the generation of harmful and persistent wastes, supporting the efforts to promote a more sustainable environment and society. The most environmentally resourceful, economically efficient and cost effective way to manage waste is to not have to address the problem in the first place. Waste minimisation should be seen as a primary focus for most waste management strategies. Proper waste management can require a significant amount of time and resources, it is therefore important to understand the benefits of waste minimisation modelling and how it can be implemented in all sectors of the economy, in an effective, safe and sustainable manner. Due to the overall framework of waste management, the scope of waste minimisation encompasses the following functions and concerns: The planning and management which includes the strategic planning; the legal and regulatory framework; public participation, financial and institutional management. Whereas waste generation and waste handling includes: waste characterization; waste minimisation and source separation; waste collection and transfer; waste treatment and disposal. The main focus of the study was the set of matters indicated in the study objectives towards achieving the purpose of this research.

1.9 Significance of the Study

Developing countries such as South Africa should consider alternative waste disposal methods and technologies. The decreasing land available for landfilling, pressure from politics and environmental protection groups as well as energy requirements, all obligates us as a nation to investigate alternative practices and develop new strategies (Bosmans et al, 2013). As the economy develops so does waste generation and also the complexity of the waste mix. Composting, recycling, reuse and waste reduction form an integral part of any solid waste management system with energy recovery being a logical next step. It is evident that various solid waste treatment options do exist, but that some of the more technologically advanced options are heavily criticised by environmental groups. In order to address these shortcomings, expensive emission and pollution controls are required. This makes such options too expensive for implementation especially in developing economies like South Africa which invariably also lacks the technical expertise and support systems required. This leaves land filling as the only cheap disposal method and therefore emphasis needs to be placed on these sites. However, the detrimental impact on the environment and the shear non-sustainability of land filling alone, require sustainable alternatives and complementary methods.

South African municipalities are responsible for the collection, transport, treatment and disposal of solid waste. In order to provide these services, municipalities need to generate funds and are partly dependent on rates and taxes paid by residents and businesses in the municipal area. Not only do municipalities have to adhere to national and provincial laws regulating waste disposal, but they are also compelled by legislation to provide free basic services to the poor. These constraints largely determine what alternative solid waste management methods are most suitable, practical and sustainable. The need to reduce the amount and types of waste being landfilled is undeniable: both from an environmental and ethical viewpoint.

1.10 Target Audience

The outcome of this research is intended for a wide audience of individuals, groups and organisations, communities and institutions that are interested in waste minimisation as service users, providers, intermediaries and regulators. The national, provincial and local government is responsible for establishing the institutional and legal framework and ensuring that local governments have the necessary authority, powers and capacities for effective waste minimisation. In assisting local municipalities to perform their duties, guidelines, capacity building measures in the section of administration, financial, technical and environmental management skills need to be provided by the provincial and national governments. Local government authorities are generally responsible for the provision of solid waste collection and disposal services. They become the legal owners of waste once it is collected or put out for collection. Responsibility for waste minimisation should therefore be specified in by-laws and regulations and may be derived, more generally, from policy goals regarding environmental health and protection. The formal private sector includes a wide range of enterprise types, varying from informal micro-enterprises to large business establishments. As potential service suppliers, private enterprises are primarily interested in earning a return on their investment by offering waste minimisation efforts through waste collection, transfer, treatment, recycling and disposal services. Operating in various forms of partnership with the public sector, they may provide capital, management and organisational capacity, labour and technical skills (Karani and Jewasikiewitz, 2011). Due to their profit orientation, private enterprises can, under appropriate conditions, provide services more effectively and at lower costs than the public sector. However, private sector involvement does not, in itself, guarantee effectiveness and low costs. Problems arise when privatisation is poorly conceived and regulated and in particular, when competition between suppliers is lacking. Other service users, including small and large scale industrial and commercial establishments and institutions are similarly interested in reliable and affordable waste minimisation. Commercial establishments are particularly concerned to avoid waste related pollution, which would inconvenience their customers. Industrial enterprises may have a strong interest in reducing waste generation and can play an active role in managing waste collection, treatment and disposal in collaboration with government authorities and specialised private enterprises (Hovde et al, 2010). Non-governmental organisations (NGOs) operate between the private and governmental realms. Originating outside of the communities in which they work, NGOs are motivated primarily by humanitarian and developmental concerns rather than an interest in service improvement for their own members. The self-creation of meaningful employment for members may also be a motivation for NGO formation (Oelofse, 2012). This work is also targeted at universities, think tanks, public and private research centres that are likely to use the work as a source of reference or as a trigger for their own research enterprise.

1.11 Chapter Outline

The thesis is structured systematically and consists of eight chapters. Each chapter is aimed at addressing the contributions towards waste minimisation modelling:

Chapter Introduction

Chapter one presents an overview of the background to waste management in South Africa and also the desired research problem. It also consists of the purpose of the research and clearly highlights the objectives that the research intends to achieve. It contains elements such as the hypotheses, the rationale of the study and an overview to the conceptual context of the research.

Housed within this chapter is an illustration of the study area; scope of the study; an overview of the significance of the study and the intended target audience

Chapter 2 Literature Review

The importance of chapter two is merely to place into context the contribution off relevant information with regards to waste management into understanding the research problem being identified. The understanding of what initiatives are being undertaken by developing countries and other developed countries provides us with an opportunity to ascertain any knowledge gaps in the South African context.

Chapter 3 The State of Municipal Landfill Sites

This chapter discusses and describes the state of the municipal landfill sites for each of the selected study areas. Attached to this is the observational schedule that was conducted on the sites and the mass of waste generated and disposed of as contained in the waste information system is also described.

Chapter 4 Resource Management

In this chapter the resource management for the different municipal waste directorates are discussed. It also brings into cognisance the elements within the study area that play role in decision-making and planning. These include human resources management, financial management and asset management.

Chapter 5 Waste Minimisation Programmes

This chapter addresses Objective 4 of the study. Relevant waste minimisation programmes are linked to key performance areas to ascertain their relevance and efficiency in minimising the amount of waste.

Chapter 6 Capacity Constraints in the Waste Chain

This chapter presents results and a discussion of analysed constraints in the municipal waste chain that lead to service delivery backlogs and a failure in the waste minimisation efforts.

Chapter 7 Design of a Waste Minimisation Model

In this chapter emphasis is placed on the design and reporting of the Waste Minimisation Model.

Chapter 8 Contribution and Conclusion(s)

Chapter eight is the final segment of the study and included in this chapter is the conclusion of the study and the final recommendations of the findings.

1.12 Summary

Chapter 1 has presented the orientation of the study that is to be undertaken. The introduction to the chapter provides the background of waste management services in South Africa and gives the reader an understanding of Municipal Waste Management Services (MWMS), the Waste Management Hierarchy (WMH) and also the drivers for waste management services. It also highlights why the study needs to be conducted and what are the underlying factors towards better waste minimisation. Chapter one consists of the research problem that identifies the issues that are currently being faced within waste management services and when addressing concerns towards better waste minimisation. The aim of this research is to design a waste-to-landfill minimisation model for South Africa's mining towns which as stated in the chapter and the research objectives and hypotheses of the research. Chapter one also describes the rationale of the study and it elucidates on the paradigm and context of the study as being housed within a combination of a positive sciences and an action-oriented research perspective. The conceptual framework of the study is presented and a graphical comparison of the current waste chain and the ideal waste chain is depicted. A map of the selected study areas, which are Klerksdorp in the North-West Province, Carletonville in the Gauteng Province, Witbank in the Mpumalanga Province and Welkom in the Free-State Province, appears in this chapter. These selected towns fall within the realm of secondary cities. The scope highlights the focus of the research which is the design of a waste minimisation model. Chapter 1 also explains the significance of the study and describes the intended target audience once this study has been completed. Also depicted graphically in this chapter is the envisaged chapter outline of the thesis which provides a backbone for the thesis. For a better understanding of words that will be commonly used throughout the study, Chapter one provides a definition of those keys concepts to make for better reading and understanding. The chapter is however a pre-requisite to Chapter 2 which further addresses issues of concern identified in Chapter 1.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Section 2.2 of this chapter covers the legal framework document on recycling in South Africa and the legislation that governs waste management. Further reinforced in this chapter is the policy and strategy on waste management. Section 2.3 on the global context provides examples from various developed and developing countries on their initiatives in waste minimisation. Section 2.4 outlines current initiatives that have been undertaken in South Africa and examples from three metropolitan areas (Johannesburg, Cape-Town and Port Elizabeth) are provided. The objectives, criteria and principles of waste minimisation efforts and highlighted and the drivers for waste minimisation explained. Challenges to waste minimisation are highlighted in this section and current minimisation initiatives in South Africa and the evaluation of such initiatives are explained. Section 2.5 is an evaluation synopsis for such minimisation efforts and current models being applied are highlighted and elaborated on. Section 2.6 further mentions the key knowledge gaps identified in relevant literature and the summary of chapter two is presented in section 2.7.

2.2 Legislative Environment

The publication by the government on its White Paper on Integrated Pollution and Waste Management (IP&WM) for South Africa (DEAT, 2014) has heralded a new approach to waste management, a move away from the traditional end-of-pipe solutions to a holistic integrated approach. This policy sets out the principles that underpin the National Waste Management Strategy (DEAT, 2013) which translates the policy principles into high level strategic plans and actions. The emphasis will be on a holistic and integrated waste management following the waste hierarchy approach through starting with waste prevention as the highest priority, followed by waste minimisation, waste reuse and recycling, and only thereafter, waste treatment and finally waste disposal. The policy and strategy vision for these preventive and proactive waste management steps are that the rate of increase of waste disposed to landfill sites will be slowed down and informal salvaging at landfills will decrease. Natural resources, renewable and non-renewable will be better conserved, landfill air-space will be more effectively utilised, and pollution and environmental degradation will be reduced. In addition, recycling has the potential for job creation, by promoting entrepreneurs to establish community collection systems and recycling centres (Reis, 2013).

A legal framework document for recycling was prepared as part of the DEAT programme for the Implementation of the NWMS (DEAT, 2012). The document presented a draft framework of the legislative action required for the implementation of waste minimisation in South Africa. The suggestions contained in this report form part of a continuing consultative process relating to waste management in South Africa, and will be considered in the light of developments with the current legislative reform process being managed by the Department of Environmental Affairs and Tourism (DEAT, 2012). Most of the suggestions contained in this report are contingent upon developments within the law reform process and must be seen in this light. An important element of the action plan for waste minimisation and recycling is the promulgation of legislation at national, provincial and local government level. This requires specific provision for recycling within the anticipated Integrated Pollution and Waste Management Act (currently the Waste Management Bill), the possible development of interim regulations in terms of the Environment Conservation Act and the National Environmental Management: Waste Act 59 of 2008, as well as provision for recycling within relevant provincial and local government legislation (Nahman, 2012).

The Framework Document identifies several issues for consideration. Specific provision for recycling should be made within national framework legislation pertaining to integrated pollution and waste management. In addition, provincial legislation and local government by-laws should provide further substance and detail (Smyth et al, 2010). At a general level, several priority issues need to be provided for within the legal framework to promote recycling. Review of recycling initiatives and related policy measures have been implemented in South Africa. Beyond here, internationally, an assessment of the reasons for the relative success and failure of these initiatives (Palmujoki, 2010). Procedures for setting and periodically reviewing appropriate recycling targets for defined waste streams are critical (Gibbs and Deutz, 2009). It is important to require that local and provincial governments include recycling within integrated waste management plans (Gavilan and Bernold, 2010). In addition, particular industrial sector organisations should be made to develop recycling business plans meeting government recycling targets (Pajunen, 2013). The promulgation of regulations requiring recycling considerations should be included within government procurement practices. This is necessary to ensure provision for recycling issues within requirements relating to the development of the Waste Information System (WIS) (Robinson and Ren, 2010). Specific provision for recycling is made in the Waste Management Bill. First, this includes adoption of policy and guiding principles reflecting the importance of the waste management hierarchy. Second, the setting up of procedures for periodically reviewing appropriate recycling targets for defined waste streams. Third, requiring local and provincial governments to include recycling within integrated waste management plans. Fourth, ensuring that an appropriate definition of waste is developed. Fifth, providing for the required institutional arrangements for recycling. Sixth, ensuring that the waste information system provides appropriate baseline data to identify priority targets for recycling and to monitor progress in achieving these targets. The waste bill empowers the Minister to promulgate required regulations relating to recycling, including possible future regulations relating to the defining of recycling requirements for particular waste streams (Poon, 2007).Seventh, implement requirements relating to extended producer responsibility. Eighth, introduce product labelling, reductions in excess packaging, minimum mandatory recycled content and mandating the use of certain packaging types (Pires et al, 2010).

The need for interim regulations and the possible choice of Act for these regulations, is dependent upon the timing and related developments within the Environmental Law Reform Programme. In particular, this depends on the anticipated relationship between NEMA and the Waste Management Bill. It may be necessary to address the issue of possible duplication and conflict with any existing legislation that may have an impact on recycling issues (Oscar, 2010). A key goal of any waste management legislative intervention for recycling should be to ensure a clear definition and formal allocation of responsibilities to the different stakeholders for recycling. The role of provincial and local government legislation is important in promoting recycling initiatives. Waste minimisation considerations should be explicitly provided for within the waste management plans and should impact on the nature of the information collected as part of the waste information system.

2.3 Paradigm Context of the Study

The view of the universe in this study falls within the realm of positive science. To put this discussion into philosophical context, the notion of positive science, which originates with Comte, has variants in many kinds of positivism (Harrison et al, 2000). The term positive science was coined by Comte for his own conception of science as it should be. A major element of this concept was that science should not go beyond what was evident from the observations and experiments of the scientist. A similar objective is considered, not as a prescriptive scientific method but as an exercise in philosophical reverse engineering. There is an awareness that not all that passes for science is good and the manner of doing science and the conclusions which scientists draw may be inappropriate. In positive science, the scientist is engaged in undertaking experiments and in reporting the results of his experiments. This study seeks to design a waste minimisation model in which available waste related data is used. There are other factors that are taken into consideration when designing this model but the study is kept within the realm of positivism.

2.4 Conceptual Framework of the Study

The delivery of a waste management service, including the storage, collection and transportation is the main point of interface between the public and waste service providers. The extent and form of provision of waste services to households and businesses also impacts directly on all stages of the waste management hierarchy. Provision of waste management services is a core function of all metropolitan municipalities and most local municipalities while district municipalities in general do not view waste management as part of their functions. Collection systems comprise household and neighbourhood (primary) waste containers, primary and secondary collections vehicles and equipment and the organisation and equipping of collection workers, including the provision of protective clothing. Selection of collection equipment should be based on area-specific data on waste composition and volumes, local waste handling patterns and local costs for equipment procurement, operation and maintenance. Regarding the design of local waste collection systems, the most effective results may be obtained through the participation of the concerned communities (Walhi, 2009). Where appropriate, the objectives of material recovery and source separation should be deliberately pursued. The introduction of source separation should be carried out in a pragmatic and incremental manner. There is a need to start with pilot activities to assess and encourage the interest and willingness of users to participate. To extend service coverage especially in low-income areas, the use of low-cost, community-managed primary collection systems should be considered. In the interest of lower costs and efficient operation and maintenance, appropriately standardised and locally available equipment should be selected (Glavic and Lukman, 2011). Design and procurement should be made with close attention to the requirements of preventive maintenance, repair and spare parts availability. The privatisation of maintenance and repair may be considered as a means of lowering maintenance costs and optimising equipment utilisation. But in the case of South Africa, often senior officials in local municipalities opt for out-sourcing maintenance as a way of defrauding the system. Design and expansion of transfer facilities and equipment should be aligned to the characteristics of local collection systems and the available capacity of environmentally safe disposal facilities (Mukawi, 2009). The size, number and distribution of transfer stations should be carefully designed to facilitate local collection while achieving efficient transfer operations and minimum transport distances and costs (UNEP, 2009). The final and least desirable step in the waste hierarchy involves land filling of wastes as well as the chemical and or physical treatment of waste. In South Africa, the treatment, processing and disposal of waste has to take place in accordance with the principles of environmental justice and equitable access to environmental services (NEMA,1998). This is particularly important in view of the fact that landfills and waste treatment facilities tend to be located in close proximity to poor communities and informal settlements (Oelofse, 2012). At present most collected waste is disposed of in landfills. Within the landfills, biodegradable waste produces methane, a powerful greenhouse gas. Plastic waste in particular is a challenge as it occupies valuable space in landfills and takes a long time to degrade (Parker, 2012). Figure 2 presents the current flow of waste along the waste chain.

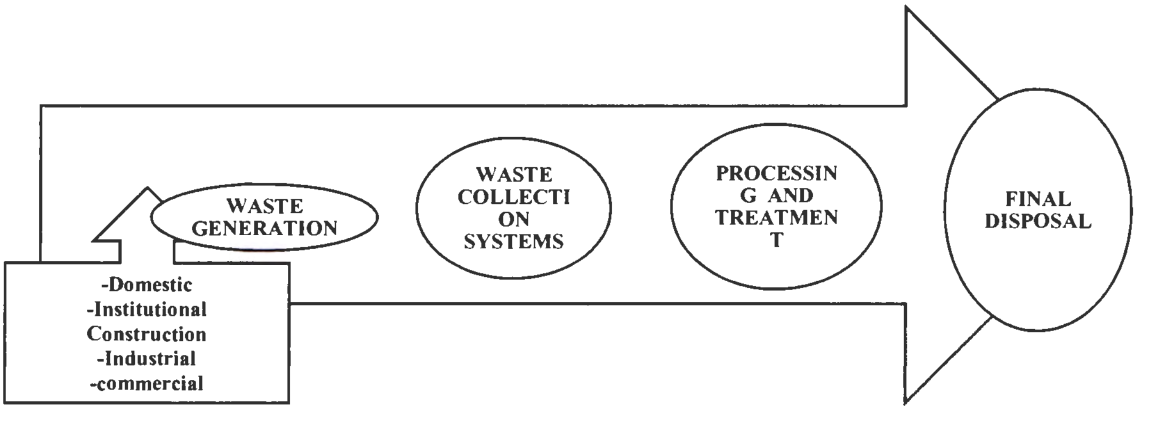


Figure 3. Typical flow of waste along the waste chain

The number of landfill sites meeting official design specifications is indicative of a country's commitment to effectively manage the full range of waste produced. As indicated in the 1996 and 2001 census, municipal waste collection has improved, but more than 50 % of the population were not receiving a regular municipal waste collection service (Wagner and Arnold, 2009). The metropolitan municipalities deliver almost 100 % services while the local municipalities in some cases deliver no service at all. General landfill sites accept domestic, commercial and industrial non-hazardous, building and garden waste. Most of the sites in South Africa are owned and operated by the local authorities. Well-designed landfill sites are important for effective waste disposal meeting legal requirements (Leonard, 2009).

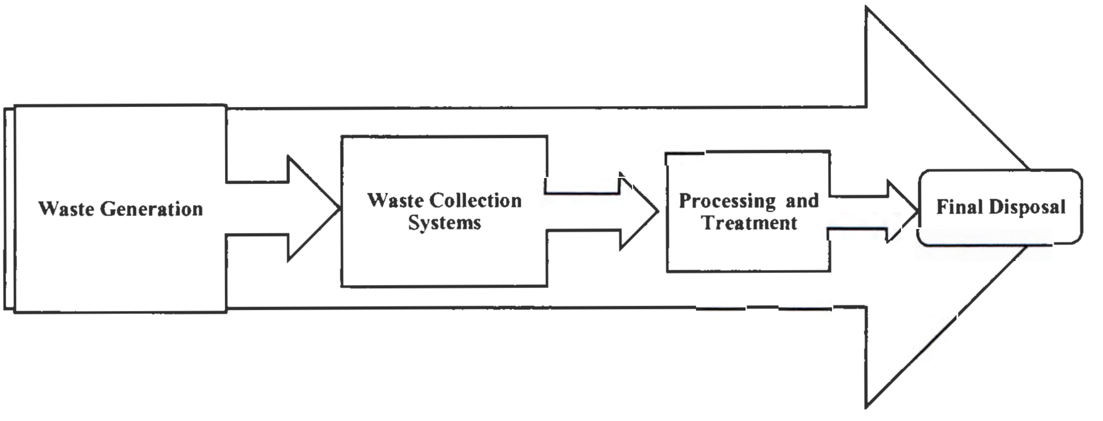


Figure 4. The ideal flow of waste along the waste chain

Figure 3 represents the ideal flow of waste along the waste chain where waste volumes should actually be minimised from the source of generation. The ideal situation is for waste interventions between stages and the interfaces of the waste chain so that less waste reaches the landfill site. Due to variations in municipal structures and geographical distribution, the same type of waste collection service will not be appropriate and sustainable across different municipalities. Service levels may vary between kerbside collection, organised transport to central collection points, community transfer to central collection point and on-site appropriate and regularly supervised disposal. At household level, the type of service will determine the type of receptacles, infrastructure and equipment required to render the service. Waste from sources other than households will require systems as determined by the type and volume of waste and the collection frequency required. The waste generated by a population is primarily a function of the peoples consumption patterns and therefore, of their socio-economic characteristics. At the same time, waste generation is conditioned to an important degree by people's attitudes towards waste, their patterns of material use and waste handling, their interest in waste reduction and minimisation, the degree to which they separate wastes and the extent to which they refrain from indiscriminate dumping and littering. In industries, using more efficient manufacturing processes and better materials will generally reduce the production of waste. The application of waste minimisation techniques has led to the development of innovative and commercially successful replacement products. Waste minimisation has proven benefits to industry and the wider environment as it assists in value creation and increased quality of work. Waste minimisation often requires investment which is usually offset by the savings. However, waste reduction in one part of the production process may create waste production in another part. There should be government incentives for waste minimisation which focus on the environmental benefits of adopting waste minimisation strategies. Transport is an expensive aspect of providing the waste management service and due to limited budgets, many municipalities struggle to meet their legal mandate of providing at least a weekly waste collection service to all households. The choice of transport vehicles may also dictate the most appropriate receptacles to be used. Regular and planned vehicle maintenance is required to ensure the reliability of the transport fleet. A contingency plan, detailing the course of action in cases of vehicle breakdowns, is required in order to maintain the required level of service. Transport routes and distances to travel between collection points and disposal/transfer facilities will influence the type and size of vehicles used. In the South African context, any combination of the following transport types deserves a place in waste collection systems - wheelbarrow, hand drawn carts, push carts, bicycles, donkey's carts, tractor trailer combinations and compactor vehicles. Different vehicle types may be appropriate for different stages along the waste collection and transport route, for example, from household to central collection point, to transfer station and lastly to landfill. Collection vehicles that are the most appropriate for the specific task should be used.

Several issues should be built into considerations around waste. Of particular importance is the type of waste to be removed, the geographical area of collection, the status of accessibility, the method of collection, distance and route to cover, and the availability of workers. Waste is stored at different stages of the waste chain calling for the appropriate receptacles to be installed. Receptacles at points of generation are intended for the storage of waste between collection days. Aspects to take into account in the choice of receptacle are size, cost, availability, durability, type of waste and ease of handling by waste generators and waste collectors. Waste storage systems should ideally allow for separation at source. The type and size of receptacles will determine the most appropriate means of transport. The choice of receptacle should also be mindful of the potential impacts at the landfill. Waste is often stored at collection points for recyclables. These facilities include clean materials recovery facilities (MRFs), garden sites, drop-off and buyback centres and other intermediate facilities prior to final disposal to landfill or prior to the waste being treated or recycled. Landfilling should be the last and undesirable option and landfill sites should meet the minimum requirements.

2.5 Global Context

A detailed review of international experiences and perspectives on waste recycling was undertaken by DEAT as part of the National Waste Management Strategy Project (DEAT, 2011). These findings are supported by more recent studies from the Netherlands (Scheinberg, 2012), Germany (J Griffiths, 2005); the United Kingdom (Sanderson, 2005) and France (Copacel, 2005). Table 2 presents a summary of efforts of some industrialised countries in recycling and waste minimisation.

Table 2. Solid waste management practices in some industrialised countries

Country	Kg/capita /day	Land filling %	Incineration %	Composting %	Recycling %
Canada	1.65	80	6	4	10
Germany	0.95	45	35	4	16
Italy	1.1	75	13	7	5
Japan	1.26	15	60	5	20
Spain	0.95	65	5	17	13
Switzerland	1.2	10	58	10	22
UK	1.15	85	8	2	5
USA	1.98	65	10	2	23

In a study covering the European Union (EU), Netherlands, Netherlands, Denmark, Germany, United States, India, Kenya and Botswana common features and anticipated trends within the recycling initiatives were reviewed (DEAT, 2012). The study reported several findings primarily for the more structured approach to recycling that is evidenced in the selected EU countries and the USA: These more structured governmental programmes for recycling demonstrate comprehensive and integrated use of the full range of policy instruments, including directive-based command-and control regulations, economic instruments, voluntary agreements and education or information activities (Young et al, 2010). Each of these programmes makes formal statutory provision for recycling. This includes provision for recycling within national environmental and waste policy frameworks, within waste management planning activities, as well as through the implementation of specific regulatory measures regarding particular products and waste streams. In some instances, such as Germany, a framework law on recycling has been implemented empowering the government to implement various regulations to promote recycling (Friedrich and Turnol, 2011). Statutory provision for recycling has included setting legally required recycling targets for particular waste streams, imposing landfill bans and recycling requirements for particular waste streams and products, requiring local governments to provide for recycling within their waste management plans, introducing product take-back requirements, mandating product labelling schemes to indicate recyclable and recycled content and finally specifying minimum mandatory recycled content (Bohne et al, 2008). Mandating the use of certain packaging types, such as the use of reusable containers for particular beverages and introducing government procurement requirements at national, provincial and local level (Frandegard et al, 2013) are additional interventions.

An important feature of many of the recycling programmes within the USA and member states of the EU is the setting of targets for preferred levels of recycling of particular waste streams (Elena and Trois, 2011). The objective of these targets is to achieve the socially optimum level of recycling (Chang, 2011). To ensure this, targets should be based on reliable background data relating to the market conditions for recycled products and raw materials. It is necessary to include full consideration of the environmental impacts throughout the life-cycle of the recycling chain for the particular waste stream. The targets should be measurable, realistic yet challenging, and developed with effective participation of stakeholders (Young et al, 2010). Yet, in South Africa, the requirement for the carrying out of stakeholder consultations often bogs down entire projects. There is increasing use within these programmes of economic instruments that are aimed at providing incentives for recycling, recovering the full social costs of waste disposal, and providing funds to initiate recycling. These instruments include waste taxes such as landfill taxes aimed at promoting a shift up the waste management hierarchy; taxes on certain forms of packaging or products such as batteries with the aim of reducing their use and recovering the full costs associated with their disposal; deposit refund schemes, particularly for beverage containers; pay-as-you-throw schemes charging households for the collection of domestic waste based on the volume of waste discarded; provision of government grants and subsidies for infrastructure, transportation and recyclable materials to assist in initial stimulation of markets for recycled products (Muswena,2012). The increasing use of co-regulatory instruments is noted. Negotiated environmental agreements involve industry covenants in terms of which sectors or individual firms enter into an agreement with government departments relating to recycling within particular processes and of products. Public voluntary programmes, including eco-labelling schemes have evolved in terms of which government provides technical, financial and marketing incentives for waste generators to participate in recycling initiatives (Fischer et al, 2011). Unilateral industry programmes, in terms of which industry sectoral organisations, with government recognition, provide incentives for members or individual waste generators to undertake recycling (Watson et al, 2012). The diversity of these approaches shows sensitivity towards an understanding of differences between countries, social classes and state policy positions.

In addition to the integrated application of these various policy instruments, there is an increasing trend towards the adoption of new product-based policies aimed at promoting more environmentally effective management of products. This approach exploits the life cycle concept of a product. Notable among these are recycling throughout the product chain, through initiatives such as design-for-disassembly and design-for-recycling (Zurbrugg and Aristanti, 2011).

The key to sustainable recycling is in finding a balance between securing the supply of recyclable materials and promoting the demand for products that are made from these materials, while appraising the social, environmental and economic impacts (DEAT, 2010). Internationally, recycling initiatives are formalised as in the case of the EU and the USA or less structured as implemented in Kenya, India and Botswana. Formalised structures rely on government intervention to enhance market conditions to promote recycling (Achillas and Barians, 2011). Policy instruments that have been implemented include directive-based regulations, economic tools, voluntary agreements and education and information activities. These have resulted in an increase in the level of recycling but have not significantly impacted on the total quantity of waste generated (Manning, 2013). Several European studies have demonstrated diminishing returns on the environmental benefits with increasing recycling rates. Life cycle analyses (LCA) of some wastes such as plastics and paper identify the incineration of the waste with energy recovery as providing the greatest environmental benefit and most cost-effective solution. In Europe, for example, incineration is generally favoured over land filling (Lincoln, 2011).

Although the design of an environmentally and economically effective recycling system is dependent upon local conditions, a number of lessons may be learnt from international experience. Prior to the implementation of a recycling programme, a detailed evaluation of the economic, environmental and social impacts of recycling need to be undertaken. This should include an assessment of the life cycle costs associated with recycling, as compared with alternative methods of disposal (Yuan and Jinui, 2012). Markets for recycled commodities need to be stimulated to promote more profitable recycling and create jobs. One of doing is this is to impose import restrictions on raw materials which be easily replaced with locally recycled materials. A national forum should be constituted comprising stakeholders of all sectors of the recycling chain, for discussing mechanisms to promote recycling and monitor their effectiveness. The coordinated implementation of policy measures aimed at integrating recycling within waste management planning, increasing public awareness of the benefits and methods of recycling, and stimulating ongoing adoption of market-driven recycling initiatives; it has been earlier indicated that stakeholder consultation processes often delay projects. In the case of waste recycling, it may not be possible to assemble actors from all sectors'. An investigation into extended producer responsibility needs to be undertaken to identify its feasibility to promote recycling. Co-ordination of the proposed evaluation of recycling evaluation with a project currently ongoing with government to identify and evaluate market-based instruments appropriate to waste management, including recycling. While the design of an appropriate recycling system is dependent upon local circumstances and conditions, there are nevertheless a number of generic lessons that may be derived from the international experience with recycling and waste minimisation that may be of relevance to policy-makers in South Africa. One initiative or approach will not necessarily meet all the identified needs in South Africa and geographical, demographic and socio-economic differences will have to be taken into account in designing a localized minimisation model. (Manning, 2013).

2.6 Waste Minimisation in South Africa

According to the Department of Water Affairs and Forestry, (DWAF, 2011) waste is an inevitable consequence of development; and hence it must be managed in an integrated and sustainable manner. As the population increases and development takes place, a concomitant increase in waste generation is expected. There are a number of problems associated with increased waste generation such as the additional risk of air, soil and water pollution, and lack of suitable locations for landfill sites. In order to prolong the life of current landfills and optimally manage new ones, the waste disposed to landfill sites has to be minimised. The vision of the Polokwane Declaration (DEAT, 2012) is to reduce waste generation to 50% of current levels and for zero waste by 2022. In order to manage waste in a sustainable manner, waste management must consider the waste stream in a holistic manner, in order to optimize the use of resources and to reduce the environmental impacts (Novella, 2000). Thus an integrated approach which combines a number of techniques such as waste reduction, reusing and recycling has to be considered. One of the mechanisms to resolve this problem is to identify what portions of the waste stream can most readily be minimised and recycled. To do this effectively, a quantitative understanding of the total waste stream is necessary. Aspects that will need to be addressed include the identification of the waste stream sources and an assessment of the waste stream composition, as well as the quantification of the main waste streams for each of these sources. Certain waste streams could be targeted for recycling like the high income domestic streams due to their high content of packaging material and those streams that are not suitable for recycling, such as low income domestic streams due to high ash and sand content (DEAT, 2012).

The Department of Water Affairs and Forestry has developed an overall waste generation profile for each of the provinces (DWAF, 2011), which gives a first-order assessment of waste generation in South Africa. There is clearly a need for accurate up-to-date data on waste generation and waste disposal to landfills. This need has been articulated in the National Waste Management Strategy and the Action Plans for a Waste Information System and Integrated Waste Management Planning. It was proposed that local authorities collect and report waste generation rates, waste categorisation and identification of waste streams that have potential for recycling. It is recognised that there are practical constraints such as the unavailability of functioning weighbridges at most medium, small and communal landfills. The security risk comes into play at those landfill sites with weighbridges but no 24- hour armed security personnel. There are financial implications of providing, maintaining and protecting weighbridges. It was proposed that a first round of Integrated Waste Management Plans should be prepared. However, since this was not a legislated requirement, few local authorities have as yet completed their IWMPs, nonetheless, major metros such as Johannesburg, Cape Town, eThekwini, and Tshwane, as well as a number of other cities and towns have initiated the process of compiling IWMPs, and the required information should become available (DEAT, 2011). Recycling has the potential for job creation and is a viable alternative to informal salvaging at landfills, which is undesirable due to the associated problems of health and safety. A number of new developments South Africa in the political, policy and legislation fields, the Constitution (GSA, 2010), the Environmental Management Policy (DEAT, 2011), the National Environmental Management Act (GSA, 2010), the Integrated Pollution and Waste Management Policy and the National Waste Management Strategy, resulted in a re-appraisal of the recycling situation.

Integrated waste management requires the implementation of a hierarchical approach to waste management, involving a sequential application of waste prevention, minimisation, re-use, recycling, treatment and ultimately disposal. Hence, recycling is an integral part of the way waste management is being implemented in South Africa (Peter and Duneed, 2013). The majority of commercial waste recycling initiatives have been developed on an ad-hoc basis and have been funded by the private sector, with minor financial inputs from the provincial and local governments. The local municipalities have tried to stimulate waste recycling by assisting with establishing waste buyback centers and garden waste drop-off centers in the larger cities and towns, at which waste is separated into different waste streams, such as glass, paper and cardboard, cans, scrap metal, plastics and garden waste (Mukawi, 2009). A number of capital-intensive recycling plants have been launched but have been unsuccessful in Klerksdorp and Witbank. Although these plants worked from a mechanical point of view, their failure has been attributed to an over-estimation of the value of recoverable materials, unrealistic requirements of the municipalities involved, and a downturn in the economy at the time the projects were launched. Due to the large quantities of recyclable materials in the waste arriving at landfill sites, informal salvaging is widespread (Leonard, 2009). This practice leads to unacceptable health and safety risks for the salvagers, as well as operating problems for the landfill staff. The implementation of successful recycling initiatives is not a short-term activity but rather an ongoing initiative that must be reviewed and revised based on experience. An ongoing campaign will be required to change people's behaviour and to take responsibility for their waste. All stakeholders must take responsibility and their activities need to be integrated into holistic waste management planning. The Polokwane Declaration (DEAT, 2002) represents a significant initiative by all South African stakeholders in the waste management field to improve this practice. The vision is broad and the level of ambition is high, but the reality is that the objective will be difficult to achieve (Young et al, 2010).

Table 3. Roles of government departments Source: (National Waste Management Strategy, 2013)

Department	Areas of Responsibility	Description
Department of Co-operative Governance	Waste services planning, delivery and infrastructure	Support municipalities to prepare IWMPs and integrate with IDPs. -Make MIG funds accessible for development and upgrading of municipal landfill sites.
Department of Trade and Industry	Industry regulation and norms and standards	Manage the overall system of industry regulation. -Apply Consumer Protection Act. -Develop norms and standards using the Technical Infrastructure. -Support the development of markets for recycled materials. -Support the establishment of SMEs for waste collection services and recycling.
National Treasury	Fiscal regulations and funding mechanisms	Oversee financial integrity of intergovernmental transfers to provincial and local government. -Manage the overall system of taxation and implement tax measures that support the goals and objectives of the NWMS. -Determine budget allocations for waste management functions at national level.
Department of International Relations	International Agreements	Give effect to Multilateral Environmental Agreements.
South African Revenue Services	Import and Export Control	Ensure waste management measures are aligned with the product codes in the Schedules to the Customs and Excise Acts.
Department of Water Affairs	Water quality and licensing	Collaborate with DEA in issuing integrated waste disposal licenses.
Department of Mineral Resources	Waste Management in the mining sector	Regulate waste management in the mining sector that falls outside the ambit of the Waste Act (including residue deposits and stockpiles), and remediate land that mining activities have contaminated.
Department of Health	Health care risk waste	Address health care risk waste and advise DEA and provincial departments on the appropriate standards and measures for the sector.
Department of Defense	Contaminated land	Remediate land contaminated by ordinance waste.

A full appraisal of the social, environmental and economic benefits and cost of recycling, in comparison with one-way consumption and disposal of used products and packaging is essential to decide on the appropriate roles and mechanisms for recycling, for specific circumstances. The Department of Environmental Affairs has numerous discretionary responsibilities that it may invoke. These include developing national norms and standards for waste minimisation, re-use, recycling, recovery and tariffs. DEA can declare priority wastes; identify products for extended producer responsibility programmes, list waste management activities, request industry waste management plans, register transporters of waste and initiate investigations of land that may be contaminated. Other national departments play important regulatory and supportive roles in implementing the Waste Act, and waste management more broadly. South Africa has taken great strides in combating waste and have adopted a zero tolerance approach in minimising waste. Policies have been implemented at a national level and this has filtered down into other spheres of government. However, this is not just a government initiative but every person should adopt these principles.

2.6.1 Objectives, Criteria and Principles

In the Starter Document for Waste Recycling: A framework for sustainable post-consumer recycling in South Africa (DEAT, 2010), the objectives for promoting and expanding recycling initiatives are proposed. These include job creation, reduction of pollution, conservation of natural resources, conservation of energy, reduction of costs in the manufacturing sector, litter abatement, reduction of the waste stream to landfills, and eventual elimination of scavenging on landfills.

These can also be used as criteria for identifying, assessing and prioritising waste streams for recycling. It is important that there is due consideration of health and safety risks. Available quantities and value of the material and commodity being recycled need to be established. There is need to assess the state of existing and potential markets for the material and commodity being recycled. The technical requirements for separating the required waste from general waste have to be addressed. Additional concerns centre around bulking factor for landfills, recycling options, access to regular and reliable data, existing recycling initiatives, programmes and memoranda of understanding (DEAT,2010).

For equity there should be access to environmental resources by all, benefits and service to meet basic needs and ensure well-being (Mentzer, 2011). Full-cost accounting decisions should be based on an assessment of the full environmental cost and activities that impact on the environment (Mudau, 2013). This is a problematic principle to apply in practice as the full environmental costs are usually not available. For inclusivity and participation, the environmental management processes should consider the interests and values of all interested and affected parties in decision making to secure sustainable development (Oelofse, 2011).

Table 4. Summary of the National Waste Management Strategy Goals

	Description	Targets (2016)
Goal 1	Promote waste minimisation, re-use, recycling and recovery of waste	-2% 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 IndWMP for paper and packaging, pesticides, lighting (CFLs) and tyres industries.
Goal 2	Ensure the effective and efficient delivery of waste services.	-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.	-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.	-80% of municipalities running local awareness campaigns. -80% of schools implementing waste awareness programmes.
Goal 5	Achieve integrated waste management planning.	-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.	-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.	-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.	-50% increase in the number of successful enforcement actions against non-compliant activities. -800 EMIs appointed in the three spheres of government to enforce the Waste Act.

Source: (National Waste Management Strategy, 2011)

The relevance of this section to the study is that the aspects of criteria, objectives and principles should be included in the design of the model. This will enable the model to compliment the national priorities that South Africa is willing to address at the same time address the issue of renewable energy and a better environment. This issue should directly address the needs of the specific location.

2.6.2 Drivers for Waste Minimisation

Banks often consider recycling projects as high-risk and are unwilling to provide financing for such projects. Part of the tourism levy should be recovered to manage the waste produced by the tourism industry. Possible sources of funding are international and local funding agencies but it was felt that improved co-ordination is required to optimize the impact of the efforts of funding agencies. The main driver encouraging recycling in the poorer provinces appears to be an economic rather than an environmental need where there is a high need for job creation because of high levels of poverty and there is a low barrier of entry into this market. Government could encourage and stimulate recycling in a number of ways through tax reductions and rebates on levies for companies that recycle waste or by use of recycled products and by including recycling as a tender requirement in its procurement procedures (Karak and Bhakta, 2012).

Because the lack of skills, capacity and capital, private sector involvement in recycling initiatives is seen as crucial. Public and private partnerships are seen as a mechanism for encouraging recycling initiatives (Ilgin and Gupta, 2010). Private recycling companies, especially those within the packaging industry, are the main drivers in terms of commercial recycling. These activities include the recycling of paper, cardboard, plastics, glass, oil, rubber from scrap tires and motorcar lead-acid batteries. In the informal sector, especially in less developed areas, various commodities such as plastic bags, beverage cans and glass bottles are re-used to make innovative products. The establishment and support of drop-off and buyback centres by municipalities are considered drivers for successful waste recycling. At these centres waste is separated into different waste stream such as glass, paper, cardboard, cans, scrap metal, plastics, garden waste and disposable waste (Johannessen and Boyer, 2010). Collection banks are used on a small scale for glass and paper, whilst green cages are provided for the collection of mixed plastics. Schools, churches and welfare organisations are involved in the collection of recycled material, especially cans, paper and returnable bottles, partly as part of the education in environmental issues, and partly to earn money for the school budgets, or for the needy (Herva and Roca, 2011). Decision makers such as politicians, councillors and officials in local municipalities need to have a change in mind-set regarding waste management and recycling. This can be achieved through awareness raising, education and capacity building (Iyer and Karshap, 2007).

School education programmes developed in partnerships with local NGOs are promoting and encouraging recycling. A common problem experienced by municipalities is that they are running out of space on their existing landfills. New landfills will be more expensive and hence the preservation of landfill space is important. Land filling costs could escalate significantly and so drive other waste management initiatives. Savings in space brought about by recycling should be quantified and used to offset recycling costs. A central processing facility could be set up in each province to capacitate and assist municipalities unfamiliar with the processes of obtaining financial aid. Current recycling initiatives are predominantly run by organized business, but workshop participants felt that involvement by government could assist addressing changing conditions in the recycling market (ISO, 2000). Producers of commodities should be involved in buy back centres through mechanisms such as extended producer responsibility. Government and business assisting through subsidising buy-back centres could address the problem of exorbitant transportation costs (Godfrey and Scott, 2012). But a cause of high costs is the location of most recycling plants in Gauteng which disadvantages distant suppliers. It is important to note that these drivers can motivate and provide the mechanism to commit in waste minimisation efforts which can stem from tax levies to rebates. These drivers provide a monetary basis that is proof enough that waste has an economic value and is a source of income.

2.6.3 Challenges to Waste Minimisation

The following waste minimisation challenges were identified at the provincial recycling workshops held in Pretoria in 2013 (DEA, 2014): Limited access to markets remains a challenge for recyclables like glass, newspapers and magazines, paper and cardboard. The Free State, North West and Mpumalanga provinces are disadvantaged by their location far from recycling plants in Gauteng. Government does not encourage recycling since it does not specify the purchase of recycled products through its procurement procedures (Tam, 2009). Prices for recyclables have also fluctuated significantly and as a result many recycling ventures have gone under. There is concern about the lack of competition in the recycling field which may result in monopolistic practices (Hunga, 2009). There is a need to create new markets for recyclables, over and above the dominance of existing large recyclers such as SAPPI, Mondi and Collect-a-Can. There is limited capacity at local governments to support sorting at source. This is because such a programme requires the restructuring of designs for receptacles, street waste bins, specialised waste trucks and even high bulk skip bins. Most local authorities do not have the necessary infrastructure to recycle waste at their landfill sites. But even if this was possible, it does not make economic sense because of distortions such a practice brings into pricing.

There is a lack of skills and capacity at the local municipality level in the area of waste management and specifically waste minimisation, recycling and re-use. Capacity constraints across municipalities can squarely be blamed on the recruitment practices in the public sector and not on the lack of skilled people in the country. Environmental health departments can possibly assist with appropriate training by utilising their health inspectors to assist with the process of waste management (Kinnaman, 2013). Public and private partnerships with industry and the larger recycling companies should be explored. There is also the safety aspects involved where some recyclables such plastics, rubber, textile off-cuts are flammable and recycling companies need to ensure the safety of their workers (Manning, 2013). There are no direct tax incentives for recycling, as is the case in certain overseas countries such as in Canada where such tax incentives are provided to producers who recycle commodities. But some of the provinces already have industrial buildings which since the collapse of homeland industrialisation following the withdrawal of incentives in 1995, have remained vacant. Given that these belong to provincial governments, they could be used as incentive to attract potential investors.

2.6.4 Current Initiatives

Johannesburg has experienced flooding, heat waves, hailstorms and other extreme weather conditions. Besides its other impacts environmental pollution produces greenhouse gases, which are considered to be a major influence in climate change (Ecotec, 2011). As a result, the City of Johannesburg is ensuring that the environmental pollution impacts stemming from waste are averted and that greenhouse gas emissions are reduced. The City's integrated waste management operation incorporates waste separation at source, garden dumping sites and composting plants. In addition, Johannesburg has successfully implemented two landfill gas-to-energy projects (Smith and Scott, 2009). At the Robinson Deep landfill site and the Marie Louise project, landfill gas is extracted, combusted and flared as carbon dioxide, to generate electricity. In the near future a total of 19MW of electricity will be generated from five landfill sites, enough power for about 12500 middle-income households. The waste separation-at-source project encouraged residents to separate their waste - paper goes into orange bags and recyclables like bottles and cans in colourless bags (Skumatz, 2008).

The city of Johannesburg has created garden dumping sites for the disposal of light garden waste, where it's chipped into manageable sizes and transported to a composting plant. The composting plant processes about 150,000 tonnes of green waste per year into soil-enhancing compost. This compost is then sold to the agricultural sector and to city homeowners for suburban gardens. The city of Johannesburg is currently disposing of about 1.6 million tonnes of waste in the four operational landfill sites. On the other hand as a result the city is spending much on transportation costs, which also contributes to air pollution and greenhouse gas emissions from the trucks used in this process. The landfill gas-to-energy projects minimise environmental damage by reducing methane emissions. Methane is sucked through the combination of vertical and horizontal pipes to the flare system where it is burnt and carbon dioxide which is less harmful than methane gas is released (Patton, 2009). The Robinson Deep landfill was completed in May 2011. For this project, 68 gas wells were installed in the first phase and this number will be increased during the second phase of the project. The project has produced 137,888 Certified Emission Reductions (CERs) and destroyed 18,288,457 m^3 of landfill gas, which would have otherwise been released into the atmosphere. Construction of the Marie Louise project commenced in February 2012 with 28 wells being installed (Lehtoranta, 2010). By 2015 a total 19,042 CERs were amassed and 3,157,656 m^3 of landfill gas was destroyed since May 2012. Eventually a total of 19MW of electricity will be generated at five landfill sites, which could power about 12,500 middle-income households (Leeuwen, 2011). Construction for the three remaining sites of Goudkoppies, Ennerdale and Linbro Park will commence in the near future. In October 2013, the Department of Energy approved the project and agreed to sign a Power Purchase Agreement (PPA) with Eskom for 18MW contribution as part of the Independent Power Producers programme (McGurty, 2011). The project was registered with United Nations Convention on Climate Change (UNFCCC) in December 2012 wherein it can start selling carbon credits accrued from date of commissioning of the sites under the Kyoto Protocol. The City of Cape Town has managed to divert 10 million cubic meters of garden refuse from going to landfill. The City recently celebrated the major milestone in the war against waste, which it achieved in partnership with Reliance, the leading organic compost provider in the Western Cape. Cape Town's solid waste landfill sites are quickly filling up and waste will need to be transported to sites outside of the municipal boundaries in the near future at a significant cost. Reliance was contracted to shred green garden refuse collected from the city's drop-off facilities and landfills in 2001 and has been taking care of Cape Town's green waste since. Reliance recycles garden refuse into compost and has put over 750 000 tons of organic compost back into the soil. The company's zero organic waste to landfill mission is in line with the City's vision. Reliance is carbon neutral and has had its composting technology approved as a

Greenhouse Gas Emission Reduction method according to the guidelines of the United Nations Framework Convention on Climate Change (Mechelson, 2009).

In Port Elizabeth, the municipality decided to launch a campaign in 2008 to stop the waste to landfill practice by asking residents not to dump waste but rather exchange it to save the environment. It was called the NMB Waste Exchange, and is one of the waste reduction projects of the Integrated Waste Management Plan. It is a free web-based system that enables generators and users of waste material to exchange waste material at no cost to them, thereby reducing waste to landfill. Once a user is registered on the system, they can either post a listing or advert for wanted waste material or search on the listings of unwanted waste material posted by other users (Lynes, 2011). Waste material can be anything that can still be used by someone else such as cardboard boxes, left over building material, recyclables, wood, obsolete furniture or building rubble, to name just a few. By making use of the WX, users can benefit by saving on transport, disposal and storage costs. It may also assist in giving companies a competitive edge in the sustainable usage of natural resources and assist in locating alternative material suppliers that offer input material for your business, at a competitive price, thereby lowering raw material or input costs. By signing up and taking part, residents helped the Port Elizabeth municipality reduce the carbon footprint while improving their business environmental and social responsibility image (McCool and Stanskey, 2011).

Landfill sites are growing at a rapid rate and waste has direct and indirect impacts on human and ecosystem health, including contamination of surface and ground water. In addition, methane emissions from waste contribute to the greenhouse gas emissions profile of South Africa. These impacts could be significantly reduced with improved waste management practices. Although the secondary cities do not have the same resources as the metropolitan areas, many programmes can still be implemented that suit localised needs and addresses the issues affecting particular municipalities (Shen and Tam, 2010).

2.6.5 Evaluation of Minimisation Initiatives

In assessing the impact and effectiveness of these structured governmental policies for recycling, a key consideration is to evaluate the extent to which these policies have resulted in increased levels of recycling (Walker, 2009). Examining first the extent to which formalised government intervention has resulted in increased rates of recycling, it is evident that in most of the countries there has been an increase in levels of recycling. However, these improvements in recycling rates have generally not been sufficient to reduce or even stabilize the overall quantity of waste generated, which has risen by nearly 10% between 1990 and 2005, as compared with an economic growth rate of approximately 6.5 % (EEA, 2009). In particular there has been an increase in the generation of glass and plastics waste. For municipal waste, landfilling remains the most common treatment. From 2000-2009 there has been an increase in the amount of municipal waste landfilled from 86 million tonnes to 104 million tonnes. Even if part of this increase may be due to better accuracy in recording data, it is reasonable to conclude that in absolute figures, the EU countries landfilled more municipal waste in 1995 than in the 2000-2009 period. Assessing the environmental and economic costs and benefits of the government-imposed recycling programme is a complex exercise. It is essential that detailed cost-benefit analyses of the various policy options are undertaken prior to introducing policy aimed simply at increasing the level of recycling. It is emphasised however that the results of studies conducted in Europe or the United States should not be seen as necessarily indicative of the results that would be found for similar reviews in South Africa (Schoer and Arsaebel, 2012).

2.7 Approaches in Waste Analysis

A great number of waste minimisation modelling tools that can be used for supporting waste management decisions at municipal level have been developed. The tools selected are based on their relevance to this study and include Life Cycle Assessment (Jorgensen, 2008), different types of Material Flow Analysis (Brunner, 2004), Cost-Benefit Analysis (Mishan, 2007) and Life Cycle Costing (Gluch, 2004). The sheer number of different methods that are available may be confusing and there is therefore a need to characterise the approaches in order to better understand the appropriateness of using different tools in different situations.

In assessments of waste treatment options, life-cycle assessment (LCA) helps expanding the perspective beyond the waste management system. This is important since the environmental consequences of waste management often depend more on the impacts on surrounding systems than on the emissions from the waste management system itself (Jorgensen, 2008). In particular, the broad perspective of LCA makes it possible to account for the significant environmental benefits that can be obtained through different waste management processes. Such benefits include waste incineration with waste-to-energy conversion could provide stand-alone small energy producing units. Material from recycling processes could replace dependence on production of virgin material. Biological treatment that exploits bio-degradation processes could reduce the need for artificial fertilisers. It is also possible incorporate incinerator ash in materials for road construction.

LCA models that calculate the environmental burdens per tonne of waste generated allow for environmental comparisons of different options for dealing with this waste but not for analyses of changes in the quantities of waste. They are inadequate for the identification and assessment of waste prevention strategies. They also fail to account for the serious challenges posed by a continuation of the short-term and long-term trends of increasing waste flows. Consequently, these LCA tools do not give information on capacity requirements for waste treatment. Traditional LCA models are also static such that they cannot give information about the appropriate time for investments in waste management plants. Perhaps more seriously, the system structure and the input data in a traditional LCA both reflect the recent past. This means that, at the best, traditional LCAs provide a basis for identifying what waste management strategies are best served to solve the needs of the current society. However, waste management plants are large investments that are intended to last for several decades, and the surrounding society can change significantly during this time. A technology that is appropriate today might be incompatible with the long-term sustainability of the society (Jorgensen, 2008).

Material flow analysis is a family of different methods (Bringenzu et al, 2007). A common feature is the focus on material flows. Substance flow analysis (SFA) is a type of MFA that focuses on a specific substance within a system. Like other MFA methods, SFA focuses on inputs but in addition it also follows substances within the economic system to trace the outputs. Examples include SFAs of waste management systems (Döberl et al, 2012) and specific treatment methods (Morf et al, 2013). Different types of economic assessments are done on a regular basis. For example, before projects are decided, an investment analysis would normally be performed. If the project involves a complex system, for example a waste management system within a municipality involving a number of different treatment facilities, a model for the economic analysis may be required. One example of such a model is MIMES/Waste (Sundberg et al, 2004). Such a model may be used to describe economic consequences of different alternatives as well as optimising a complex system with regard to cost.

The disadvantages of the MFA is that it needs a lot of data to be implemented. In the study area selected, there is only a limited set of reliable data and there is also a need to deal with uncertainties. The other disadvantage of this tool is its inability to predict the future. Tools are often used in order to inform a decision-maker about the possible or likely consequences of a decision. Investments in waste management can be long-term, for example, a waste incineration plant can have an economic lifetime of decades. The consequences of such an investment will thus depend on the future developments, for example concerning energy prices that may pertain in the future. Accurate prediction of such price escalations is at least a difficult exercise. Although there are a number of different approaches which may be used to assess likely or possible futures, it is clear that the future is inherently uncertain. This brings uncertainty into the analysis.

Cost benefit analysis (CBA) tool for assessing the total costs and benefits from a planned project. It is a well-established tool described in textbooks on environmental economics. In principle, all costs and benefits, including environmental costs, should be included and monetised. This means that both marketed and non-marketed goods and services are given a price (Johansson, 2013). In the evaluation the costs are compared to the benefits. Although it is typically applied on projects, it can be used more broadly especially as a valuation method. Many CBAs of waste management have been carried through on the national level in the past decade (Ibenholt et al, (2013). Traditional CBAs include emissions and fuel demand of transport and take transport distances into account when calculating environmental burdens. However, they do not differentiate between emissions occurring at different locations. Instead, all emissions of each specific pollutant are totalled without any spatial information. Environmental impacts of several pollutants may depend heavily on their spatial locations. Because of its inability to handle spatial information, a typical CBA model does not accurately describe many environmental impacts. A typical LCA also does not give information that is adequate for deciding where a waste-management facility should be sited either.

The other limitation is the valuation and weighting of different impacts. In several of the models, different impacts have to be weighted (valued) against each other. There are a number of different approaches available for weighting developed within different scientific disciplines. For example, within environmental economics, a number of different methods are used to value the economic value of environmental impacts (Bockstael et al, 2000). Also within the area of Multi-Criteria Decision Analysis, a number of non-monetised methods have been developed (Guitouni and Martel, 1998). It is important that the valuation methods developed and used can be critically discussed and evaluated (Stirling, 1997). A problem however is that we do not know which values are "correct" and the results from a valuation can therefore always be challenged.

Life-cycle costing (LCC) can be used to assess the costs of a product or a service from a life-cycle perspective. It can include different types of costs (Norris, 2001). It is an analytical tool and has been used for waste management studies (Carlsson, 2005). If the LCC includes external costs –that is costs borne by society at large for example due to environmental pollution, an LCC can be similar to a CBA. LCC models are typically linear steady-state models of physical flows (Guinée, 2002). The LCC results can indicate what waste-management option contributes the least to different environmental impacts. In reality the environmental burdens of collection and minimisation are likely to be a non-linear function of the collection rate. There will be initial activities and environmental burdens when a collection system is established and at very high recycling rates the required extra transports and processing of materials may increase fuel consumption and emissions greatly for each additional tonne of material that is collected (Sakai et al, 2011).

Since LCC results are linear they cannot be used for identifying the optimum mix of waste-management options - recycling, landfilling and incineration. This means that typical LCC models cannot be used for identifying optimal re-use and recycling rates. Many LCC's use average data to model the background systems, that is- the systems indirectly affected by the actual system under study. In LCCs of waste management, important background systems include for instance the energy system and the production of materials and fertilisers, all of which may be significantly affected by decisions concerning waste management. The use of average data to model these systems may be relevant if the aim is to perform an attributional LCC (Tillman, 2000); however, it may be misleading if the aim is to model the consequences of a decision. The use of average data means that the LCC model is inaccurate in describing how the background systems are affected by changes in the waste management system, because changes in the waste management system will not affect all parts of a background system equally. In general, all actions in the waste-management system can be expected to have marginal effects on the production of bulk materials, energy carriers, or fertilisers. Marginal effects are the consequences of infinitesimal or small changes in the quantity produced of a good or service (Ekvall & Weidema, 2004).

Waste management models can be useful at a number of different levels in society. It can be used by companies to support strategic decisions, by municipalities for waste management planning, and for local, provisional and national governments for policy decisions. Experiences have shown that waste management models can be useful for learning and for getting different organizations to find common ground for discussion. The benefit of using waste models in analysing waste management systems is that they provide a comprehensive view of the processes and impacts involved. A waste management system is in itself a large and complex system that is difficult to survey. The system grows even more complex as one considers its links to other sectors such as manufacture, energy production, and agriculture.

The comprehensive view provided by such models is important if one strives to avoid system sub-optimization, such as reducing the impacts of treating the waste at the expense of increased impacts from transportation. A life-cycle perspective can also illustrate the benefits of different waste treatment methods such as the production of heat and electricity from incineration or the production of new raw materials that can replace production from virgin materials. Indeed, some models have been shown to provide policy relevant and consistent results. However, it should also be made clear that the study will always be open for criticism as it is a simplification of reality. This is something all waste management models have in common. There is thus a need in South Africa for both site-specific and a wide systems approach using non site-specific methods. No method can handle all these requirements. Therefore combinations of methods are needed to try and address the issues of waste minimisation.

2.8 Key Knowledge Gaps

The literature review has highlighted several knowledge gaps. These are briefly explained.

a) Conventional analysis:

Conventional waste analysis using LCA, LCC and CBA techniques is limited in terms of application into future projections. In addition, the data basis of these approaches remain inadequate in capturing the true flows along the waste chain.

b) Modeling applications:

A significant amount of work involving linear mathematical models already exist in the public domain. These have applications beyond waste management into industrial processes, construction and business. But the greater the generalisation achieved through this exercise, the greater will be the generalisations in the underlying assumptions. Yet, all modeling of physical systems must be informed by an understanding of environmental parameters in the target area where the model is supposed to apply. Models imported as is-from other geographical areas may not be particularly suited to different conditions.

c) Recycling sector:

The high costs associated with the transportation of recyclables from different sources are generated by the location of recycling facilities. The tendency for recycling facilities to be located close to or within the most industrialised regions of a country is in line with the economics of location and the potential benefits of agglomeration. This means that waste minimisation programmes which normally integrate with waste recycling cannot ignore the geography and economics of location.

d) Community participation:

In industrialised western economies, Japan, New Zealand and Australia, community based programmes in the waste sector are well established and advanced. In developing countries, these schemes have been primarily driven by local communities and do not get adequate support from local governments. At the same time, existing commercial operators in waste recycling are reluctant to collaborate with community initiatives which appear to lead to direct manufacturing processes.

e) Waste sorting at source:

The industrialised countries have put adequate facilities and initiatives in place in support of their programmes in minimising waste. These countries have set legally required targets for particular waste streams. The low level of government support for similar initiatives in most developing countries means that the multiplier effects of waste sorting at source are poorly appreciated. Where these are understood, governments have not been particularly aggressive in financing these or in enforcing their implementation. The effect is that the radical transformation of waste management systems has not yet occurred.

f) Coordination:

Modelling waste minimisation, around which this study is based, requires high levels of coordination within government, within the industrial sector and across communities. Underlying such coordination is an understanding of the dynamics of the waste chain and how its efficiency generates multipliers that are beneficial to all.

2.9 Summary

Chapter 2 discussed the background of waste generation and waste minimisation in South Africa and the global community. It has been mentioned that there are legislation governing waste management and related activities in South Africa and these range from the Constitution to the National Environmental Management Act: Act 107 of 1998, the National Environmental Management: Waste Act 59 of 2008 and other relevant legal frameworks. A comparison has also been made taking examples from the global community and relating them to activities undertaken in South Africa. It is evident that great strides have been made in waste reduction efforts and the drivers involved in such programmes, and also the obstacles involved in reduction efforts. Current waste minimisation efforts are mentioned and also the initiatives that major metropolitan such as Johannesburg, Cape Town and Port-Elizabeth have taken in trying to reduce their waste. Current waste minimisation models have been listed and their limitations made known to try and ascertain whether or not they can be exported and utilised in the study areas. The importance of the literature review section is that it shows a clear sounding and understanding of where South Africa stands as a country in trying to minimize the amount of waste entering our landfill sites as compared to other countries in the global community and their best practices. It shows that South Africa lacks far behind and there is a need to adopt a change in mind set if South Africa's goals and objectives to minimise waste and prolong the lifespan of the country's landfill sites are to be achieved.

CHAPTER 3: THE STATE OF MUNICIPAL LANDFILL SITES

3.1 Introduction

Chapter 3 looks at the state of the selected municipal landfill sites in the study area and discusses the material and methods used to address objective 1 and the criteria used in selecting these sites. The viewer is given a layout of the location of the selected sites and presents the minimum requirement, as observed by the researcher, for the operations of the landfill site. Chapter 3 also reports on the amount of waste stream entering the site, waste treated on site and the amount of waste recycled and recovered so that. These are compared to the infrastructural element, so as to have a clear understanding on the life cycle of these sites and their daily operations. The general characteristics of the sites, as surveyed, are listed and in closing this chapter a brief indication of the processes needed in closing a landfill site is mentioned as well as the significance of the chapter and a summary of the chapter is given.

3.2 Materials and Methods

3.2.1 Research Design

In addressing objective 1, a quantitative descriptive and non-experimental approach was undertaken. Data had to be obtained from non-participant field observations and surveys of the selected study areas. Observations along the waste chain were done and measurements of values were recorded and presented graphically.

3.2.2 Population

The landfill sites in each of the study areas were selected based on their status of being licensed and permitted according to Chapter 5 of the National Environmental Management: Waste Act, 2008 (Act 59 of 2008). These sites conform to certain practices and standards and comply with national and local legislations. Non-permitted landfill sites and illegal sites were discarded as they are not recorded and the local municipalities have no control over them. They do not comply with national legislations and municipal by-laws. In the Klerksdorp Local Municipality only the Klerksdorp landfill site was selected, in the Carletonville Local Municipality only the Rooipoort Landfill site was selected, in the Witbank Local Municipality only the Ga-Nala and Phola landfill sites were selected and in the Welkom Local Municipality only the Virginia, Henneman, Odendaalsrus and Welkom landfill sites were selected.

3.2.3 Data Sources

For each of the selected landfill sites, observations and surveys were carried out. Each of the sites is equipped with a weighbridge to record the waste stream entering and disposal of the waste. The data obtained were captured on the South African Waste Information system. The system was developed by the Department of Environmental Affairs (DEA) for use by government agencies and industry for capturing of routine data on tonnages of waste generated, recycled and disposed of in South Africa on a monthly and annual basis. This was further reinforced with the use of existing secondary data that was obtained from the respective waste management directorates from each of the study areas that conform to the minimum requirements as stipulated by the Department of Water Affairs and Forestry. Primary data was collected at the weighbridges onsite and this was further validated and screened using data from the South African Waste Information Services (SAWIS). The data accumulated from the observations and surveys was tabulated.

3.2.4 Instruments and Collection

The instruments used for data collection on the selected study sites was covert observational research integrated with survey schedules. A standard observational and survey schedule was designed for the selected landfill sites and the elements contained are those prescribed according to the minimum requirements as stipulated by legislation. As compared with quantitative and experimental research, covert observational research was more reliable and often more valid. The main advantage of covert observational research as carried out was its flexibility. It allowed for changes to the approach when needed and when entering landfill sites there was no need for identification and in some cases observations could be carried out from a distance. The advantages of this approach are that it is not necessary to get cooperation from relevant authorities and the behaviour of the authorities had no effect on the data. The surveys included a technical overview of the landfill e.g. age of the site and its carrying capacity and also elements such as the collection sites and transportation.

3.3 Results and Discussions

3.3.1 Minimum Requirements for Landfill Sites

According to the minimum requirements for waste disposal by Landfill (DWAF, 1998) there are certain minimum requirements for the operation of a landfill site. The general objectives are to verify that the landfill sites conform to the required standards and the site permit conditions. These requirements are also needed for establishing and opening of new landfill sites. More specific objectives are to function as a control measure to ensure that the operation conforms to the required standards, to quantify any effect that the operation has on the environment and to serve as an early warning system so that any problem that arises can be timeously identified and rectified.

Table 5. Observations on the minimum requirements of the landfill sites in the study areas

	CLASSIFICATION SYSTEM							
LEGEND **1 Very Low ; 2 Low** **3 Moderate; 4 High** **5 Very High**	Klerksdorp Carletonville Witbank				Welkom			
	Carletonville (Rooipoort landfill sie)	Klerksdorp	Witbank (Ga-Nala	Witbank \(Phola landfill	Welkom	Odendaalsrus	Henneman	Virginia
MINIMUM REQUIREMENT								
Facilities & Resources: Sign Posting	2	3	4	5	2	4	2	3
All weather roads	3	1	2	3	2	5	4	3
Controls: Waste acceptance procedure	4	4	4	4	4	4	4	4
Fencing	3	2	4	5	4	3	2	4
Control of vehicle access	1	1	2	1	2	2	2	1
Site security	2	2	2	2	2	2	2	2
Operating plan	4	4	4	4	5	3	4	4
Response action plan	3	3	3	3	3	3	3	3
Waste load allocation	2	1	4	2	3	2	1	1
Resource & Infrastructure: Weighbridge	1	1	1	1	1	1	1	1
Collection of waste disposal tariffs	5	5	5	5	5	5	5	5
Site office	3	3	3	3	3	3	3	3
Laboratory	1	1	1	1	1	1	1	1
Adequate plant & equipment	2	2	3	2	3	2	2	3

Responsible person	4	4	4	4	4	4	4	4
Sufficient qualified staff	2	2	2	2	2	2	2	2
Landfill operation: compaction of waste	4	4	4	4	4	4	4	4
Daily cover	3	3	3	3	3	2	3	2
Two weeks cell or trench capacity	1	1	1	1	1	1	1	1
Protection of unsafe excavations	2	3	2	4	2	2	3	1
End-tipping prohibited	1	1	3	2	2	2	3	3
Waste reclamation prohibited	1	1	1	1	1	1	1	1
Registration of reclamation	1	1	1	1	1	1	1	1
Protective clothing	2	2	1	2	2	2	1	1
Control of nuisances	1	1	1	1	1	1	1	1
Waste burning prohibited	1	1	1	1	1	1	1	1
General site maintenance	5	5	5	4	3	3	4	3
Sporadic Leachate reporting	1	1	1	1	1	1	1	1
Landfill gas control	1	1	1	1	1	1	1	1
Rehabilitation & vegetation	1	1	2	3	5	3	3	3

(Source: DWAF, 1998)

Table 5 provides a general overview of the standard requirements as stipulated by the Department of Water Affairs and Forestry and should be taken into cognizance by various stakeholders who operate and manage landfill sites. Its shows the status of the eight sites in the study area in complying with the minimum requirements. Out of a possible score of 150, the highest score level observed was to be 76 and the lowest was 65. These requirements make up the structure of the landfill sites and ensure its day-to-day functioning and operations. Housed within these requirements are the standard operating procedures for the landfill sites. Any deviation from these requirements has serious implications on the permit status and the application for a permit. These requirements are statutory and are critical for the successful maintenance of any landfill site. One of the benefits of these requirements is that in an event such as natural disasters the surrounding land use areas will not be severely affected.

3.3.2 Control Variables

The object of these requirements is to ensure that all waste is disposed of in an environmentally and socially acceptable manner and to ensure that the disposal operation is acceptable to those whom it affects. Therefore command and control is very important in this regard.

a) Signage

Signs in the appropriate official languages must be erected in the vicinity of the landfill site indicating the route and distance to the landfill site from the nearest main roads. These traffic signs must conform to the requirements of the road ordinance. Suitable signs must also be erected on site to direct vehicle drivers appropriately and to control speed. A general notice board must be erected at the site entrance. This must also be in the appropriate official languages, stating the names, addresses and telephone numbers of the permit holder and the responsible person, the hours of operation, and an emergency telephone number. It is of particular importance that the sign clearly states the class of landfill site and the types of waste that can be accepted. As described from Figure 5 Witbank landfill sites (Ga-Nala and Phola landfill sites) provide sufficient sign postage and this is followed by the Odendaalsrus and Klerksdorp landfill sites respectively. The Henneman and Carletonville landfill sites are lacking in this regard.

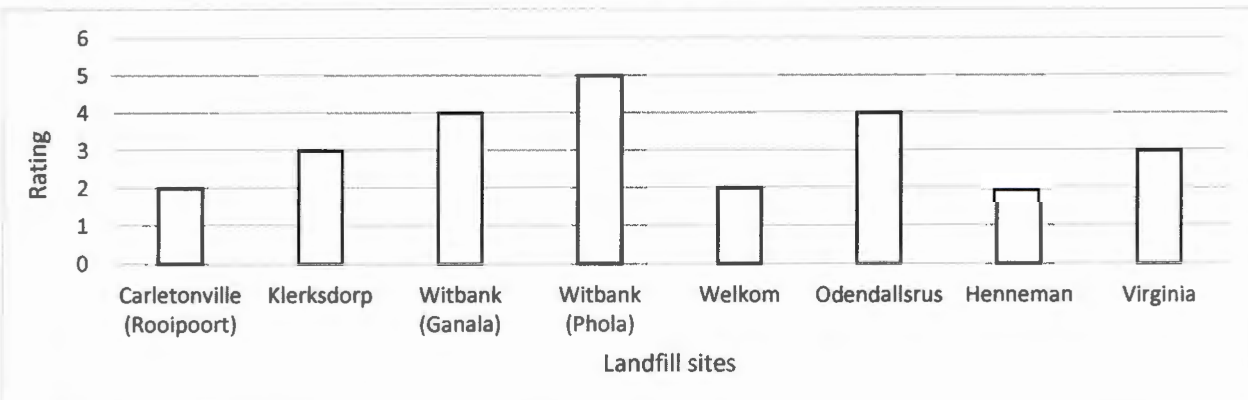


Figure 5. Signage rating for landfill sites in the selected study area.

b) All Weather Roads

All weather roads enable the flow of vehicle entering and exiting the dumpsite. Proper and well maintained roads have a lasting impact on the wear and tear on vehicles. This is in contrast to roads that are damaged and have potholes which cause damage to vehicles with consequent financial implications. As depicted in Figure 6 the roads in Henneman, Carletonville and Odendaalsrus are well maintained and in good order compared to the roads in Klerksdorp which are degraded. The roads in the Welkom, Witbank and Virginia landfill sites in good condition but need to be maintained.

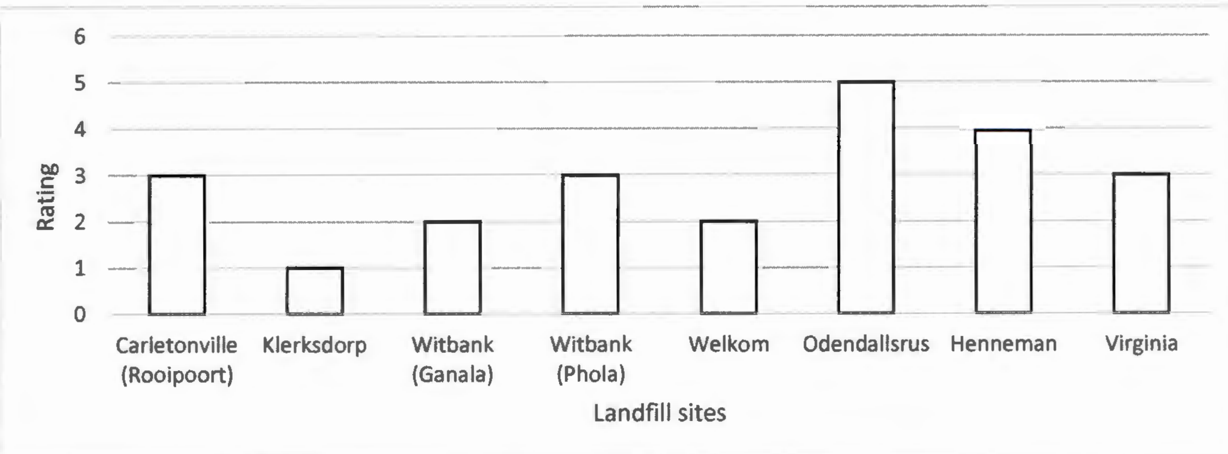


Figure 6. All weather roads leading into landfill sites in the selected areas

c) Waste Acceptance Procedure

One of the purposes of the landfill classification system is to ensure that general waste disposal sites receive only the general waste for which they are designed and that all hazardous waste is disposed of only at hazardous waste disposal sites. Prior to waste being accepted at general waste disposal sites, it must be inspected by suitably qualified staff and the transporter must confirm that it is general waste. In the case of doubt, any industrial waste should be considered as potentially hazardous until proven otherwise. This is being well implemented by all the landfill sites.

d) Fencing

Fencing ensures that no unauthorized entry is made into the landfill sites. Fencing also prevents anyone from gaining access to landfill sites for unauthorised activities. It also deters animals from gaining access. Fencing also provides a security measure and enables efficient command and control. The Witbank landfill sites have a proper fencing installation in place whereas the Klerksdorp and Henneman landfill sites are lacking in this regard. As depicted in Figure 7 the Witbank Phola landfill site has a well-maintained fencing installation. Henneman and Klerksdorp landfill sites have improper fencing available due to the fact that most of the fences are being regularly stolen. It was observed that a continuous fence monitoring system is in place at the Welkom landfill site.

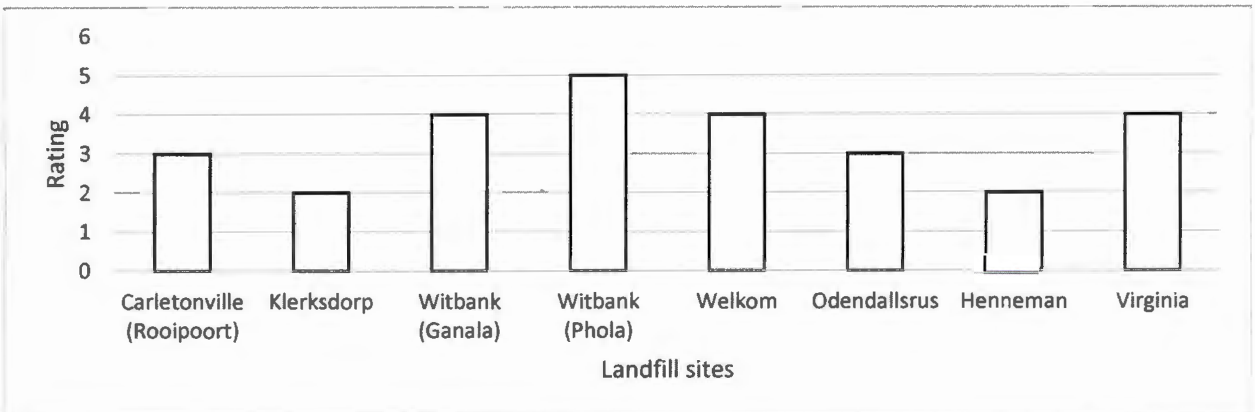


Figure 7. Fencing rating at landfill sites in the selected areas

e) Access Control

In order to facilitate the above waste acceptance procedures, access to the site must be controlled. It is therefore a minimum requirement that vehicle access to a site be limited to a single controlled entrance, to prevent the unauthorised entry and illegal dumping of waste on the site. The site entrance must comprise a lockable gate which must be manned during hours of operation. Additional security after operating hours is required at all hazardous waste disposal sites and general waste disposal sites where appropriate. This enables effective and efficient command and control of the landfill site. Vehicle entering these site have to be signed in and out. The benefit of this is that proper data collection of the waste trucks is done. This is a very important aspect for the management of the site. As depicted in Figure 8 the Witbank, Odendaalsrus and Henneman have proper entrance control procedures in place whereas Carletonville, Klerksdorp and the Virginia landfill sites do not enforce the procedures.

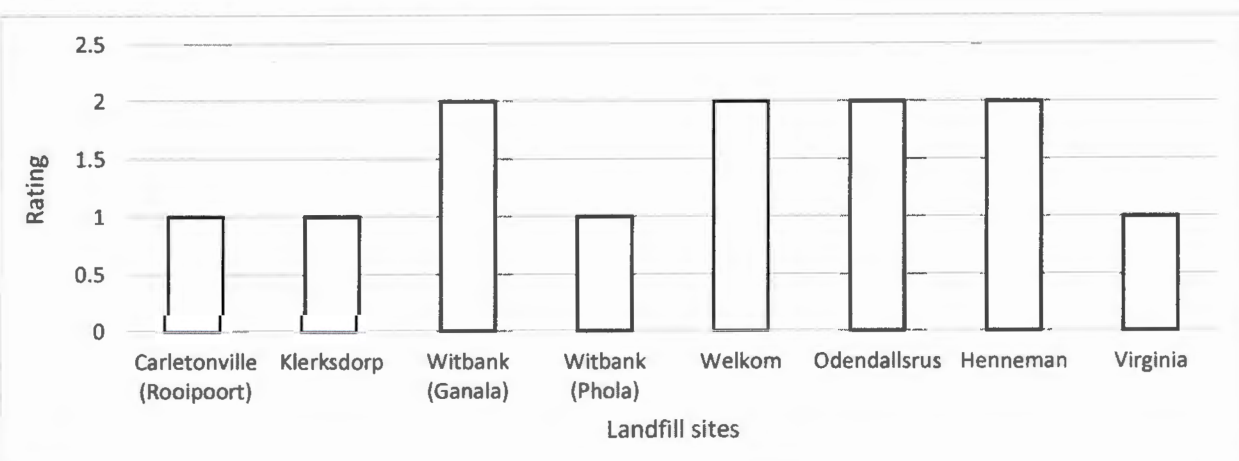


Figure 8. Access control at landfill sites in the selected areas

f) Site Security

In addition to access control, suitable security must be provided to protect any facilities and plant on site. It is a requirement that unauthorised pedestrian access be strictly prohibited at hazardous waste disposal sites, although this may be difficult in some instances. Primarily for the purpose of protecting public health and safety, waste reclamation and squatting should be discouraged at general waste disposal sites. It is a requirement that no reclamation be allowed at hazardous waste disposal sites. Since fencing is not always effective, additional measures may be necessary. This task is undertaken by people employed by the local municipalities but it was observed at the Klerksdorp landfill sites that private security operatives perform this task. Security operatives oversee the total management of the site and discourage any illegal activity from taking place on the sites. The main function is protect valuable assets of the site and are a deterrence of crime. All landfill sites have instituted some security measures in place but a common issue affecting these sites is the theft of fences.

g) Operating Procedures

An Operating Plan is a site-specific document forming part of the landfill permit application procedure. It describes the way in which the landfill is to be operated, commencing at the level and detail of daily cell construction and continuing through to the projected development of the landfill with time. Everything pertaining to the operation of a landfill should therefore be included in the operating plan and the plan must be updated regularly. The complexity of the Operating Plan can vary from a very simple plan to a very detailed and sophisticated document depending upon the class of site. As described in Figure 9 the Welkom landfill site are strictly adhering to their operating procedures. The Odendaalsrus landfill site is lacking in this regard.

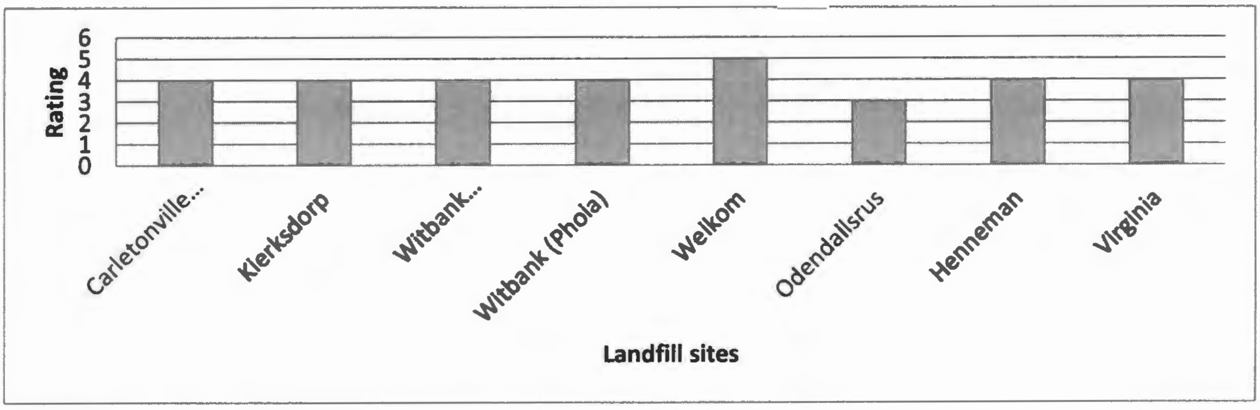


Figure 9. Operating procedures at landfill sites in the selected areas

h) Response Action Plan

The Response Action Plan refers to emergency preparedness and response plan. This could be a plan in response to natural disasters such as flooding or fires to name just a few. In the Response Action Plan is included the Landfill Closure Plan and a Rehabilitation Plan. The Response Action Plan should be read in conjunction with the Procedural Plans. All the landfill sites have such plans in place and form part of the standard operating procedures.

i) Waste Load Allocation

This is described as the area allocated for certain waste streams that are usually categorised in the landfill sites. As depicted in Figure 10, the Witbank and Welkom landfill sites have a higher waste load allocation then at the Virginia, Henneman and Klerksdorp landfill sites. As can be depicted in Figure 10, the Odendaalsrus, Witbank and Carletonville landfill site have an average waste load allocation.

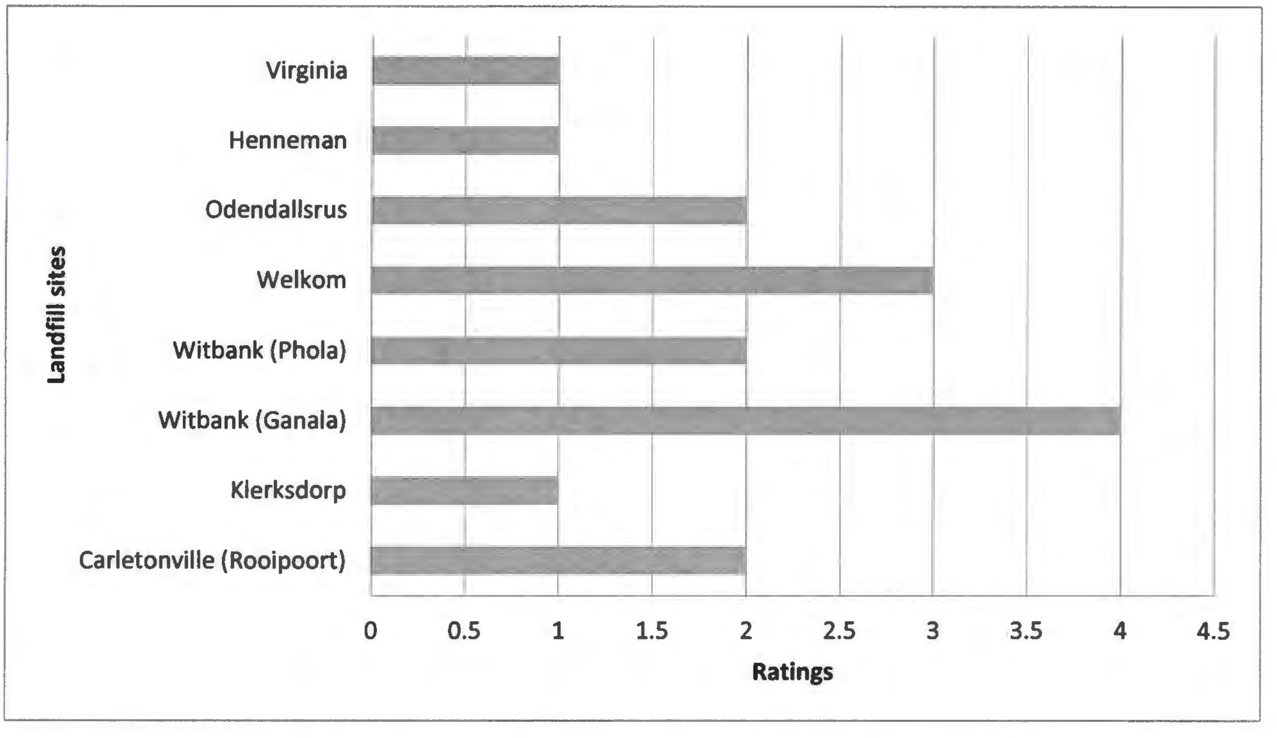


Figure 10. Waste load allocation at landfill sites in the selected areas

The significance of the waste load allocation for the control variable is that it provides efficient measures and mechanisms for the purpose of command and control. Its importance is that it prohibits the uncontrolled dumping of waste and access of vehicles into and out of the site. It also enables the monitoring of substances that can be very harmful to the neighbouring land uses. When vehicles enter the sites they are checked and documents verifying the nature of their business are well validated. The control aspects also enable correct recording of data and ensures that waste streams that do not belong at the site are disposed at their correct locations.

3.3.3 Resource and Infrastructure

The facilities at a landfill site will vary in accordance with the size of the operation. In the case of a site designated G: C, only access control would be a requirement. Larger sites would typically have services such as water, sewerage, electricity, telephones, security and infrastructure such as weighbridges, site offices and plant shelters. In the case of hazardous waste disposal sites, an on-site laboratory would be a required.

a) Weighbridges

Landfill site operators, facility users and the Department of Environmental Affairs will all require waste disposal records for different reasons. Over and above the measurement of incoming waste for commercial purposes, records are also necessary for site management and control. Such records are obtained from record keeping at the gate or weighbridge. The method of waste recording must be appropriate to the nature and the volume of the wastes entering the site. Such data bases are sometimes termed 'dynamic records'. The degree of sophistication required will be dependent upon the class of site involved. In general, however, records must be kept of all waste entering the site. Waste must be categorised by the number of loads, the type of waste and the source. Hazardous waste must also be defined in terms of its hazard rating. Records must be kept on both a daily and a cumulative basis. Such historically factual records are sometimes termed 'static records'. These should be maintained and archived. It was observed that all the landfill sites in the selected areas have such measures in place.

b) Collection of Waste Disposal Tariffs

Although minimum requirements increase the standards of waste disposal, they also increase the cost. In order to offset these costs, waste disposal tariffs should be levied and collected at all landfill sites, from medium size upward. Tariffs should be displayed on the notice board. They should be based on mass, where a weighbridge exists, or on estimated volumes. The landfill sites collect certain tariffs for the disposal of large volumes of waste. In some instances tariffs are being deducted from the normal rates and taxes that the municipalities charge. The tariffs for each of the study areas differ based on their environmental management by laws. Site offices are constructed on all the landfill sites. They enable the proper conducting of administration. The basic requirement include a computer, table, chair, telephone connection and stationery.

c) Plant and Equipment

Plant and Equipment are necessary for the maintenance of the landfill site and include equipment such as spades, kudus and other equipment. As depicted in Figure 11 all landfill sites have the basic tools and equipment. Other important equipment are the PPE as stipulated by the occupational health and safety guideline. As indicated in Figure 11 Virginia and the Witbank landfill sites have the highest rated equipment. Observations at these sites indicate that the waste directorates have allocated a budget for buying of new equipment and the replacement of older ones. Landfill sites at Henneman, Welkom, Klerksdorp and Carletonville are still using old outdated equipment.

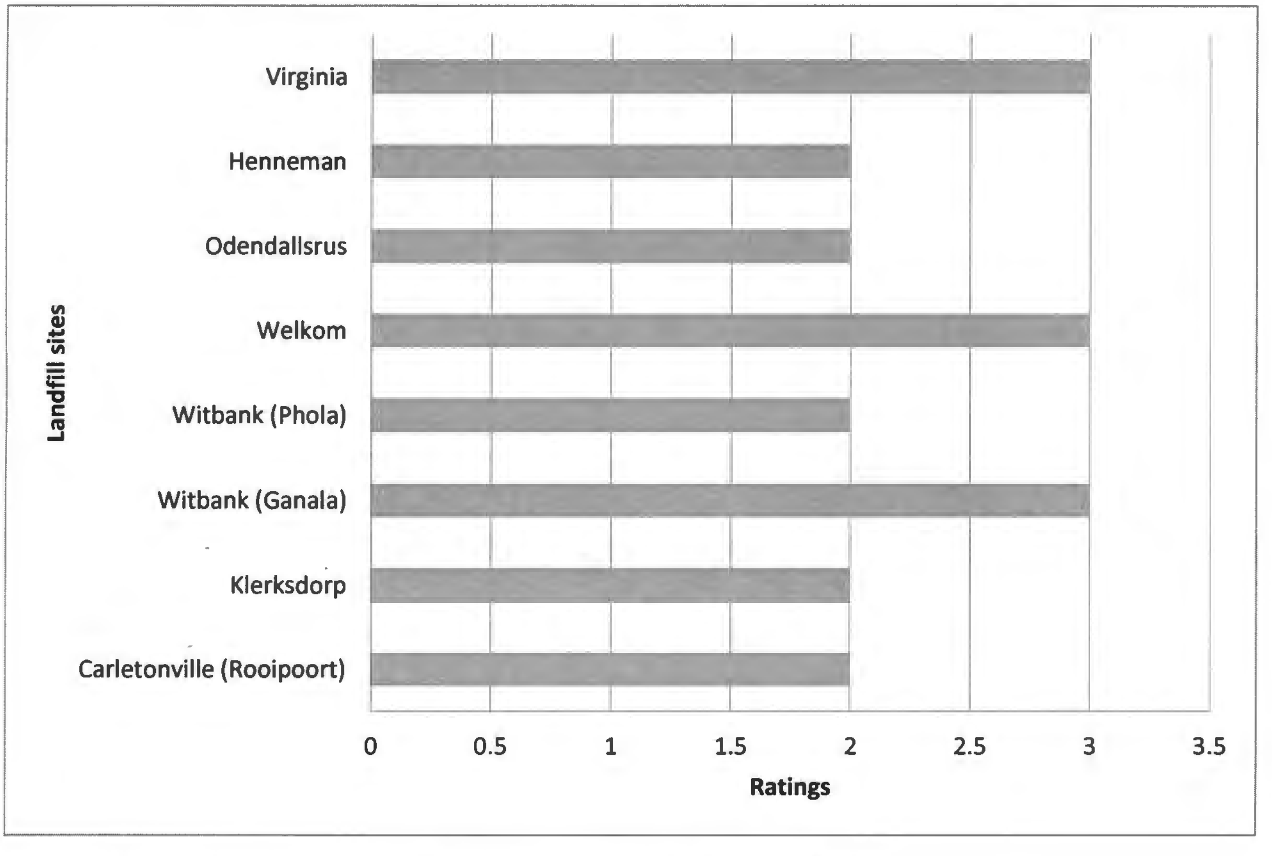


Figure 11. Plant and equipment at landfill sites in the selected areas

d) Responsible Personnel

Responsible personnel can be described as the person in charge of the landfill sites. This can range from an environmental officer or waste manager. Usually such personnel see to the daily operations of the site and instil command and control. They report to their supervisors at higher headquarters. Each landfill site in the study area has a person who is designated to be in charge of the site.

e) Ground Staff

As indicated in Figure 12 with exception of the Virginia landfill site, all the other sites have sufficient staff in place to enable the smooth running of the site. The responsible person must in all cases be supported by suitably qualified and competent staff. This staff complement would be commensurate with the size and type of the operation, as well as with the facilities and plant involved. Sufficiently qualified staff and back-up are required to ensure that the minimum requirements relating to the operation are met. Where applicable, the responsible person must also ensure that the requirements of the Occupational Health and Safety Act are met, with regard to visitors and site staff.

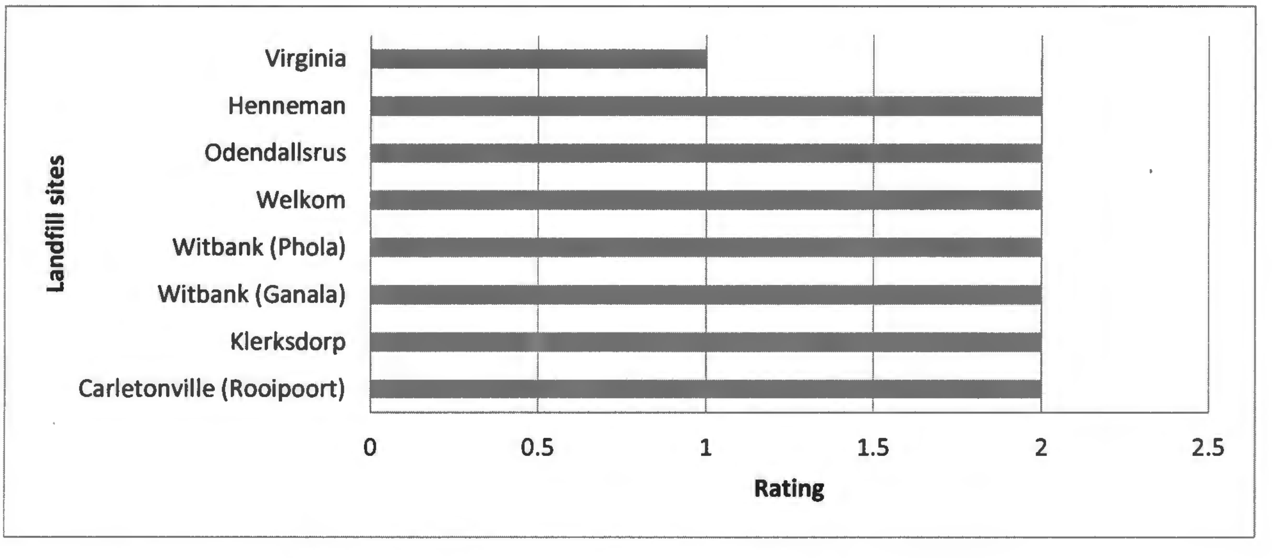


Figure 12. Ground staff rating at landfill sites in the selected areas

f) Compaction of Waste

Waste should be compacted daily to prevent animals rummaging through it. Compaction is best achieved if the waste is spread in thin layers and compacted by a purpose-built landfill compactor.

This compaction procedure is a minimum requirement at sites designated G: M, G: L and hazardous waste disposal sites. At smaller sites, where purpose-built equipment is not available, the best practicable compaction is required. All the landfill sites in the study area are compacting their wastes.

g) Daily Cover

The sanitary landfill definition specifies daily cover. It is therefore a minimum requirement that the waste be fully covered at the end of each working day. In certain instances, such as existing small or remote sites with a shortage of cover material, the Department of Environmental Affairs may allow this requirement to be appropriately amended. However the consent of the internal action plans would be necessary before relaxation could be considered. Most sanitary landfill operations are based on a series of trenches or cells which are prepared to receive the waste. In either case, the general layout must be in accordance with the operating plan. Waste is deposited in trenches or cells, spread, compacted and covered so that each day's waste is effectively isolated from the environment. As depicted in Figure 13 the Carletonville, Klerksdorp, Witbank and Virginia landfill sites are covering their waste regularly. However, the Welkom and Henneman sites are lacking as such a requirement is seldom adhered to.

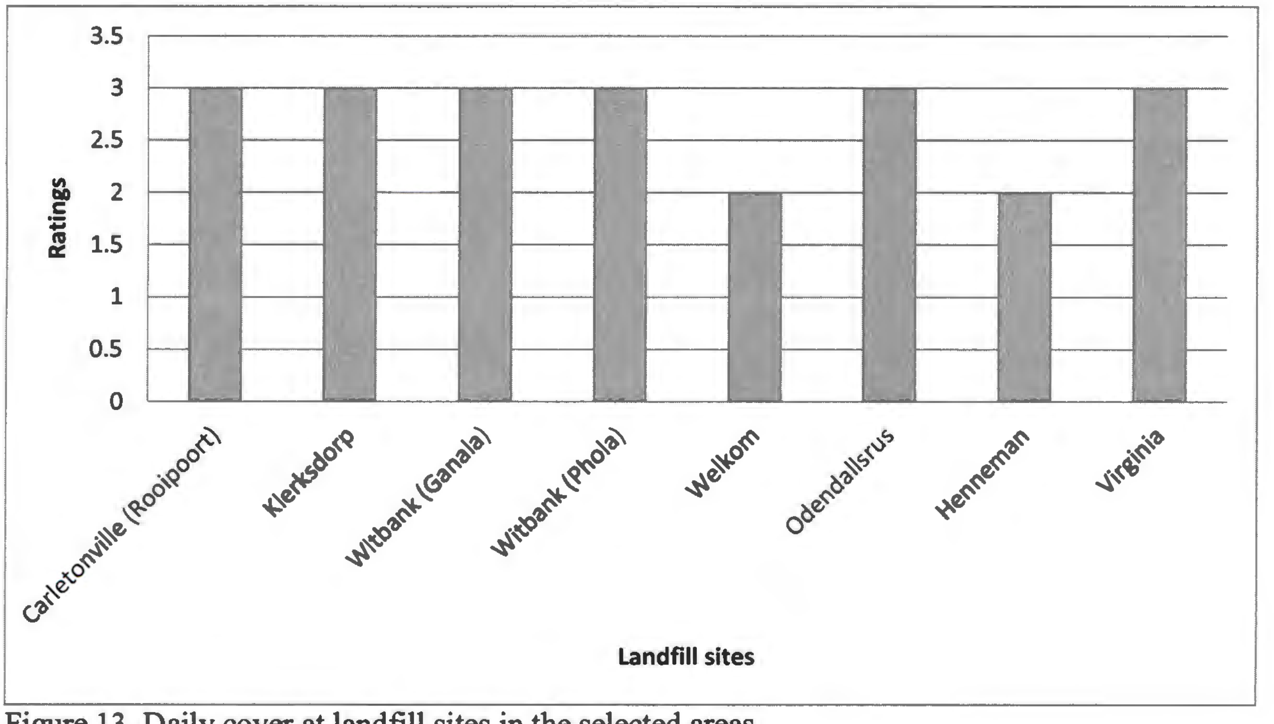


Figure 13. Daily cover at landfill sites in the selected areas

h) Trench Capacity

At designated G: C and G: S class landfill sites, where relatively small volumes of waste are disposed of, trenches are often made in preference to cells. Such trenches must be excavated on an ongoing basis during the operation. Nonetheless, this must always be done in accordance with the original design parameters and the operating plan. There must always be sufficient trench capacity on site to accommodate at least two week's waste. Trenches must always be suitably fenced or protected and off-loading must be such that persons or vehicles cannot accidentally fall into the excavation. Waste is deposited into the trench, spread and compacted as much as possible, until it reaches a depth of between 0,5m and 1,0m. With the trench method, daily covering is always a requirement, as spoil from the excavation makes this possible.

i) Protection from Unsafe Excavations

Where cover is excavated on site, the responsible person must ensure that the separation between the floor of the excavation and the wet season high elevation of the ground water, as specified in the design, is maintained. This will ensure that an adequate separation between the future waste body and the ground water will be maintained should the excavation be used for waste disposal in the future. Excavations must also be properly drained to avoid ponding of accumulated surface water, especially near the waste body. Where the base of such an excavation forms the base of the landfill, it should be sloped to direct leachate to a control point. In all cases, but particularly in the case of B+ and hazardous waste landfills, the base should also be appropriately lined. As depicted in Figure 14 the Witbank landfill sites provide adequate protection of people from the trenches. Compared to the other sites, the Virginia landfill site provides minimal protection.

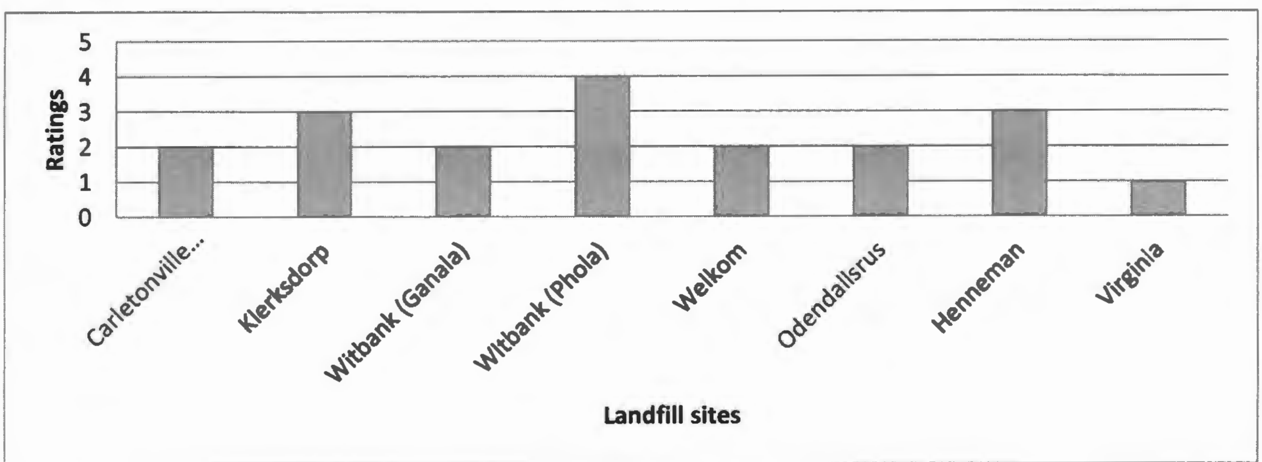


Figure 14: Protection from unsafe excavations at landfill sites in the selected areas

j) End Tipping

End tipping, which is is a method of offloading a delivery vehicle whereby the vehicle reverses onto the point of offloading and the waste is deposited of, is prohibited at all sites as this can cause the vehicle to be stuck, tipping over or causing injury or death. As can be described from Figure 15, the Carletonville and Klerksdorp landfill sites do not enforce this requirement. Witbank, Henneman and Virginia enforce and monitor this through security measures.

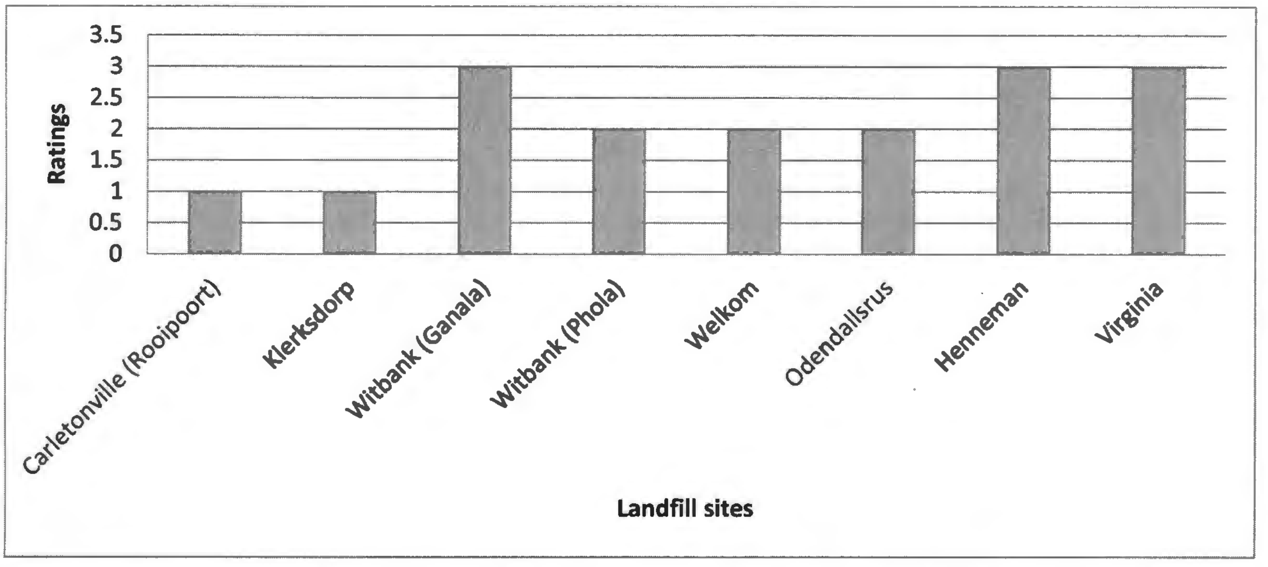


Figure 15. End tipping enforcement rating at landfill sites in the selected areas

k) Waste Reclamation and Registration

Waste in sometimes reclaimed for use by people or groups. The regulatory requirement is that in cases of this nature, the people or groups must be registered at the administration office of the local municipality. This is a mechanism for command and control at the sites

l) Protective Clothing

It is the duty of the responsible person for each site to ensure that all members posted at the site have proper protective clothing. This is in accordance to the Occupational Health and Safety Regulations. Failure to adhere to this can result in members having negative health issues. The protective clothing include face masks, gloves and the appropriate uniform. As described in Figure 16, the Odendaalsrus, Welkom, Witbank, Klerksdorp and Carletonville landfill site have procured the correct personal protective equipment for their personnel. Due to budgetary constraints the Virginia and Henneman landfill sites lack in this regard.

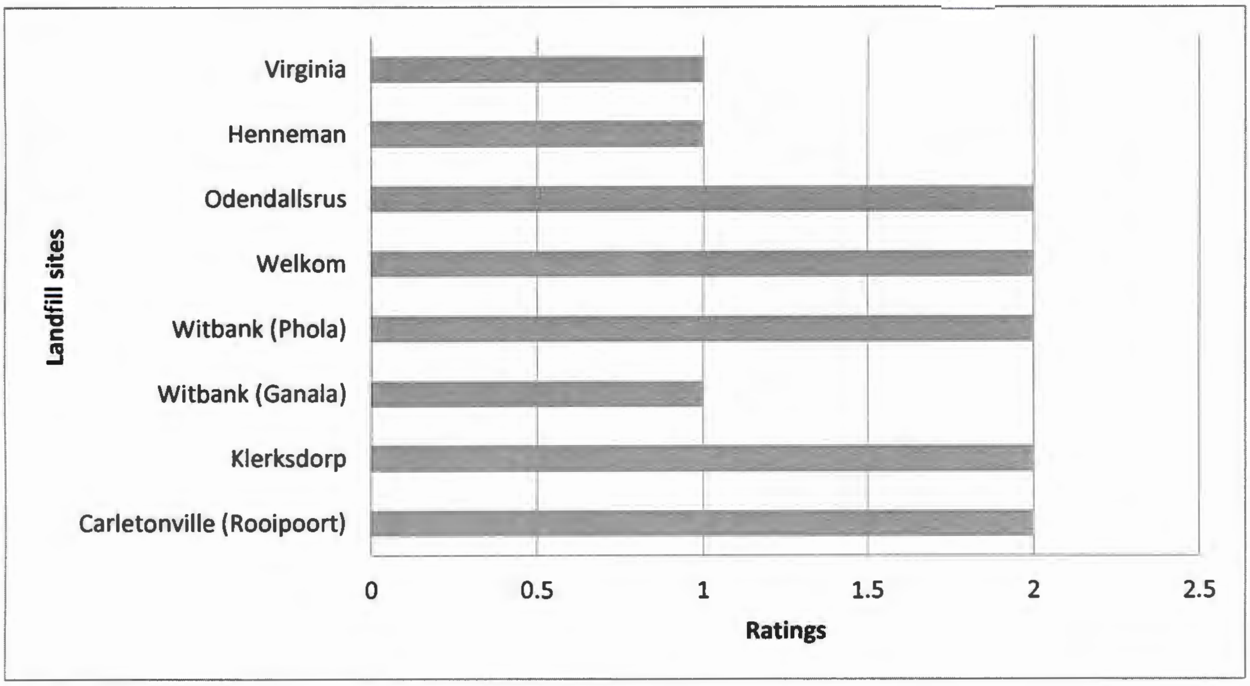


Figure 16. Protective clothing at landfill sites in the selected areas

m) Control of Nuisance

All the landfill sites seem to adhere to this requirement, that all litter be contained within the site. This may be achieved by applying the sanitary landfill principles of compaction and cover. On sites characterised by high winds, however, movable litter fences are a requirement. Windblown litter must be picked up and removed from fences and vegetation on a daily basis. Odours must be combatted by good cover application and maintenance. Furthermore, the prompt covering of malodorous waste to reduce odour problems is a requirement. In extreme cases, odour suppressants such as spray curtains may be required. All equipment used on site must conform to the local authority's by-laws concerning noise levels and hours of operation. In the absence of by-laws, national regulations on noise control must be complied with. Unsurfaced roads and areas with no grass cover or unpaved areas, which give rise to dust problems, must be regularly watered to restrict dust to levels which do not pose a nuisance to workers or users of the facility.

n) Waste Burning Prohibitions

At present, the burning of waste takes place at landfill sites to reduce the volume of waste and its attraction to vermin and livestock. However, the burning of waste is considered unacceptable because of aesthetics, odours, and the potential of health dangers from air pollution. On account of these adverse impacts, therefore, the Department of Environmental Affairs prohibits the burning of waste at landfill sites.

o) General Site Maintenance

General Site Maintenance is the responsibility of the person in charge of the site. The duty of such a person is to ensure that all procedural protocols are adhered to. The budget for maintenance is held with the waste directorates. As depicted in Figure 17, all the landfill site have general maintenance processes in place but the areas of Virginia, Odendaalsrus and Welkom lack when compared to the other areas.

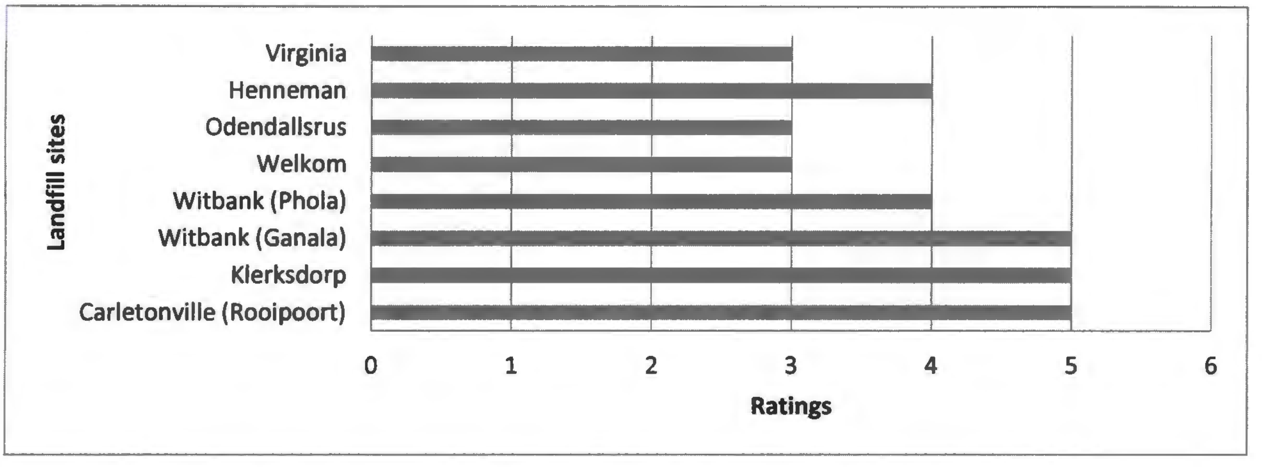


Figure17. General site maintenance at landfill sites in the selected areas

p) Sporadic Leachate Reporting

Leachate is the liquid that drains or 'leaches' from a landfill. It varies widely in composition regarding the age of the landfill and the type of waste that it contains. It is a requirement that all landfill sites report any leachate leakages. Such leakages could find its way into underground water sources and this can result in that water as unusable. So it's very important that a sporadic leakage reporting system be in place. All the landfill sites in the selected areas have such a reporting mechanism in place.

q) Landfill Gas Control

In all landfill sites, significant leachate is generated and leachate management is mandatory. The design for such sites will include a leachate management system. As with the drainage system, however, the leachate management system requires to be maintained and continuously adapted and developed, as the landfill develops. Where treatment is involved, a whole separate operating procedure must also be adhered to. This procedure would be written up in the operating plan. At B– sites, any sporadic leachate generated on account of unusual circumstances must be both reported to the Department of Environmental Affairs and properly controlled. This could also include leachate recycling. Where a gas management system exists at a site, it must be correctly operated, maintained and monitored to ensure that any landfill gas emanating from the site is properly managed.

r) Rehabilitation and Vegetation

The progressive rehabilitation of landfills by means of capping and the subsequent establishment of vegetation is a requirement. Capping, which is the process of placing a cover over the contaminated material in landfill sites, should be implemented on all areas where no further waste deposition will take place, and vegetation should commence as soon as possible. Screening berms are the first areas where vegetation must be established. This ensures that waste disposal operations take place behind vegetated berms. These are extended upwards in advance of the disposal operation to ensure continued screening. This is referred to as the rising green wall approach. As indicated in Figure 17, the Welkom landfill site has a rehabilitation programme in place where as the Carletonville and Klerksdorp have fairly adequate measure in place.

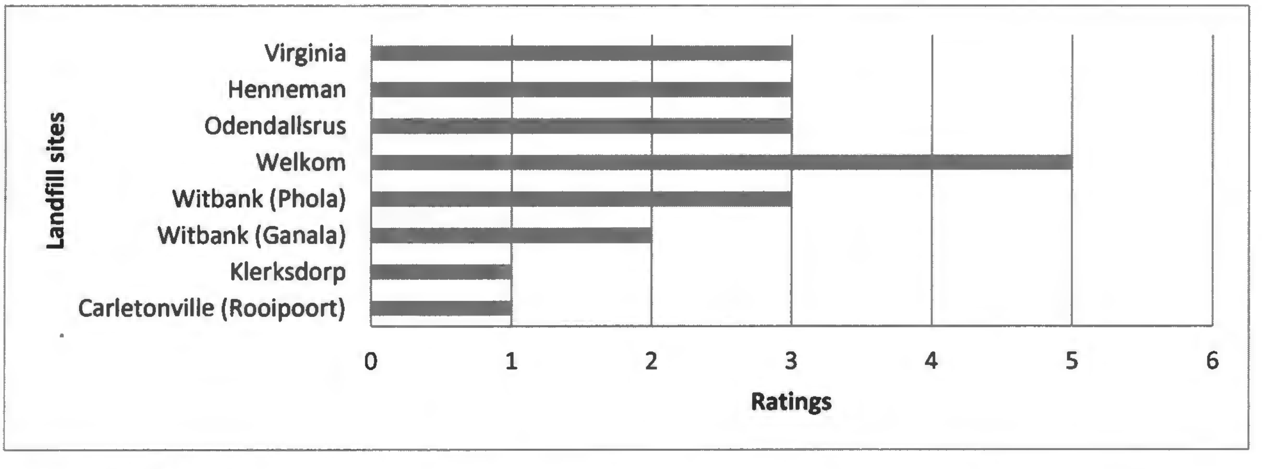


Figure 18. Rehabilitation and vegetation rating at landfill sites in the selected areas

The significance of the resources and infrastructure elements is that it provides a guideline in the proper management of the landfill sites. When auditing and inspecting these sites emphasis is placed on these elements. Any deviations can result in the permit status being revoked. A revoked status is not a good indicator for governance and can have legal implications.

3.3.4 Analysis of the Minimum Requirements

In the analysis of minimum requirements, all the landfill sites were assessed in terms of (i) facilities and resources; (ii) site controls; (iii) resource and infrastructure and (iv) landfill operations. Figure 19 is a graphical representation of the results of this analysis. The figure should be read in conjunction with Table 6 on the scoring of the minimum requirements for the landfill sites. From Figure 19 we can make a deduction that the Facilities and Resources aspects of the landfill sites are in a critical stage across the selected landfill sites in the selected areas and consequently require serious interventions from experts. For the control aspect the Witbank landfill sites is in a critical stage and the Welkom and Klerksdorp landfill sites are stable and being routinely maintained. For resources and infrastructural element intervention are required to enable the landfill sites not to drop into the critical stage. Landfill operations score fairly well and are stable. Table 6 represent a scoring sheet that should be utilised for the interpretation and understanding of Figure 19. The scores should be set against the variables on Figure 6.

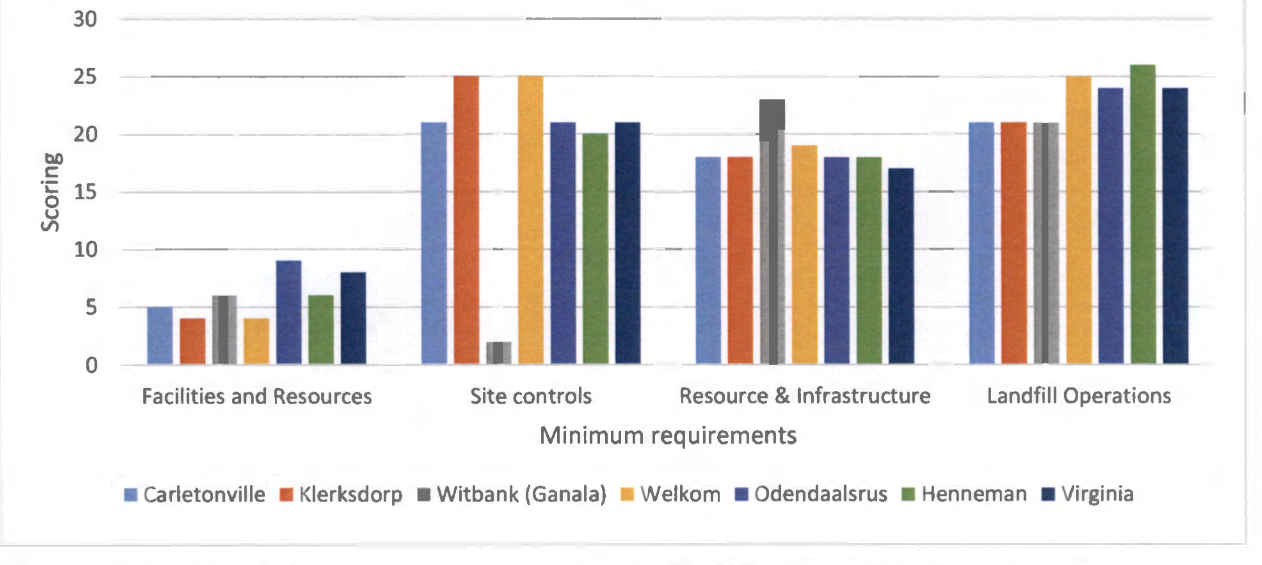


Figure 19. Scoring of the minimum requirement for landfill sites in the selected areas

Table 6. Scoring sheet

SCORING SHEET		
Score	Definition	
0-10	Critical	Requires serious interventions from subject matter experts.
10-20	Interventions required	Requires monitoring, auditing and evaluations.
20-30	Stable	Continuous and repetitive maintenance is required

The significance of data is that it provides an opportunity to intervene at those levels within the landfill sites that are not performing. Non-performing levels have serious implications in the maintenance, daily operations and the standard operating procedures of any landfill site. They can result in the mismanagement of resources, the withdrawal and the permit status and to some degree legal prosecution. With the data provided proper mechanism can be put in place to improve those negative conditions.

3.3.5 Waste

The sources of waste generation in the study areas are institutions such as schools, businesses and domestic households. Domestic waste is also derived from the different mines where the mine workers reside. This section gives a clear understanding of the amount of waste entering and ultimately leaving the landfill sites and this can be through recycling, recovering and means of thermal treatment. It is very important to indicate this data so that at a later stage assessment of what programmes have been put in place to reduce the amount of waste streams entering the sites can be done. This data also enables a better understanding of the state of our landfill sites and projections can be made whether or not these sites will be closed in the near future with respect to the landfill capacity.

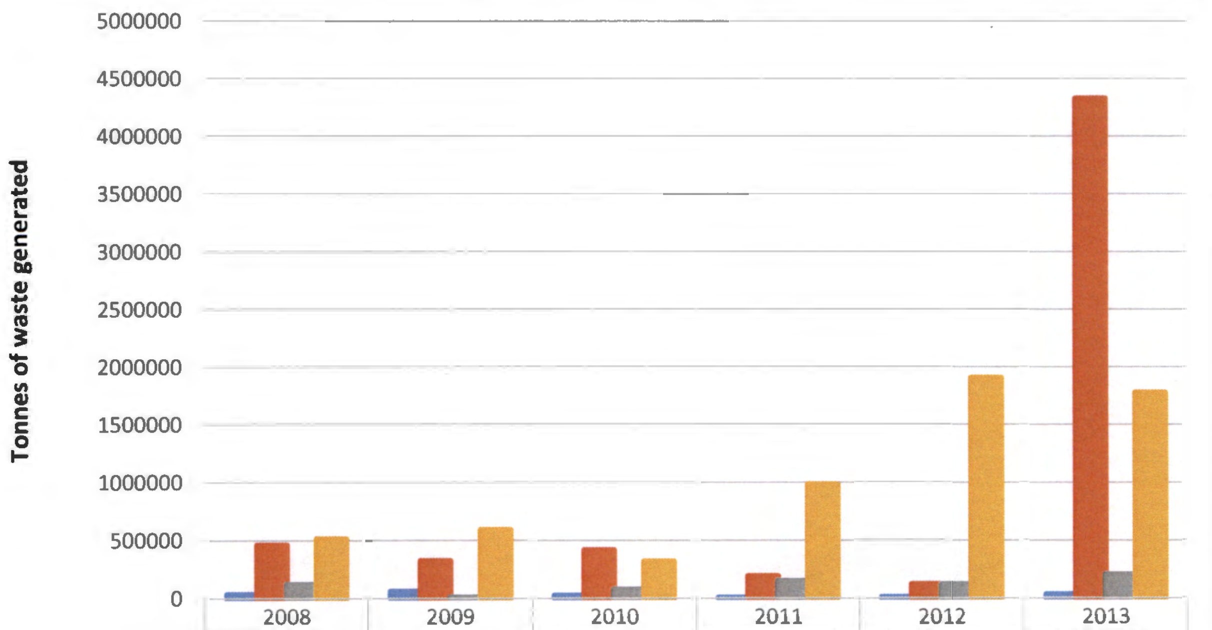
The waste generation rates were collected from weighbridges of the municipalities. At the weighbridges, vehicles are weighed at the point of entry and at the point of exit. The difference of the weight between entrance and exit provides an estimate of the mass of waste. The weighbridge operator correctly identifies the type of waste disposed of and this data is then captured into the South African Waste Information System. At some landfill sites such as Henneman in Welkom and the Phola landfill site in Witbank where weighbridges are not established, a different approach is used. This approach is to calculate the waste amount using a template developed by the DEA.

This template makes use of estimations by mass that has been based on the size of the vehicles measured in m^3. The formula used is:

Waste mass (kg) = vehicle volume (m^3) x load (tonne) x waste density (kg/m^3)

a) Waste Generation

Figure 20 shows the amount of waste generated in the selected areas from 2008 to 2013. The graph is clearly dominated by the amount of waste generated in Welkom in 2013 compared to other years and also compared to other areas considered in this study. In general, the graph shows that from 2008 to 2013, waste generation increased. The waste generated at Klerksdorp has remained relatively constant from 2008 to 2013. The Witbank area has also seen an increase of waste from 2008 until 2013 but there was a short decline in 2010. This can be attributed to the fact that a number of programmes were initiated at that time that caused a decrease in waste. Waste generation in Carletonville remained constant throughout.



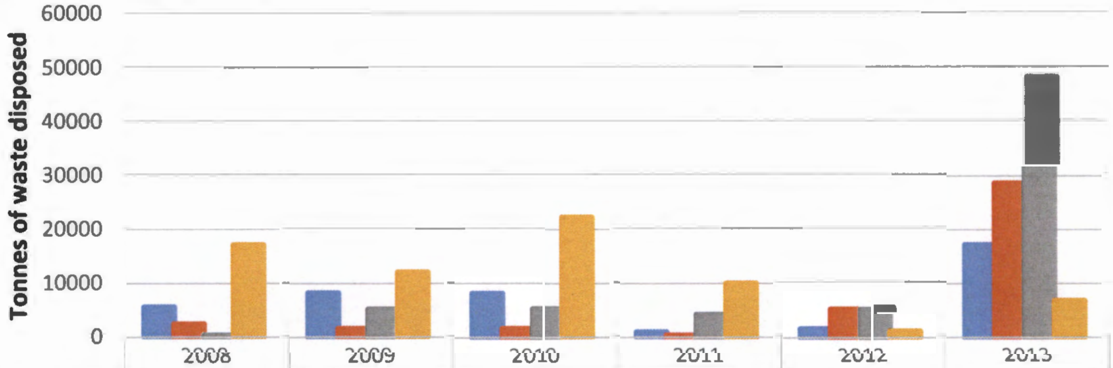
	2008	2009	2010	2011	2012	2013
CARLETONVILLE	34065	59455.1	22085	2369	5197.5	28578.9
WELKOM	458283	321168	415950	188824	118655	4322357.5
KLERKSDORP	120992	9929.3	75459.2	149010.2	118655	201474.6
WITBANK	512643.1	586896	315664	980221	1901091	1773059.3

Years

Figure 20. Waste generation for landfill sites in selected study areas

b) Waste Disposal

Figure 21 indicates that the Carletonville area had an increase of waste disposed from 2008 until 2009. There was a constant disposal between 2009 and 2010 and a decrease in disposal from 2011 until 2013. The Welkom area had an increase in waste disposal from 2011 until 2013. From 2008 until 2010 there was an increase with a drop in 2011 and 2012. For the Klerksdorp area there was an increase in waste disposed of from 2008 to 2013. For Witbank there was a decrease from 2008 to 2013. Figure 21 highlights the fact the 2012 was the year in which a higher amount of waste was being disposed of. We see that Welkom generated the largest amount of waste. Factors such as increased housing, access to basic services and the renewed efforts of the local municipality in delivering these services might have contributed to the increased waste generation. Klerksdorp and Carletonville have both respectively maintained a constant flow in waste generation from 2008 to 2013 whereas Witbank has seen an increase in waste generation from 2008 to 2013. It should be taken into consideration that the four cities in the selected areas are mining towns and that the economy of these cities are dependent on the operations of these mines. For example the closing of different shafts in a mine or even complete mine closures can lead to a decline in the income of most people that are employed there. This tends to cause less generation of waste as the affected people are less able to generate waste. Likewise the constant running and re-opening of mines and other shafts improves the income of the area and this tends to increase the waste being generated. Carletonville shows a constant generation of waste over the years.



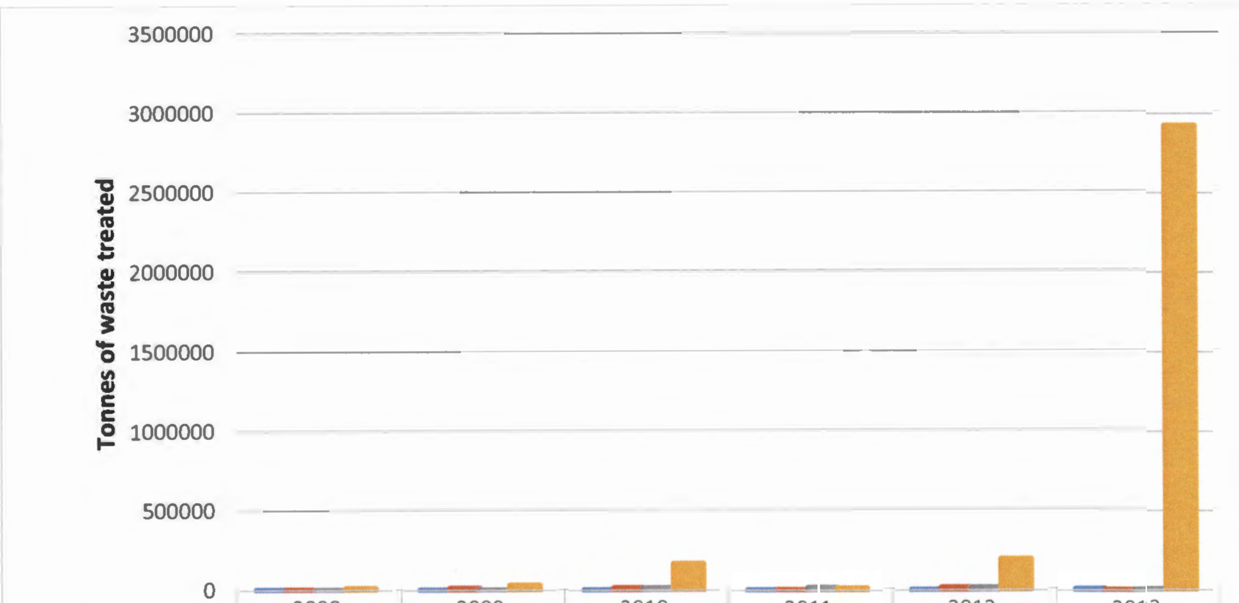
	2008	2009	2010	2011	2012	2013
CARLETONVILLE	5556	8172.5	7998	950	1598	17121.9
WELKOM	2369	1575.1	1597.9	386.3	5197.5	28578.9
KLERKSDORP	350	5201	5292.9	4207.4	5197.4	48107.4
WITBANK	17003.4	11970.6	22194.5	9920.6	1124	6767.9

Years

Figure 21. Tonnes of waste disposed in landfill sites in selected areas

3.3.6 Waste Treatment

Figure 22 shows of waste treated at the landfill sites in the selected areas between 2008 and 2013. In Figure 22 Witbank seems to be taking greater lengths in treating waste. From 2008 until 2013 greater efforts have been put in trying to reduce the waste ending up at landfill sites. The reason for this can be attributed to the fact that waste reclamation companies have been established within the area and interests in treating and recycling waste has taken over. This can also be said for the other local municipalities that have their own respectively established companies within the areas. Another point to note is that the improved numeration and monetary value in treating waste and that such markets are relatively new. There has been a decrease in the amount waste being treated at the Witbank Local Municipality between 2010/2012. It seems in 2010 there was a greater amount of waste being treated in Witbank and this could be closely associated with the fact that Witbank was selected as the host for the 2010 FIFA World Cup and efforts were made to clean up the city. The local municipalities of Welkom and Carletonville show a gradual and slow response in treating its waste. This could be as a result that only a few companies that could treat waste or recover waste were operational or established at this period in time.



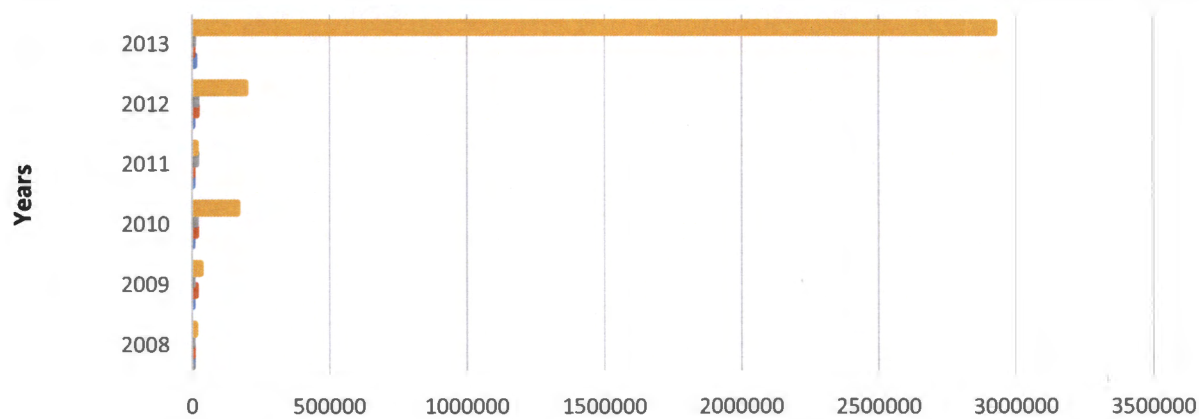
	2008	2009	2010	2011	2012	2013
CARLETONVILLE	1366	1736.7	1210	520.9	985.7	9009.1
WELKOM	991	13258	14500	1083	16558	611.2
KLERKSDORP	860	520	14500	16027	17009	5476
WITBANK	10685.5	30768.5	165242	13136.7	193947.9	2922269.7

Years

Figure 22. Tonnes of waste treated at the landfill sites in the selected areas

a) Waste Recovered and Recycled

Figure 23 is a graphical presentation of waste recovered and recycled at landfills in the selected areas over the years from 2008 to 2013. Once again, it is clear that Witbank role in recovery and recycling is much greater than the other three areas for the period 2008 to 2013. The amount of waste recovered and recycled at Witbank is also greater than any other areas for of the years from 2008 to 2013. In 2008, all the sites recovered and recycled almost the same small amounts of waste. From 2009 the amount of waste recovered and recycled at Witbank started to go up by large amounts year on year. The amounts of waste recycled and recovered by the other three sites have remained relatively stable at just over 2008 levels. The deduction from the graph is that recycling and material recovery being done at the landfill sites has greatly improved. However it is the Witbank Local Municipality that has made the biggest contribution in this aspect. This can be attributed to the fact that local businesses have taken advantage of this new market and also at the amount of waste being generated.



	2008	2009	2010	2011	2012	2013
WITBANK	10685.5	30768.5	165242	13136.7	193947.9	2922269.7
KLERKSDORP	860	520	14500	16027	17009	5476
WELKOM	991	13258	14500	1083	16558	611.2
CARLETONVILLE	1366	1736.7	1210	520.9	985.7	9009.1

Tonnes of waste recoverd and recycled

Figure 23. Tonnes of waste recovered and recycled at landfills in the selected areas

b) Sources of Waste

Figure 24 provides an analysis of the main contributors and sources of waste generation in Klerksdorp. As expected domestic waste makes up to 70% of the total waste generated in the

Klerksdorp local municipality. Electronic waste has the least amount of waste generated and this is a very unpopular waste type.

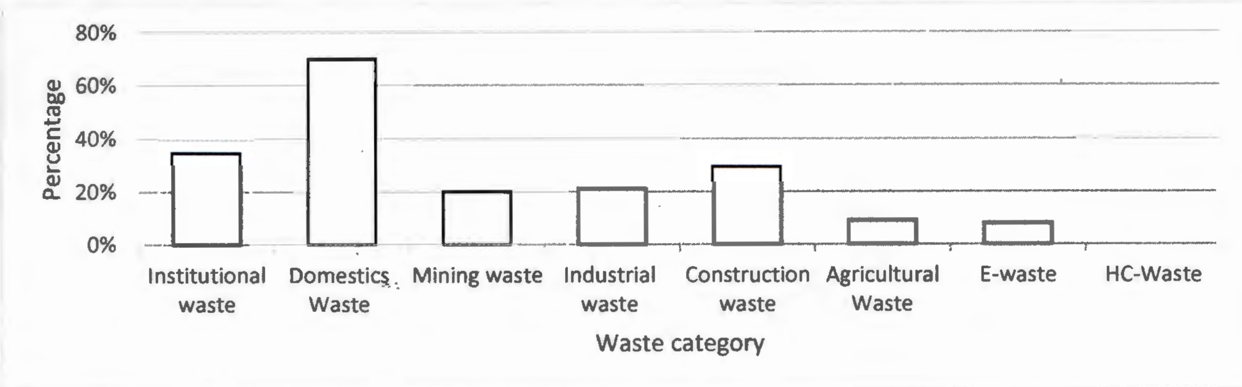


Figure 24. Sources of waste in the Klerksdorp local municipality

Figure 25 provides an analysis of the main contributors and source of waste generation in Welkom. From Figure 25 domestic waste accounts for 80% of the generated waste in the Welkom area. This is waste that has been collected weekly from different locations in the area. Institutional waste accounts for 48% of the waste. Mining waste is waste collected from the pickup slashes at the mining shafts and disposed of at the local landfill site. It is referred to as mining waste but in essence falls within the category of domestic waste. Hazardous mine waste is not accepted at landfill sites.

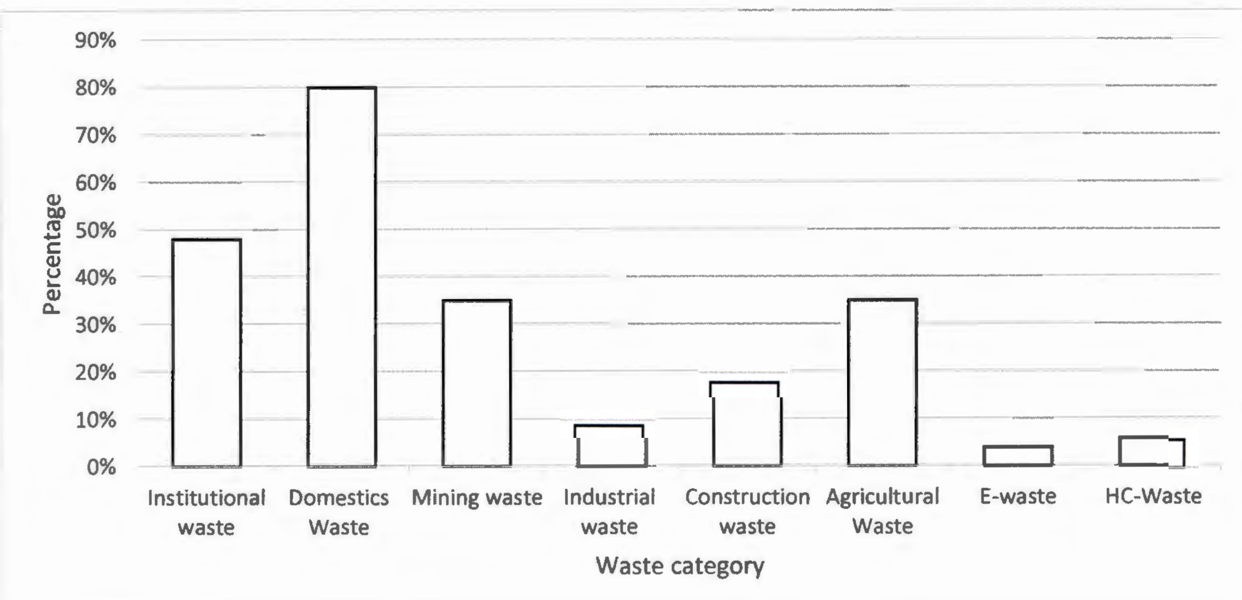


Figure 25. Sources of waste in the Welkom local municipality

Figure 26 provides an analysis of the main contributors and source of waste generation in Witbank Local Municipality. Figure 26 shows that 60% of waste generated is from institutional waste. This can be attributed to the fact that several colleges and further learning and education facilities have been established in this area. This has attracted many people aspiring for a better education. In turn this has resulted in an increase in the generation of domestic waste which is at 85% of the total waste. As a result of population increase construction waste has risen to 35% of waste generation and health care waste remains at the least source of waste at 3%.

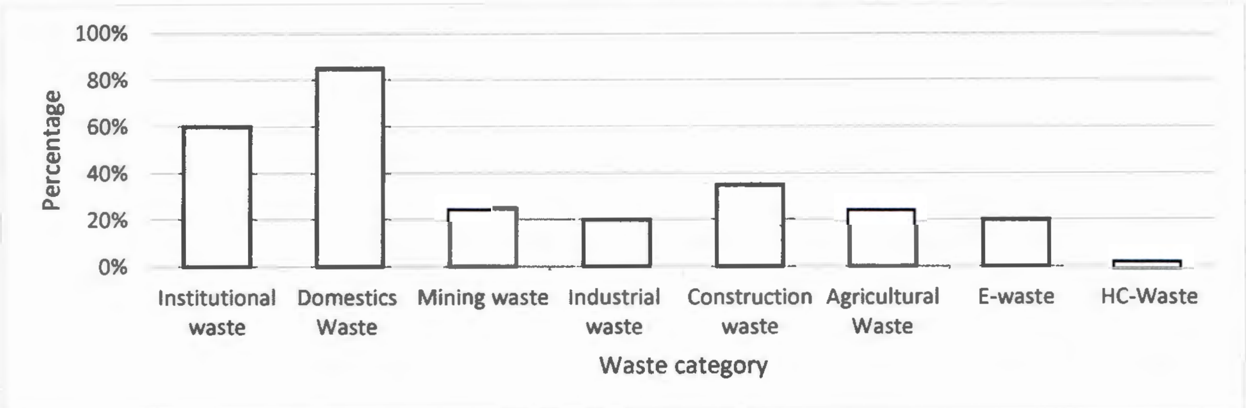


Figure 26. Sources of waste in the Witbank local municipality

Figure 27 provides an analysis of the main contributors and source of waste generation in Carletonville Local Municipality. In Figure 27, the main source of waste generation in Carletonville Local Municipality is domestic waste at 90% of the total waste. Institutional waste is 40% and for a mining town the waste generated is very low at 21%. As observed in previous Figure 26 in the case of Witbank, electronic waste and health care waste have insignificant contributions to the waste generated.

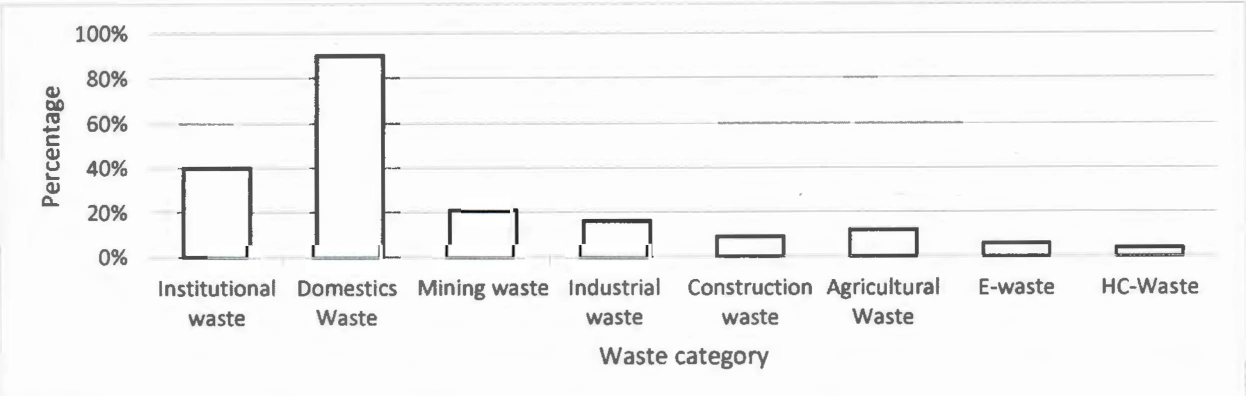


Figure 27. Sources of waste in Carletonville local municipality

Table 7 provides a significant ranking of the waste stream that is most disposed of. As depicted in the table domestic waste accounts for the most disposed of waste stream in the study areas. Health care waste is the lowest ranked. This can be as a result that many health care facilities have contracts in place where hazardous waste is being collected and treated. The significance of this comparison table is that it provides an idea as to what waste is disposed and which interventions will be suitable for this waste. This is very important because interventions need to address the most disposed of waste stream. It has been observed that in all the study areas, domestic waste seems to be the main source of waste generation.

Table 7. Significant ranking of waste types

Significant rank	Waste type	Klerksdorp %	Welkom %	Witbank %	Carletonville %
1	Domestic	36	27	28	35
2	Institutional	25	20	19	24
3	Mining	12	17	16	15
4	Construction	9	13	14	9
5	Agricultural	7	11	11	8
6	Industrial	6	8	9	6
7	E-Waste	3	3	2	2
8	HC-Waste	2	1	1	1

These are mining towns but waste generated in mines is very insignificant. The hazardous mine waste, however, is being disposed of by private companies and for the sake of this study are not taken into account as this waste does not end up in the landfill sites of the selected study areas. It was observed in the Klerksdorp Local Municipality that waste is being converted to energy at a facility was available in the area. The analysis of this section will enable provision for better methods in minimising the volume of waste delivered at each stage of the waste chain; provide means and strategies to prolong the lifespan of the landfill sites; provides alternative and/or economically beneficial utilisation of re-usable waste within the secondary city; informs waste diversion from landfill strategies in secondary cities and to assist secondary cities in decision making regarding alternatives to waste disposal at landfill.

3.3.7 Landfill Site Characterisation

The survey for landfill site characterisation was conducted with regards to the general characteristics of landfill sites, as stipulated by the Department of Water Affairs and Forestry and the Department of Environmental Affairs. These elements formed the base line for the survey. It is to be noted that this was a normal routine survey and not an audit. Table 8 was designed in such a way to provide a standard platform to satisfy each area surveyed and the results were captured in the accompanying Table 8.

Table 8: General characteristics of landfill sites

CLASSIFICATION SYSTEM								
LEGEND 1 Very Low 2 Low 3 Moderate 4 High 5 Very High	Carletonville - Klerksdorp - Witbank				Welkom-General Waste			
	Carletonville (Rooipoort)	Klerksdorp	Witbank (Ga-Nala)	Witbank (Phola)	Welkom	Odendaalsrus	Henneman	Virginia
LANDFILL CLASSIFICATION STATUS	G:M:B	G:S:B	G:M:B	G:M:B	G:S:B	G:M:B	G:M:B	G:MB
Lifespan of the site (yrs.)	25	30	15	15	25	15	15	15
Carrying capacity of the site (m^3)	1500	2000	200	1500	750	180	150	135
Size of the landfill sites (hectares)	5	15	21	5	9	4	9	13
**Estimated life span remaining(yrs.)	9	8	4	3	4	5	4	3
Rate of disposition (ton 000'/annum)	1502	15425	852	1236	2365	1256	998	475
Rate of treatment (ton/annum)	235	458	125	568	129	875	123	98
Rate of recycled (ton/annum)	129	985	98	452	95	68	99	123
Number of boreholes	1	2	1	1	1	1	1	1
Site water balance (m^3)	4.2	9.8	4.3	6.9	8.6	7	4.5	7
Air quality volume(m^3)	2.3	1.2	2.3	2.3	1.3	3	0.9	0.5
Climatic water balance								
Annual rainfall (mm)	390	380	510	530	370	391	360	380
Available air-space (%)	1.2	0.9	1.6	0.98	1.3	0.2	0.5	0.6
Annual airspace utilization (%)	0.9	0.4	0.9	0.006	0.89	0.08	0.0	0.0
Average rainfall(%)	1.9	2.3	1.3	1.2	0.9	0.8	0.9	0.7
Water Quality Monitoring	4	4	1	4	3	5	2	3
Leachate detection systems	2	4	5	3	5	2	3	3
Management and monitoring systems	3	2	3	4	3	2	3	3
Gas management and monitoring	1	1	2	2	1	1	1	1
Erosion control measures	3	3	3	4	3	3	3	3
Compliance:								
Quality control programme	2	3	2	1	1	2	3	2
Conservation of natural resources and environmental requirements	3	2	4	2	1	2	2	2
Compliance with occupational health and safety	3	3	3	3	3	3	3	3
End use design	4	4	4	3	3	4	4	3
Landscaping	2	2	2	2	2	2	2	2

Permanent storm water diversion	2	2	3	2	3	2	2	3
Anti-erosion measures	P	2	3	3	2	2	2	3
Leachate management	1	1	1	1	1	1	1	1
Gas management	2	2	2	2	2	2	2	2
Inspection and maintenance	3	3	3	3	3	3	3	3

Table 8 provides an estimated lifespan remaining for each of the selected study areas and on average the estimated life span is about 8 years for each of the sites. When a comparison is made between the estimated lifespan remaining to the rate of deposition, the rate of treatment and the rate of recycling should be equal to deposition but deposition is higher which would indicate that the site will fill up sooner than it's expected lifespan. However this provides an opportunity to implement initiatives and programmes aimed at minimising the rate of disposal. The ultimate output of the model is to prolong the lifespan of these landfill sites and provides alternatives in minimising waste from entering the sites. It is also very important to have an idea when a landfill site will reach its life span as this will enable better planning for new sites. In the meantime, mechanisms for reducing waste entering these sites need urgent attention.

a) Life Span

Figure 28 depicts the life span of the selected landfill sites in the study area. From figure 28 Carletonville appears to be the oldest landfill site whereas Klerksdorp appears to have the most recently constructed landfill sites. The sites of the Witbank, Welkom, Odendaalsrus, Henneman and Virginia study areas appear to have the same lifespan.

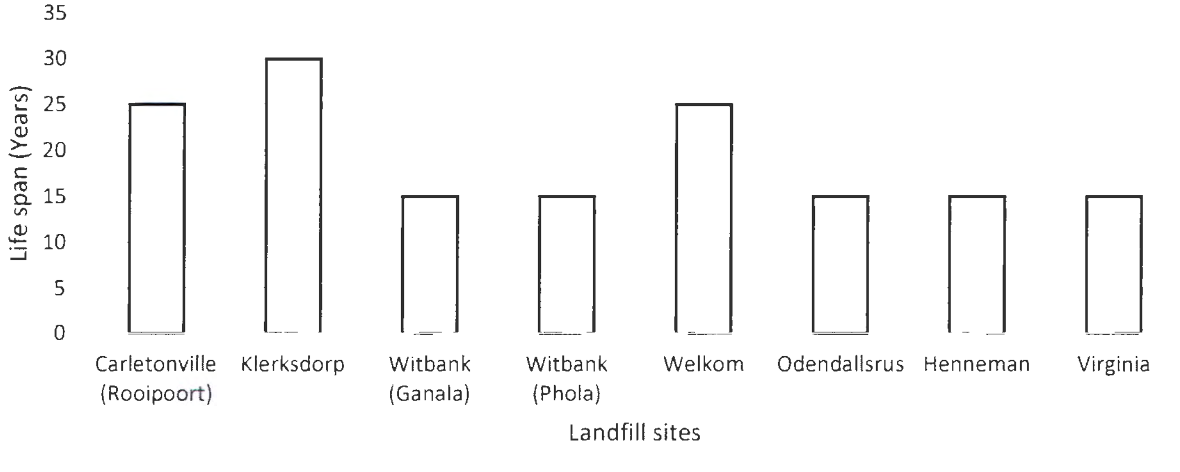


Figure 28. Life Span of the landfill sites in selected areas

b) Carrying Capacity

Figure 29 shows the carrying capacity of the landfill sites in the selected areas. The carrying capacity of the Klerksdorp LM site is 2000m^3 while that of Carletonville and Witbank (Phola) are lower at 1500m^3 each. Welkom comes next at about 750m^3 followed by Witbank (Ga-Nala) at about 200m^3 and lastly Virginia at 135m^3 capacity qualifies as the smallest of them all. The Virginia landfill site is the smallest landfill sites as compared to the Klerksdorp (2000m^3) landfill site. The others are Henneman with capacity of 150m^3 and Odendaalsrus at 180m^3.

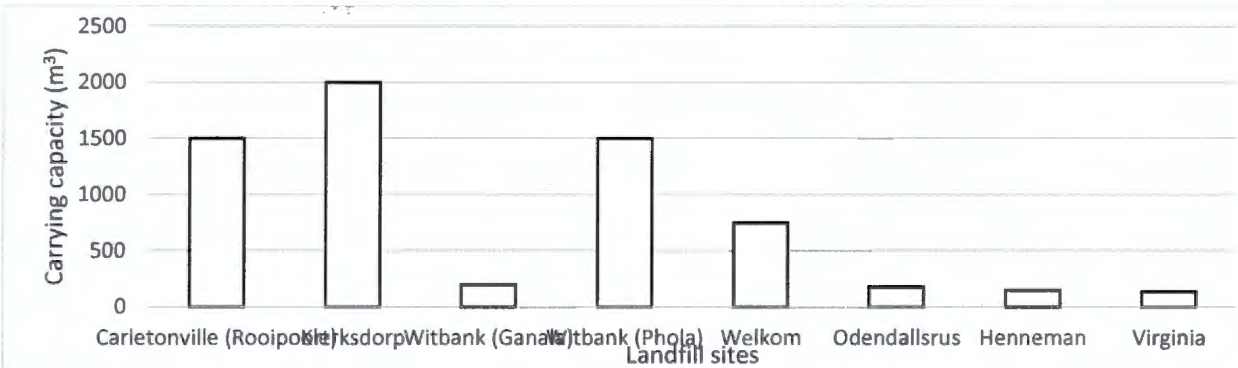


Figure 29. Carrying capacity of landfill sites in selected areas

c) Size of the Landfill

The size of the landfill includes the surrounding areas that encompass the landfill site. This includes the office space, parking bay areas and reserved land for future expansion of the sites. It does not necessarily include the landfill itself. As depicted in Figure 30, the Witbank Ga-Nala landfill has the largest proportion of land compared to its relative carrying capacity. This could be that future expansion of the site has been envisaged. The Phola, Odendaalsrus and Carletonville landfill sites have the smallest landfill sizes.

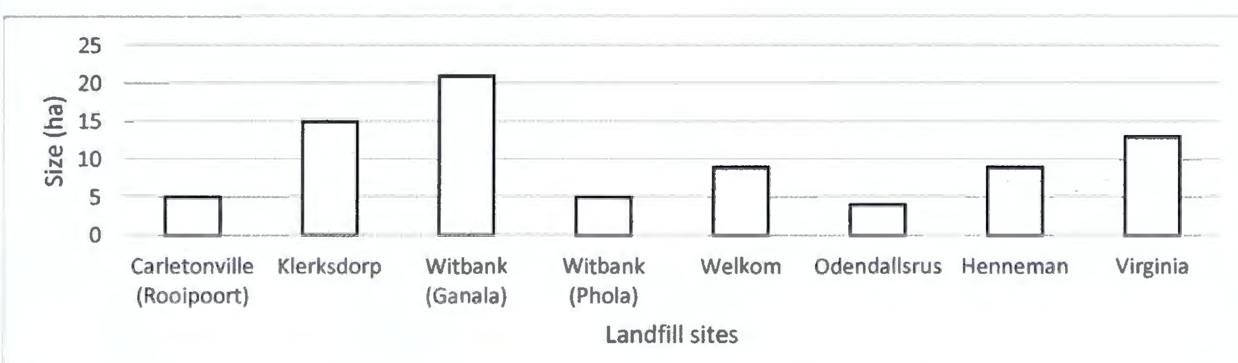


Figure 30. Size of the landfill sites in selected areas

d) Estimated Landfill Site Remaining

Figure 31 shows the estimated landfill site remaining lifespan for each site in the selected areas. The estimated life span remaining is an indication as to how long the site has before reaching its carrying capacity. This is a very important factor as the proposed model seeks to address this issue by prolonging the life span of a site. As depicted in Figure 31 Carletonville has the most years remaining before reaching its lifespan. Klerksdorp and Odendaalsrus need to put in measures in place for closure and reopening of landfill sites. The Witbank and Virginia landfill sites have fewer than 4 years remaining before reaching their carrying capacities.

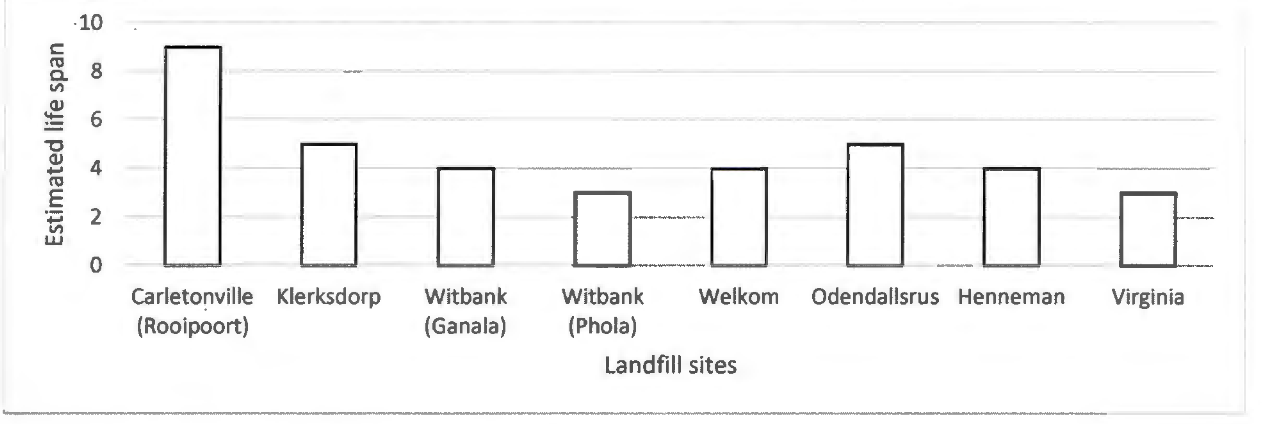


Figure 31. Estimated landfill site remaining

e) Number of Boreholes

The number of boreholes that a site has is an indication of its ability to provide its own water. It helps to relieve pressure from the local municipality in providing water supply to these sites. As depicted in Figure 32 the Klerksdorp landfill site has two boreholes and it was observed that the other site only have one borehole each.

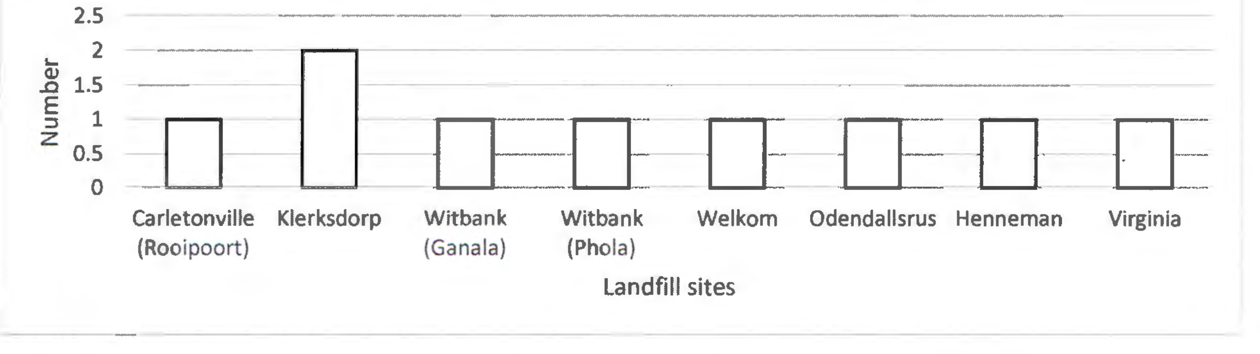


Figure 32. Number of boreholes in the landfill sites in selected areas

f) Site Water Balance

At every site, usable water should not be affected by leakages from the landfill site. The responsible person should ensure that the site water balance is well maintained. Figure 33 shows the water balance at the landfill sites in the selected areas. For the Klerksdorp, Welkom and Virginia landfill site, the site water balance is very high and the proper process should be activated to minimise this. From Figure 33 can be observed from the Witbank landfill site where the site water balance is being monitored and remedial actions taken when they reach a high point.

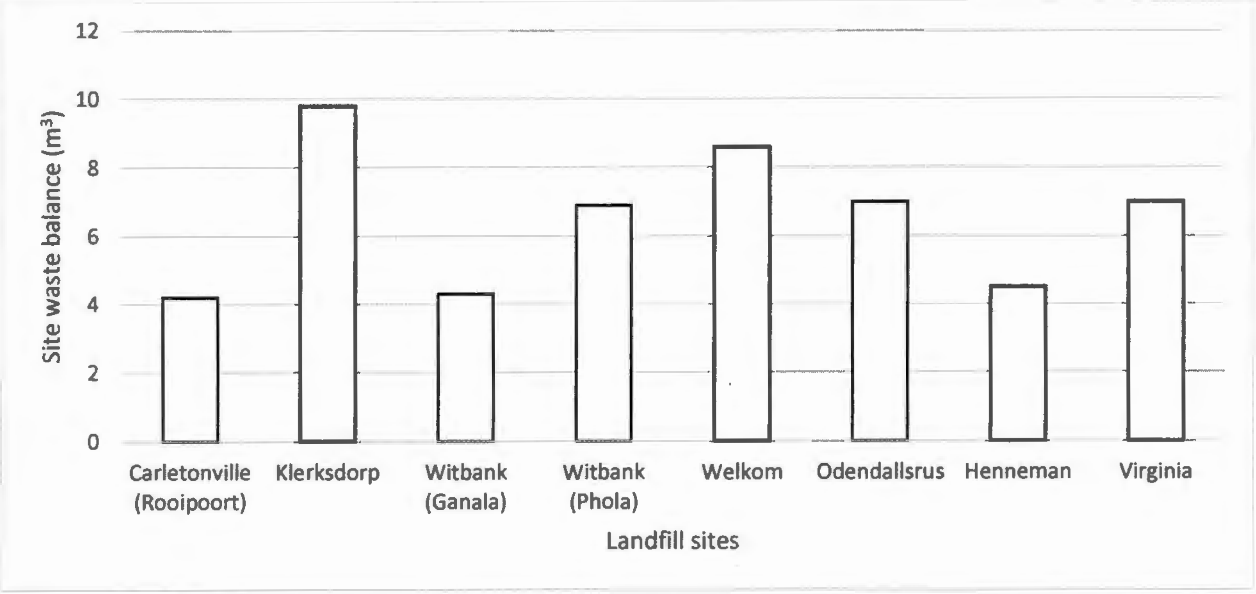


Figure 33. Site water balance at landfill sites in selected areas

g) Air Quality Volume

Figure 34 shows the air quality by volume for each of the landfill sites in the selected areas. Indirectly, the figure represents the process of waste decomposition whereby gases, collectively referred to as landfill gases, and are generated. Landfill gas is typically malodorous and usually comprises a major component of methane, generated in the methanogenic phase of waste decomposition. Where methane concentrations reach between 5% and 15% of atmospheric air, landfill gas becomes an explosive hazard, as well as a potential health risk. The responsible person must be aware of the problems associated with landfill gas and must ensure, during the site investigation, that there is no way in which gas can migrate from the landfill site under consideration to a structure where it could accumulate and represent an explosion hazard. As depicted in Figure 34, the area with the highest air quality volume is Odendaalsrus, with Virginia experiencing the lowest air quality volume. Carletonville and the Witbank areas have the same average air quality volume ranges.

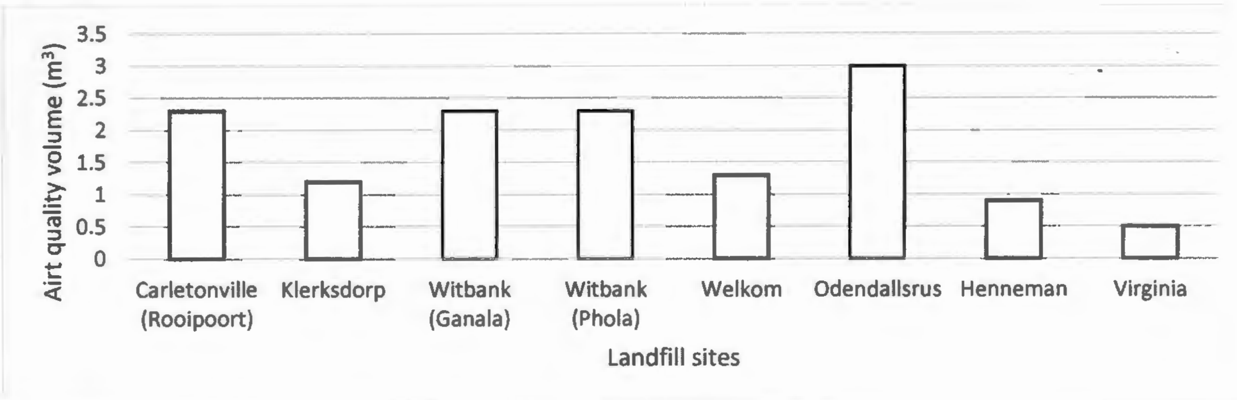
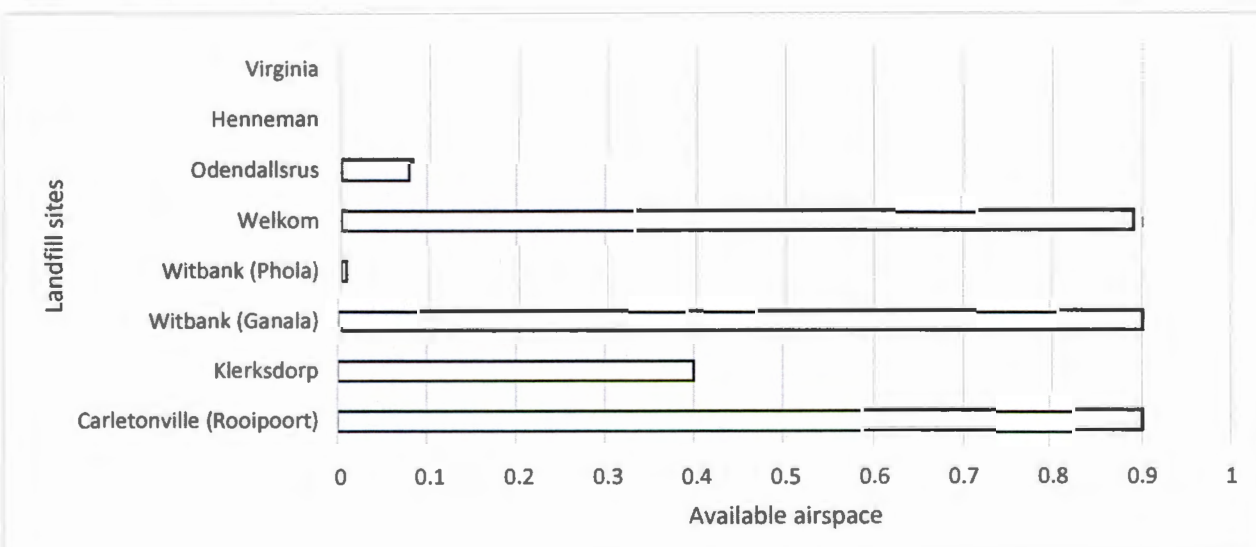


Figure 34. Air quality by volume at landfill sites in selected areas

h) Available Airspace

The potential volume or airspace of a site is calculated first by quantifying the volume of cover material available and then by applying a cover to waste ratio of between 1:4 and 1:6 by volume to arrive at the total airspace. This means that for every $1m^3$ of cover available, between 4 and $6m^3$ of compacted waste can be disposed of. Cover availability is thus a major factor determining the air space at a given site, if it is to be operated in accordance with sanitary landfill principles. As depicted in Figure 35 the Carletonville, Welkom and Klerksdorp areas have the highest amount of available air space.

Figure 35. Available airspace



i) Leachate Detection Systems

Leachate management is not necessary at B landfill sites, provided that they are properly designed and operated. However, if this is not the case, and significant leachate is generated as a result of poor drainage or the disposal of high moisture wastes, it must be detected as soon as possible. As depicted in Figure 36 Welkom and Witbank have adopted the leachate detection system. Carletonville and Odendaalsrus do not adhere to the detection of leachate protocols.

Figure 36. Leachate detection systems

j) Management and Monitoring Systems

Although landfill gas has been recognised as a source of odour and as a potential explosion hazard, few gas management systems have been constructed in Southern Africa to date. Most of those that have been constructed have been designed to extract gas by applying suction to a system of perforated pipes within the landfill. Such active gas extraction significantly reduces the odour problem and the potential explosion hazard. Figure 37 shows the rating of management and monitoring systems at landfill sites in the selected areas. The higher the rating, the better the management and monitoring systems installed at the site. Form Figure 37, Witbank places more emphasis of the management and monitoring systems than the other sites. However, the other landfill sites also have some management and monitoring system in place.

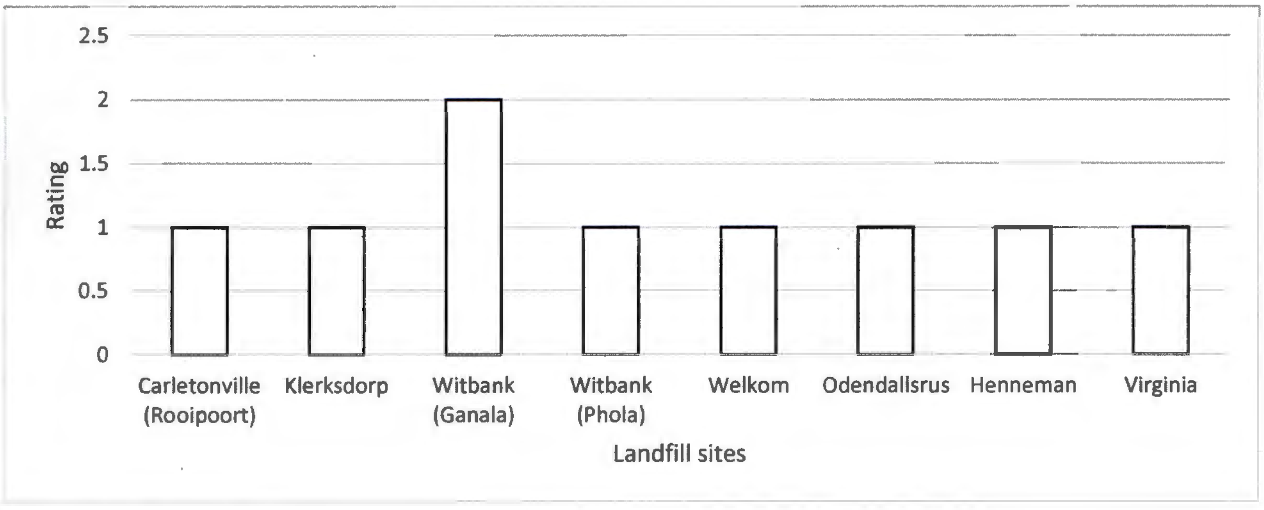


Figure 37. Management and Monitoring Systems

k) Gas Management and Monitoring

Passive gas management may also be used to achieve cheaper gas management. This may include the construction of impervious migration barriers adjacent to the landfill and passive venting from boreholes and perforated pipes within the landfill. The resultant gas may be flared or passed through filters to remove odour. If there is a need for gas management, the system and its design specifications must be agreed with the Department of Environmental Affairs prior to construction. According to Figure 38 Witbank has the highest outcome of gas management and monitoring systems as compared to the other landfill sites which are constant.

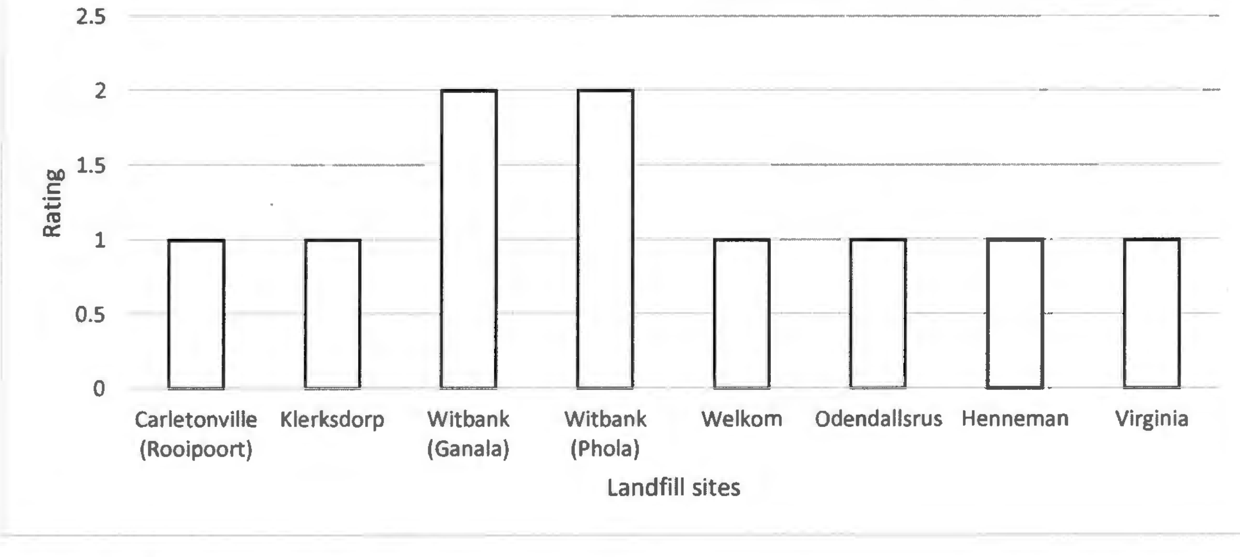


Figure 38. Gas management and monitoring

l) Erosion Control Measures

Soil slopes can erode very severely through the action of both wind and water. The outer slopes of a landfill should be equipped with crest walls and storm water channels to prevent water from cascading down the slopes from the next horizontal top surface. Outer slopes should be made as flat as possible and should not have an uninterrupted length along the slope exceeding 20m. Wherever possible, the length of an outer slope should be broken into shorter lengths by incorporating berms or step-backs. The storm water channels to which surface water flow on slopes should be directed must be paved or armoured. The channels are laid on the completed surface of the landfill by grading the surface towards the drains. Berms on outer slopes should also be provided with collection drains where it is necessary to drain water down a slope, e.g. to drain the top surface of the landfill. The surface between drains should be stabilised.

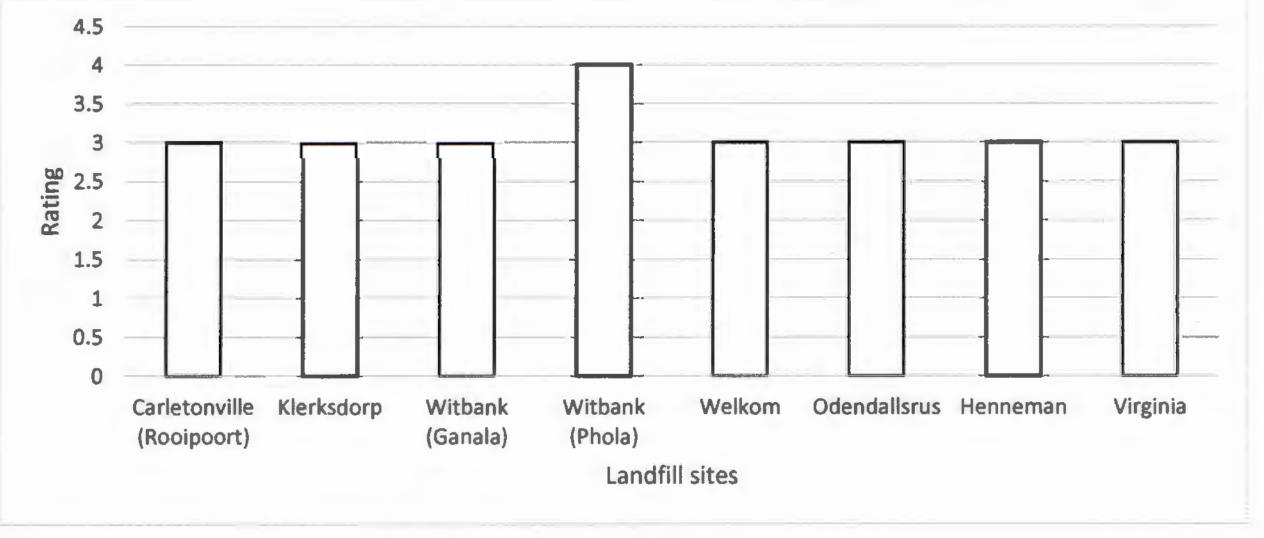


Figure 39. Erosion control measures

m) Quality Control Measures

Prior to the commencement of any construction, the responsible person shall provide the contractor with the quality control programme for all activities to be carried out on the site. The programme, together with independent checks carried out by the responsible person and the Department of Environmental Affairs, shall be sufficient to ensure conformance with the design, specifications and drawings. The correctness of the facility and the quality of the construction must be attested to by the responsible person on completion of the construction activities. As depicted in Figure 40 all the landfill sites have proper erosion control measures in place.

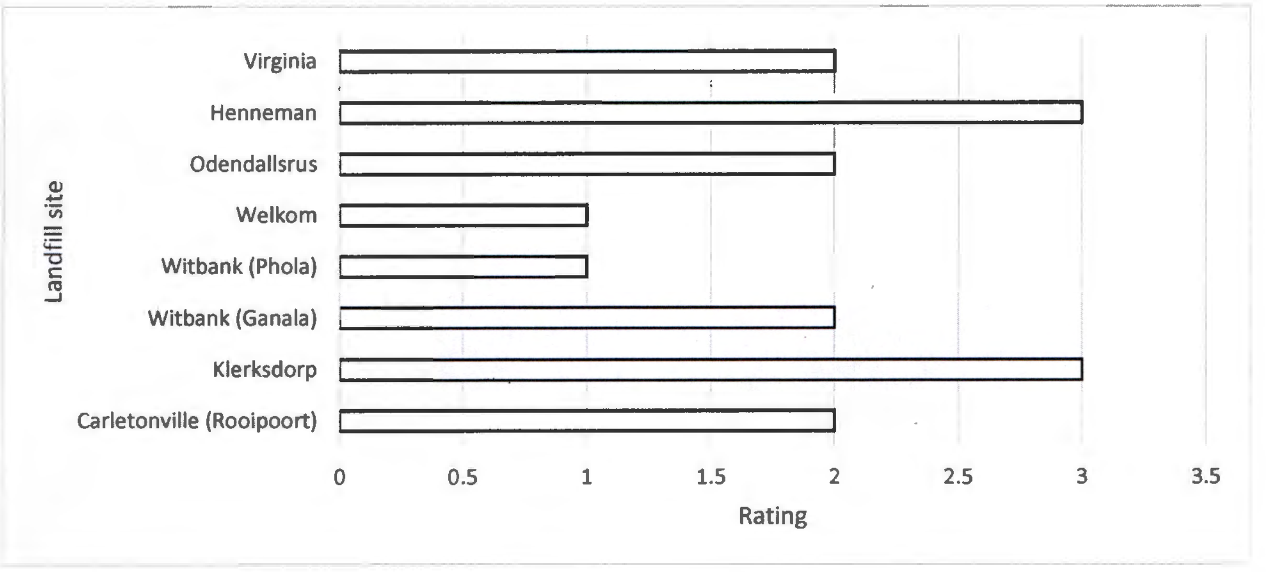


Figure 40. Quality control measures

n) Conservation

The contractor must conform to the environmental requirements of the site and the design at all times during the preparation of the landfill site facility. The minimum of disturbance to the local flora and fauna, as well as the generation of minimum nuisance, must be ensured. Natural resources, such as topsoil and general cover, shall be stockpiled and maintained for future use where necessary and as directed by the responsible person. As depicted in Figure 41 Witbank is implementing conservation measures whereas Welkom has the least measures in place. The areas of Odendaalsrus, Henneman and Virginia have the same measures in place.

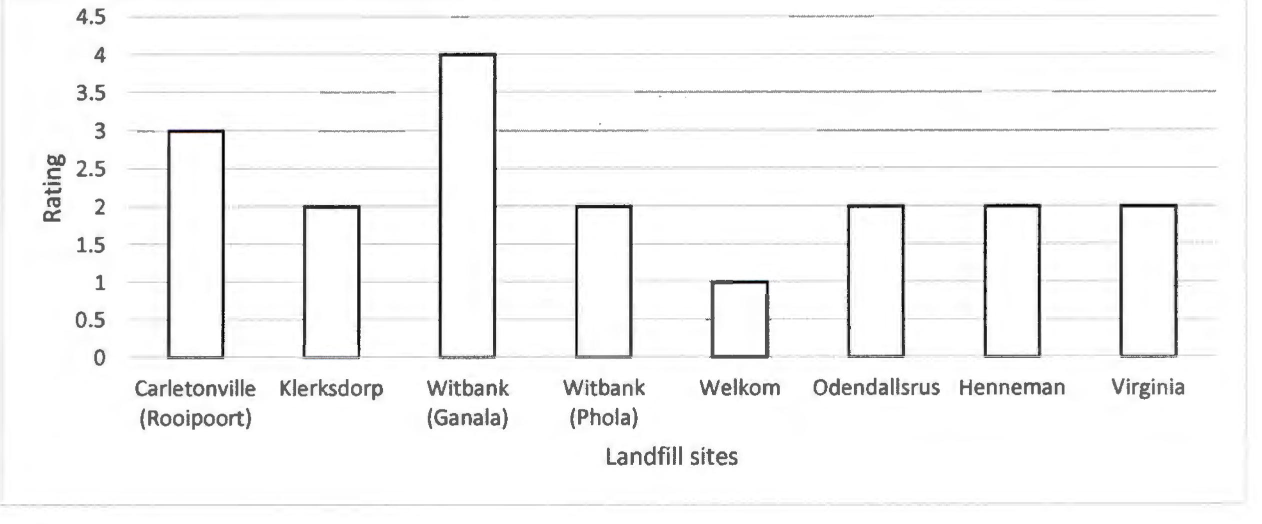


Figure 41. Conservation

o) End-Use Design

The end-use of a landfill refers to its after-use, that is, how it will be developed after closure, to fit into the environment. The most common landfill end-use is open space, which may be used for sport and recreation. Other end-uses also exist and will be accepted if they are safe. Only approved structures will, however, be permitted on top of or adjacent to a closed landfill, because of the problem of on-going settlement and the possible generation of methane gas. No public access will be permitted onto closed hazardous waste landfills, because of the hazardous nature of the wastes contained therein. This must be clearly indicated by signposting. In exceptional circumstances, where very conservative designs are involved, however, relaxations may be motivated and considered.

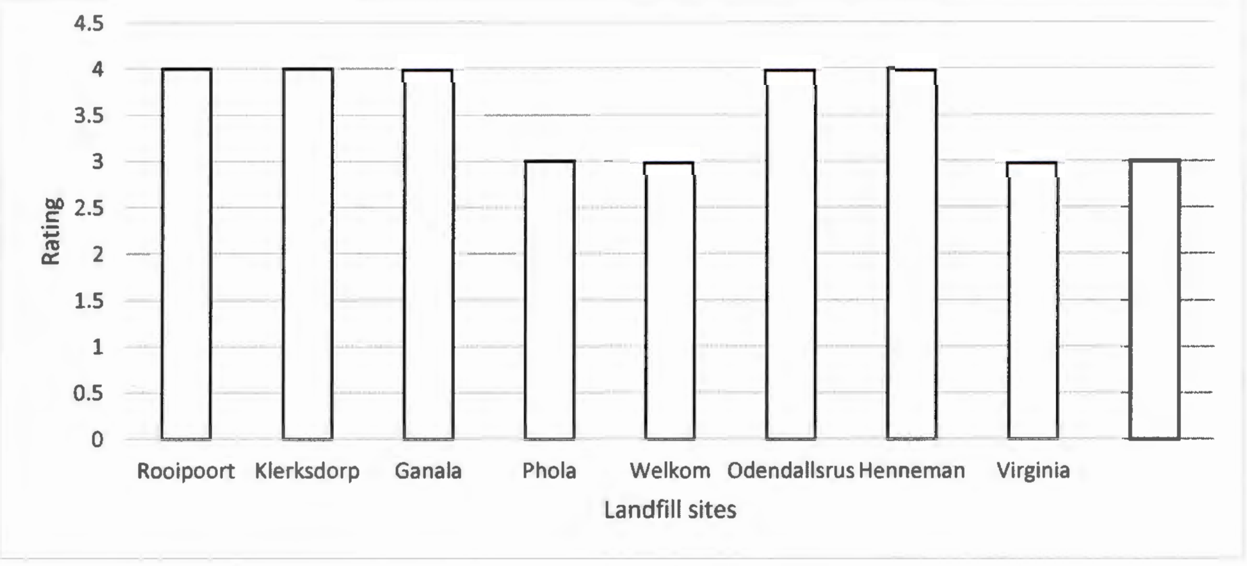


Figure 42: End use design

p) Permanent Storm Water Diversion

During the site investigation, surface water quality in any associated drainage feature is monitored both upstream and downstream of the proposed landfill. Sampling points must be selected at representative, easily identified sites. While a single upstream sampling point may suffice, the size and complexity of the site, that is, its class, will determine the number of downstream sampling points required. The sampling points upstream of the proposed landfill will provide ambient background values. The sampling points downstream of the proposed landfill will ultimately indicate any pollution resulting from the site.

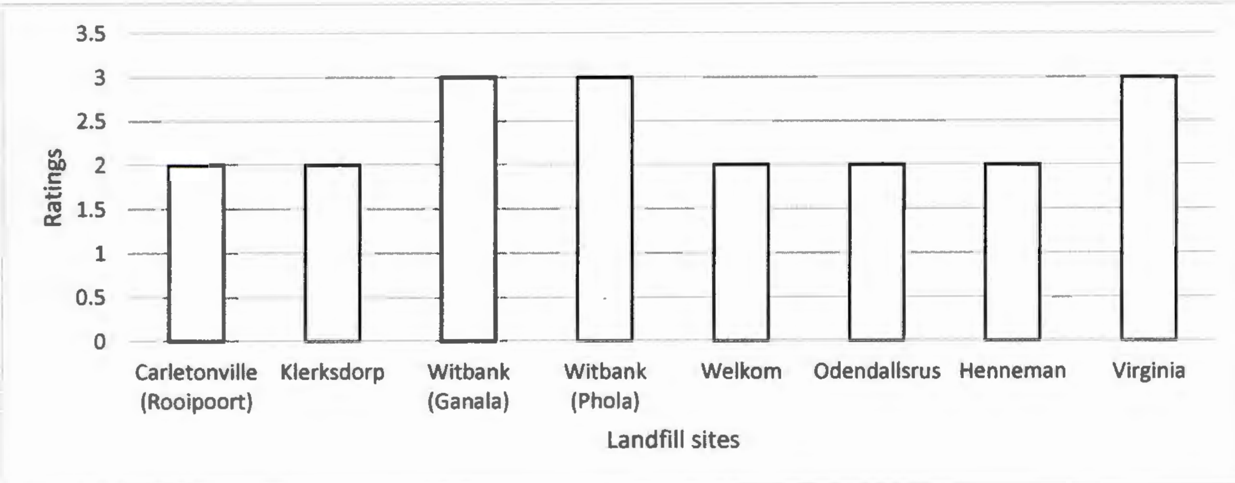


Figure 43: Permanent storm water diversion

q) Inspection and Maintenance

The long-term environmental impacts, public health, safety and nuisance problems associated with a landfill may persist long after the site has been closed. Ongoing inspections and maintenance are therefore required after site closure to ensure that such problems do not continue unidentified and unabated, and that the end-use design is properly implemented. Ongoing inspections must be carried out at regular intervals to monitor cover integrity, subsidence, fires, vegetation, drainage, erosion, and any other aspects of the closed site which could cause nuisances. Post-closure water quality monitoring must also take place. The inspections will be carried out at six or twelve monthly intervals, as specified in the minimum requirements.

3.3.8 Closure of Landfill Sites

Before final closure, the site must be inspected by officials to determine whether closure should be permitted. Should further rehabilitation measures be required, the permit holder will be duly informed of this in writing. A site will only be considered closed once closure has been authorised by the department. The permit holder will remain responsible for monitoring the landfill for up to 30 years after closure. This period may, however, be shortened or extended at the discretion of the department. Should fires, exposure of decomposing waste as the result of erosion, or other problems develop on the closed landfill, the permit holder will still be responsible and will have to undertake remedial action to rectify such problems. Figure 44 merely to highlight the necessary procedures if such an event occurs and this did not happen throughout the course of this study.

Closure is the final step in the operation of a landfill as depicted in Figure 44 In order to close a landfill properly however, closure must be preceded by rehabilitation to ensure that the site is environmentally friendly.

Applying the Minimum Requirements to the Closure of Landfills

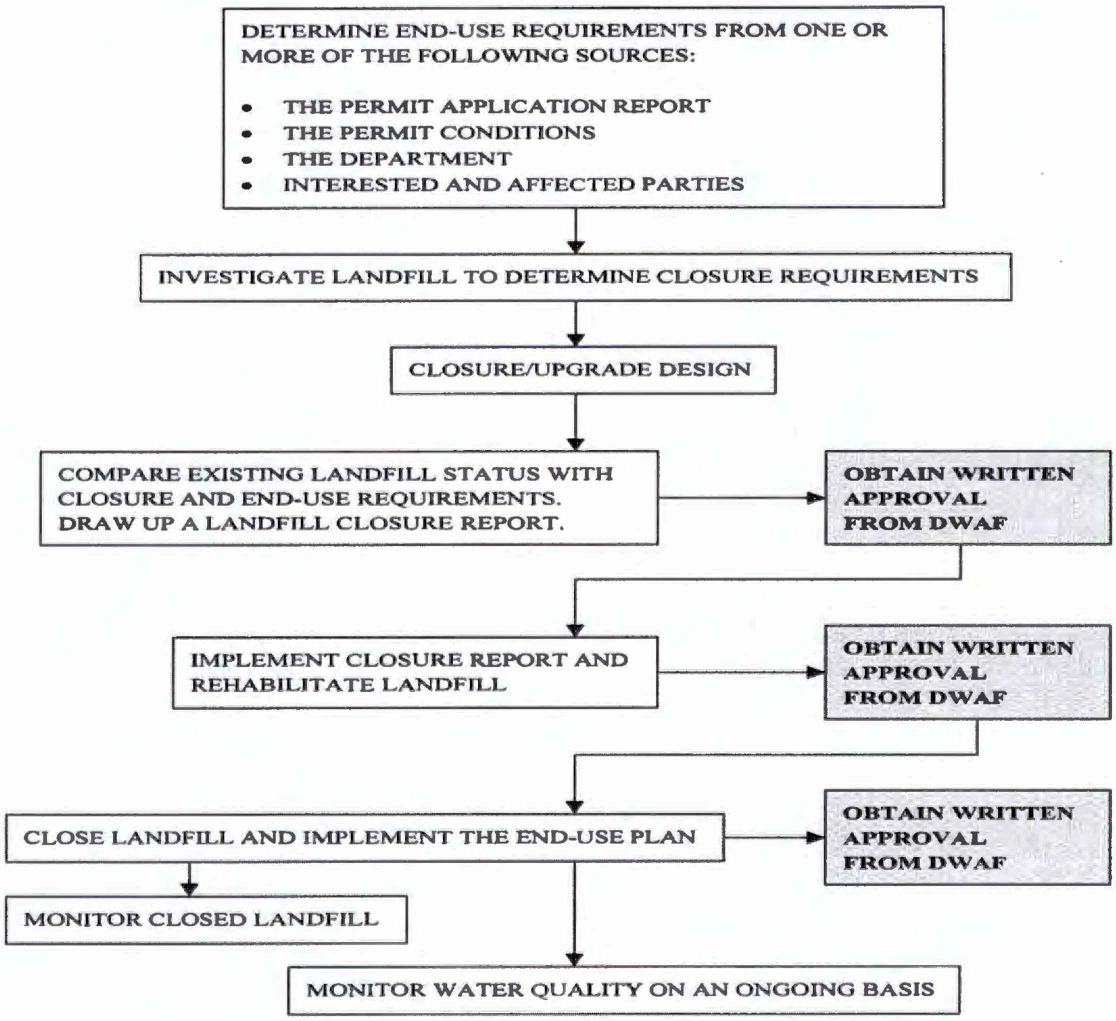


Figure 44. Minimum requirements for the closure of a landfill site. Source: (DWAF, 2008)

The site must also be rendered suitable for its proposed end-use as determined during the permitting and set out in the end-use plan. Should the permit holder intend to close the landfill, permission to do so must be obtained from the Department of Environmental Affairs. Once all minimum requirements have been met, the appropriate office of the department must be informed in writing at least one year prior to the intended closure date. Closure must take place in accordance with the conditions of the permit and the associated minimum requirements.

3.4 Key Findings

On the basis of these results, several findings are reported. First, the amount of waste disposed or ending up at the landfill site is greater than the volume of waste recovered and recycled. Second, household waste and waste from business are the two dominant forms of waste stream by volume in the study areas. Third, except for Witbank, e-waste is not yet a significant component of the waste stream. Fourth, institutional, mining and agricultural waste are ranked second highest in Table 6. A significant part of agricultural and food waste provides the requisite raw material for waste-to-energy conversion. Seventh, variations in the waste stream of each of the four sites should inform the decision decided upon with respect to modelling minimisation. Eighth, the carrying capacity of landfill sites in the study area will soon reach the maximum level allowed. Planning has to be initiated early enough for opening new landfill sites.

3.5 Summary

This section has looked at the state of the municipal landfill sites in the selected study areas. A brief introduction is given in the opening of the chapter and the materials and methods ascertaining to data collection are described. Elements that were taken into consideration to assist in reaching the conclusion that the landfill sites are complaint towards legislation, according to the minimum requirements includes: the infrastructural elements of the site and the location of the site with the appropriate graphs; The resources that are required to ensure an ongoing environmentally acceptable waste disposal operation such as the staffing compliment. The results generated in chapter 3 has highlighted potential areas of intervention with respect to waste minimisation. The amount of different waste categories entering the landfill sites is indicated and lastly the minimum requirements necessary for the closure of any landfill site is described. On the basis of these results, objective 1 has been addressed.

CHAPTER 4: RESOURCE MANAGEMENT

4.1 Introduction

Chapter 4 highlights the management aspects of the waste directorate for each of the selected study sites. These aspects include the necessary requirements needed in the daily operations of the site such as the human resources management which entails how many people (personnel) are employed in the waste management directorates at all job levels. These range from the executive managers down to the casual workers who are on the ground. The financial management aspect entails how much of the municipal budget is allocated to the waste directorates and a portion of that committed to waste minimisation and to landfill site operations. The asset management aspect entails the equipment (vehicles and tools) used for transportation of the different waste streams to the landfill sites and the vehicles used at the different stages in management. This also includes the vehicles necessary for the daily operations of the waste directorates.

4.2 Materials and Methods

4.2.1 Research Design

Addressing objective 2 of the study required the use of quantitative descriptive and non-experimental approach is undertaken. Data is obtained from non-participant field observations and surveys of the selected study area. Observations along the waste chain are done and measurements of values are recorded and presented graphically in this thesis.

4.2.2 Population

The population selected consists of the waste directorates of the Klerksdorp, Carletonville, Welkom and Witbank local municipalities. These study areas are described in more detail in the Chapter 1.

4.2.3 Data Sources

Data was obtained from reputable sources such as Statistics South Africa (StatsSA), the Departments of Environmental Affairs, the Cooperative Governance and Traditional Affairs and this was further correlated with data from the waste directorates for each of the local municipalities.

This was further reinforced by the use of existing secondary data such as IDP (Integrated Developmental Planning), IWMP (Intergrated Waste Management Plans) and Annual Municipality Reports obtained from the respective local municipalities' waste directorates.

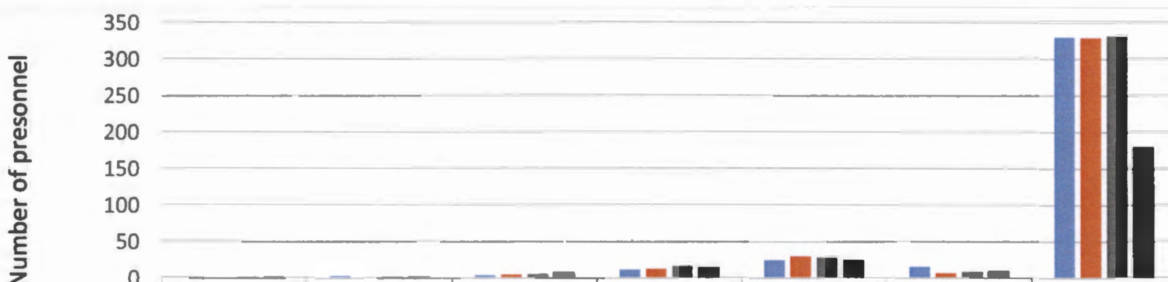
4.2.4 Instruments and Collection

The instrument used for data collection on the selected study sites was covert observation research integrated with survey schedules. A standard observational and survey schedule was designed for the selected landfill sites and the elements contained are those as prescribed according to the minimum requirements as stipulated by legislation. In comparison with quantitative and experimental research, covert observational research tends to be more reliable but also often more valid. The main advantage of covert observational research is its flexibility. It allows for change to the approach when needed, for example when entering landfill sites there is no need for personal identification and in some cases observations could be made from a distance.

4.3 Results and Discussions

4.3.1 Labour Force

The labour force at the waste directorates is a very important element. It is at this level that command and control, execution and supervision of duties, implementation of initiative and programme takes place. Figure 45 describes the comparison of the labour force for the study areas. It can be noted that level 19-20 for the study areas make up the bulk of the labour force and that level 0-3 makes up the least number of personnel of the labour force.



	Level: 1-3	Level: 4-6	Level: 7-9	Level: 10-12	Level: 13-15	Level: 16-18	Level: 19-20
Klerksdorp	2	3	4	12	25	16	330
Carletonville	1	1	5	13	30	7	329
Witbank	2	2	6	17	29	9	332
Welkom	2	2	8	15	25	10	180

Job level

Figure 45. Personnel employed at the waste directorates

Table 9 represent a key reference for the different job levels and describes the positions of the levels. This should be read in conjunction with Figure 45.

Table 9. Key reference for job levels

Job Level			
1-3	Executive managers	10-12	Junior managers
4-6	Senior managers	13-15	Supervisors
7-9	Middle managers	16-18	Controllers
		19-20	Casual workers

From Figure 46 it can be observed that few personnel are employed in senior post (Job Level 0-3 and Level 4-6). These are positions that require specialists and a certain level of academic qualifications coupled with the necessary experience. The highest number of personnel fall within the 'bottom level bracket' (Job level 19-20). Posts at these levels are mostly manual in nature. Included are include grounds men, vehicle drivers and many common posts. Those employed in the 'mid-level post' include the superintendents and supervisors. For areas such as Klerksdorp, Witbank and Welkom these posts encompass personnel that are deployed at cemeteries, parks, and recreation centres.

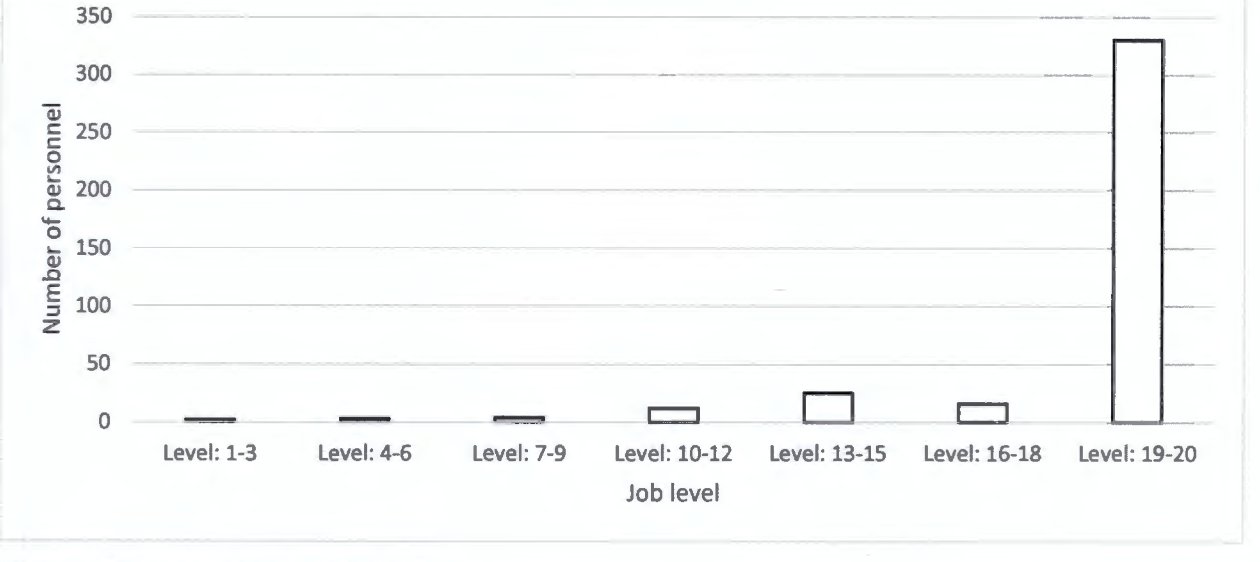


Figure 46. Labour force: Klerksdorp

Inspection of Figure 47 shows that there is a slight increase in personnel numbers from level: 1-3 to level: 13-15 for Merafong. This represents a positive image as the channels of command and control are clear. At Level: 16-18 there is a slight dip in numbers whereas level: 19-20 has an increase in personnel. With the exception of Level: 16-18, the trend of post seniority is balance. One would have expected that Level: 16-18 personnel numbers would be more than those for Level: 13-15 since Level: 13-15 has a supervisory role for Level: 16-18. The discrepancies could be owed to the fact that few of these posts are being advertised and occupied as the personnel at these level have either reached their retirement.

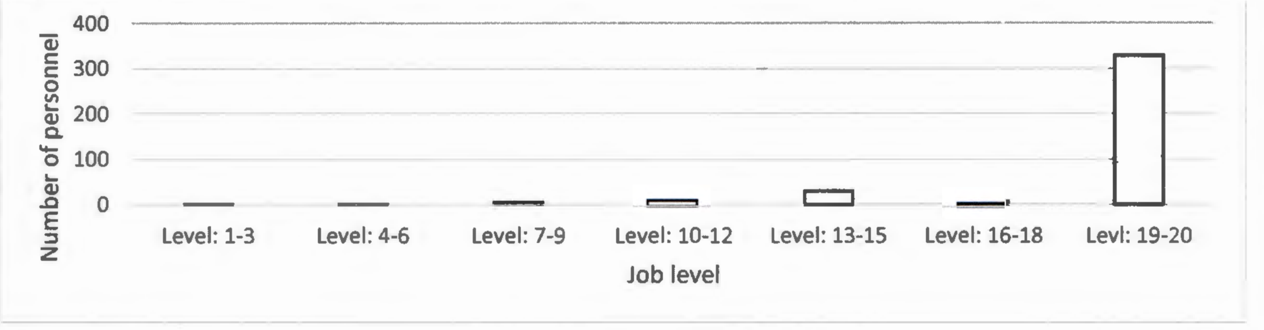


Figure 47. Labour force: Carletonville

Figure 48 represents similar characteristics which are that the bottom three job levels will experience challenges in command and control structures. Supervisors at level13-15 are more than their juniors at the level 16-18. The implications of which creates a management vacuum. This can lead to delays in service deliveries and backlogs in the collection of waste. As seen from Figure 48, there is a steady increase of personnel from level 0-3 to 19-20. This is a good indication that command and control processes can be easily observed and that there are clear definition of the chain of command. Thus institutional red tape will not affect service delivery.

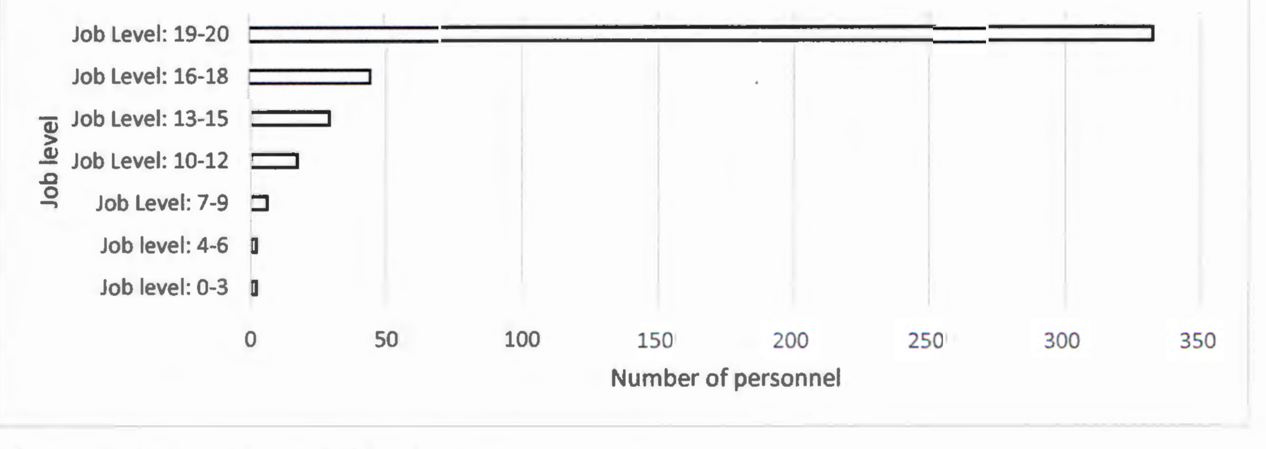


Figure 48. Labour force: Witbank

Figure 49 exhibits the same traits as in Figures 17, 18 and 19. But what was observed in this regard is that many personnel at this level are old and have taken early retirement. It was also observed that posts in this level have not been advertised due to budgetary constraints and there have been delays in approving structure and financial authority.

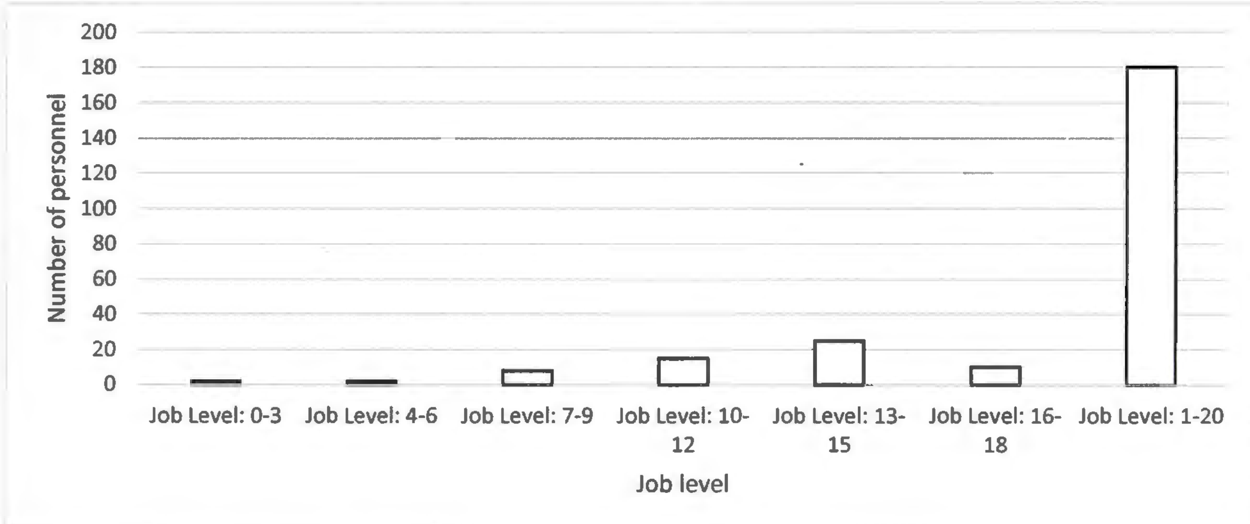


Figure 49. Labour force: Welkom

It is very important to have an idea on the number of personnel employed at the waste directorates as this gives an indication of whether the municipalities are placing any emphasis on waste management. Posts should be advertised and filled and packages should be made lucrative to recruit and retain specialists in the area of waste management. Local governments should also develop and empower their personnel by investing in education through seminars, workshops and tertiary studies. In order to improve morale and a good working environment, personnel at a lower job levels should be promoted and those vacant ranks filled as soon as possible. Human resources is a very crucial part in the waste chain and when this element is strengthened more emphasis and energy will be placed in waste management.

4.3.2 Budget Allocation

It must be recognised that not all municipalities are the same and this should be kept in mind when assessing the financial health of and setting the benchmarks for a municipality. A municipality can be ranked into a developing or growing municipality. Developing municipalities will require significant additional resources and funding to conduct the growth that is expected of them. With the demand for growth come risks that need to be managed. The priority from the financial perspectives is the viability and sustainability of the municipality. The budget allocation and related strategies will need to address a number of key areas in order to achieve this goal. Thus the budget allocated to the waste management division includes refuse removals, environmental management, parks and recreation, landfill site administration and the division administration itself.

Figure 50 is shows the overall budget vs the allocated budget to waste management for Klerksdorp Local Municipality. From the figure, a deduction can be made that the budget allocated for waste management is insignificant when compared to the overall budget for the local municipality. The 2009/2010 financial year has the lowest budget allocated for waste services whereas the 2013/2014 financial year has the highest allocation. However, from 2009 to 2014, there has been an increase in the budget allocated and this is a move in the right direction as it portrays that the local municipality is committed towards waste management. The average % of budget for waste management compared to the total budget for 2014 was less than 5%.

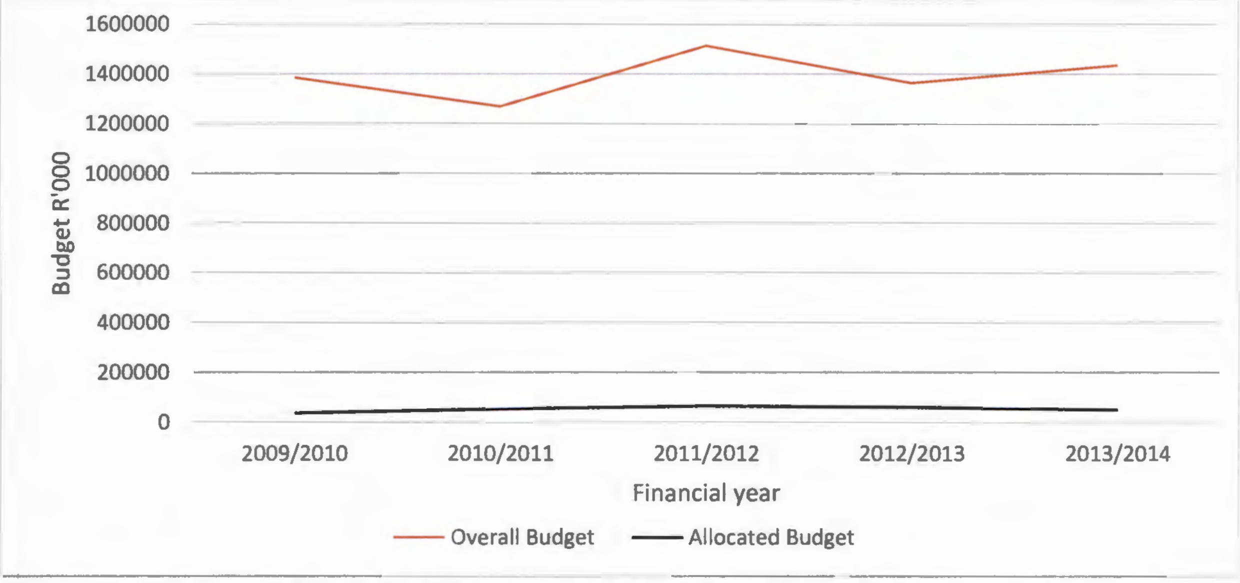


Figure 50. The overall budget vs the allocated budget: Klerksdorp local municipality

Figure 51 is shows the overall budget vs the allocated budget for Welkom Local Municipality. The figure has the same trend as Figure 50, where there is an increase in the budget allocated toward waste management services. From the 2009 to the 2014 financial year there had been a steady increment in the budget for the waste directorates whereas the municipal budget fluctuates.

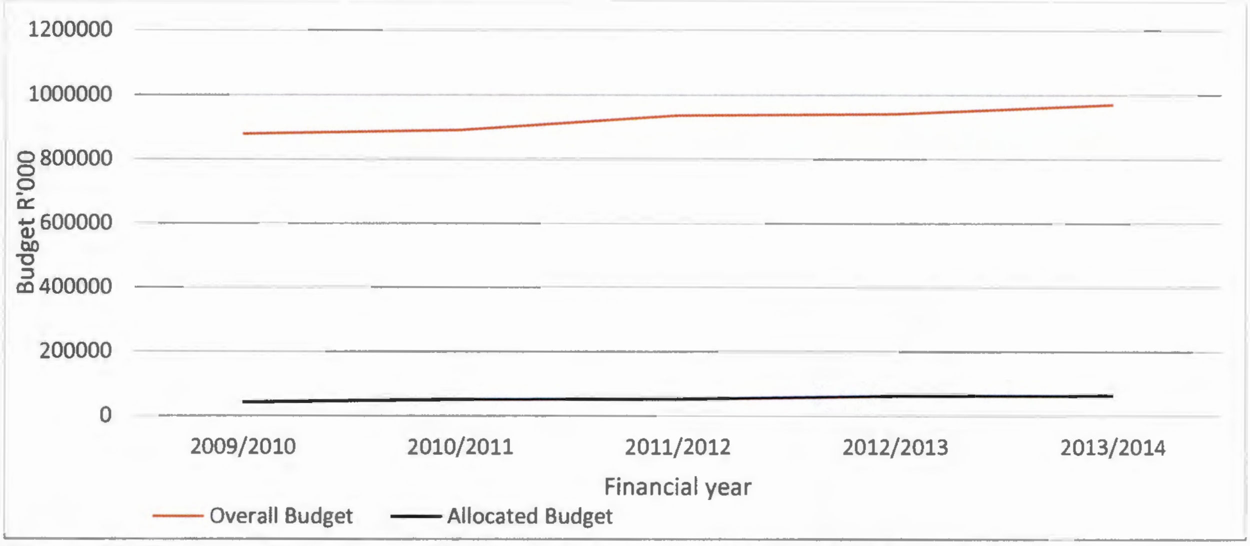


Figure 51. The overall budget vs the allocated budget: Welkom local municipality

Figure 52 shows the overall budget against the allocated budget for Witbank Local Municipality. From the figure, it can be deduced that the Witbank Local Municipality budget allocated for waste services remains constant over the period 2009 to 2012. However, both the 2012/2013 and 203/2014 financial years have higher allocations. In all cases, the budget allocated for waste management is small when compared to the annual budget allocated to the municipality.

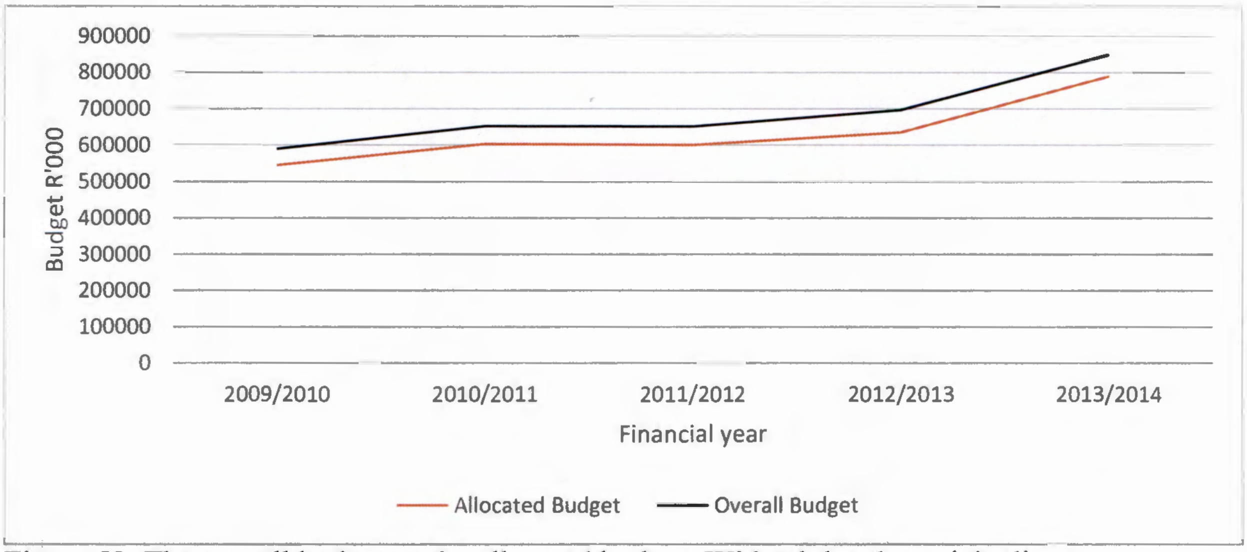


Figure 52. The overall budget vs the allocated budget: Witbank local municipality

Figure 53 shows the overall budget against the allocated budget for Carletonville Local Municipality. From the figure it can be deduced that the Carletonville local municipality is committed to waste management services. The comparison of the budgets shows that the amount allocated to waste is significant as compared to the overall budget.

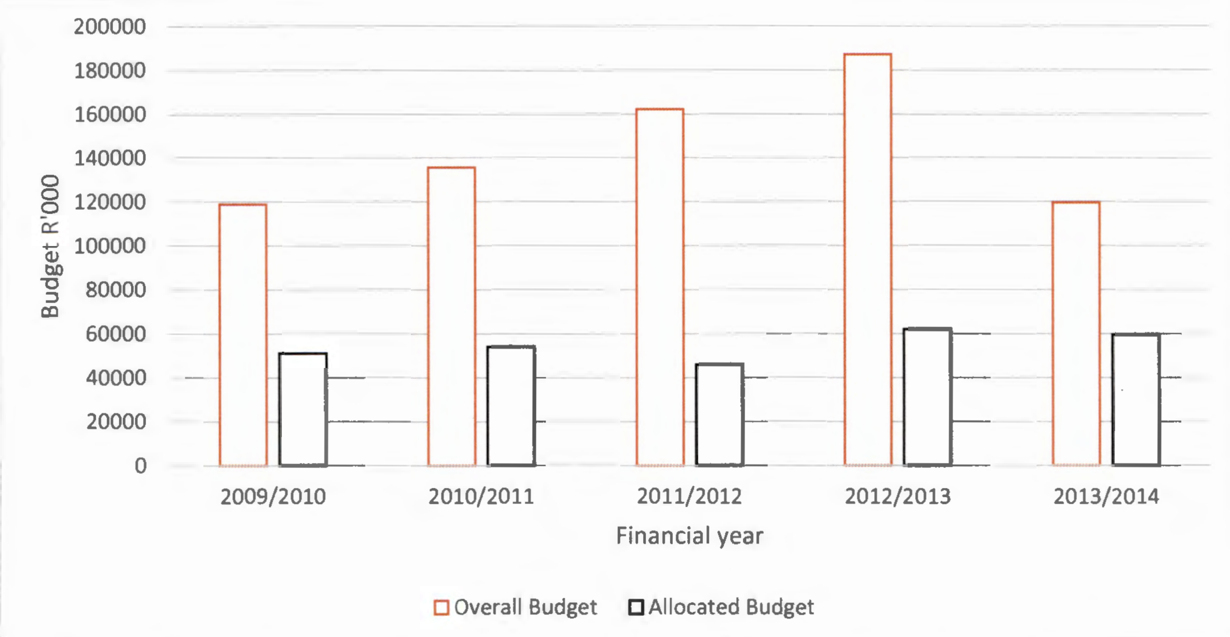


Figure 53. The overall budget vs the allocated budget: Carletonville local municipality

The mere fact that portions of the budget of each local municipality is allocated towards waste services shows a commitment from each area in dealing with waste. It is however not satisfactory as this amount is further divided and subdivided for the daily operations of the environmental management, parks and recreation, landfill site administration, cemeteries and the division administration itself. When put into perspective not much remains for recycling. The implications of this are that less attention is given towards waste management and this could result in backlogs and a negative impact on service delivery. This shows a need for more financial commitment from each area in dealing with waste.

4.3.3 Vehicle Fleet

Transportation along the waste chain is a very important and critical element and this is provided through the use of municipality fleets. The bulk of waste collection services are provided through the use of refuse compactor trucks and such services currently offered by the municipality are unsatisfactory. The challenges experienced by the municipalities and observed is that waste collection is not carried out regularly in all areas. Collection vehicles are consistently working double shifts and constantly breaking down and in need of repairs. As a result illegal dumping was evident while passing through residential areas and this is a good indicator of an ineffective waste collection service and transportation problem. The fleet and equipment managed by the municipality consist of refuse trucks, tipper trucks, bakkies, graders, front end loaders and low-beds. The tools consist of equipment such as spades, hose pipes, brush cutters and kudus. Described in this section are vehicles that are operational and non-operational. The operational vehicles are those vehicles that are well maintained and serviced. Non-operational vehicles are described as vehicles that are parked in the maintenance yards, that have been stolen, that are in need of repairs and that are privately hired etc. Non-operational equipment is described as equipment that is too old, stolen, in dire need of repairs etc. Figure 54 represents the comparison of vehicles that are operational and that which non-operational. As can been seen 69% of refuse tractors are operational and 31% are non-operational. 78% of tipper trucks are operational and 22% are non-operational. 82%of bakkies are operational and 18% are non-operational. 65% of graders are operational and 35% are non-operational. 50% of the tools used are operational and 50% non-operational. 60% of the low-bed is operational and 40% is non-operational. These results show that for front-end loaders, low-bed trucks and graders serious shortfalls exist.

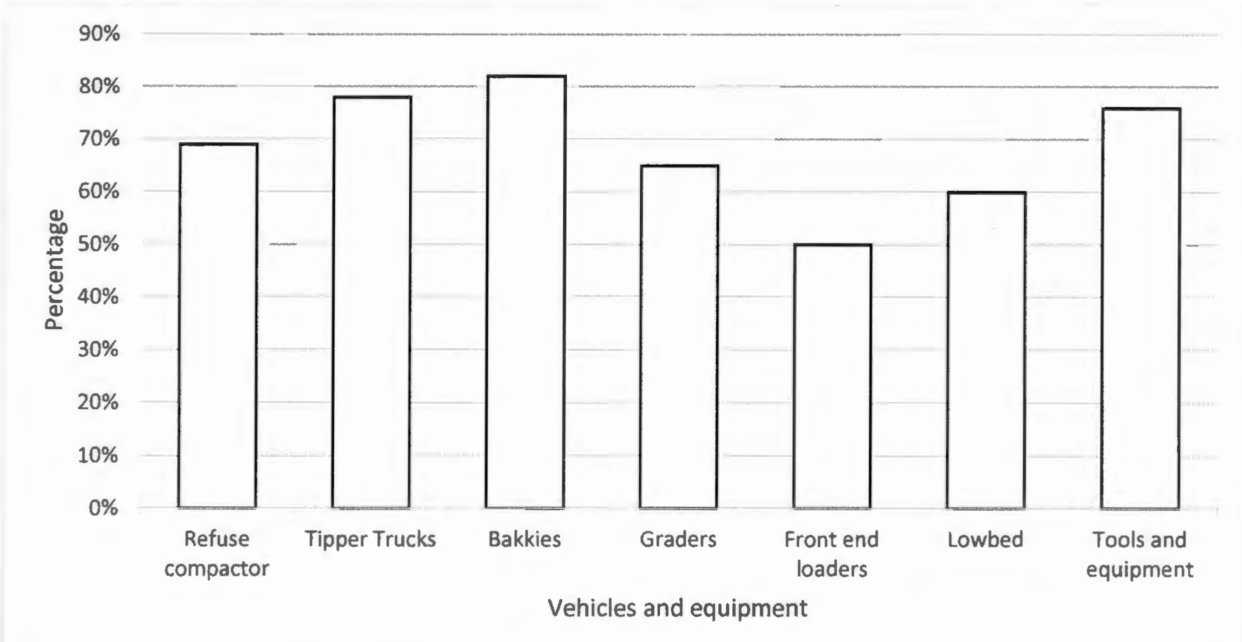


Figure 54. Operational status of vehicles and equipment in Klerksdorp

From Figure 55 it can be assumed that 75% of refuse compactors are operational and 25% are non-operational. 69% of tipper trucks are operational and 31% are non-operational. 95% of bakkies are operational and 5% are non-operational. 72% of the graders are operational and 28% are non-operational. 66% of the tools and equipment are operational and 34% are non-operational. 52% of the low-beds are operational and 48 are noon-operational.

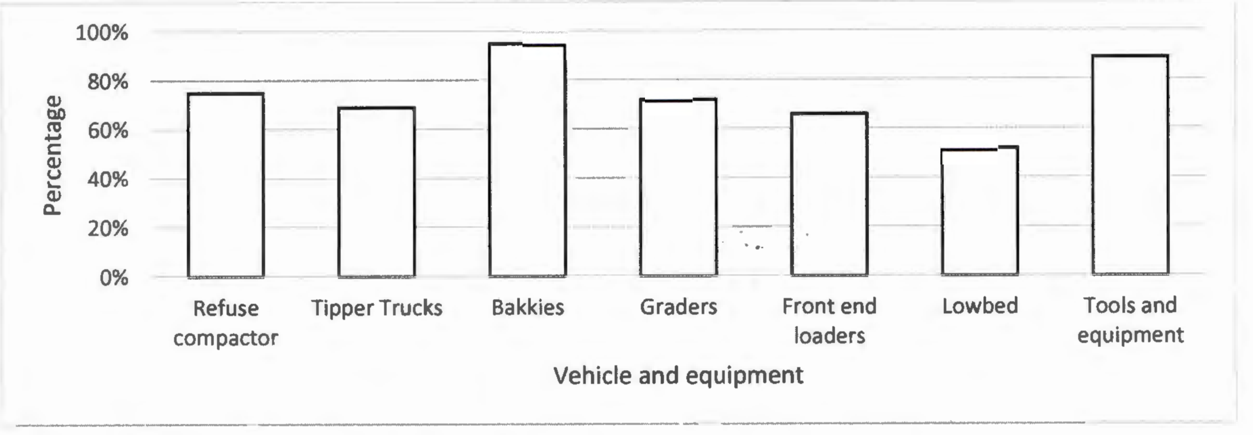


Figure 55. Operational status of vehicles and equipment for Carletonville

Figure 56 shows that 82% of refuse compactors are operational and 18 are non-operational. 76% of tipper trucks are operational and 34% are non-operational. 89% of bakkies are operational and 11 are non-operational. 69% of graders are operational and 31% are non-operational. 52% of front end loaders are operational and 48% are non-operational. 49% of low beds are operational and 51% are non-operational. 95% of the tools and equipment are operational and 5% are non-operational.

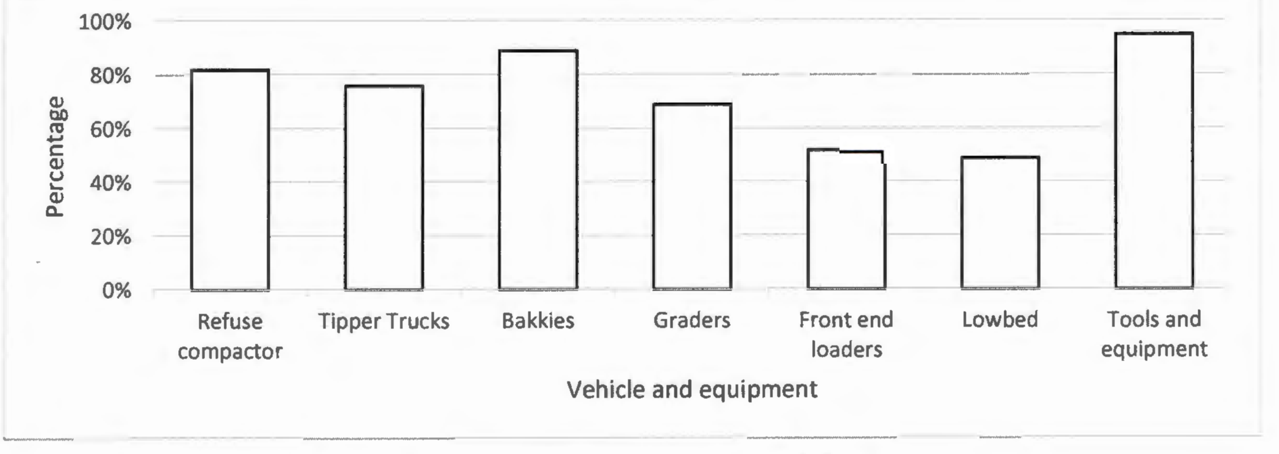


Figure 56. Operational status of vehicles and equipment for Witbank

Figure 57 represents 79% of refuse compactors being operational and 21% as non-operational. 96% of tipper trucks are operational and 4% non-operational. 78% of bakkies are operational and 22% are non-operational. 55% percent of graders are operational and 45% are non-operational. 69% of front end loaders are operational and 31% non-operational. 68% of low beds are operational and 32 are non-operational. 92% of the tools and equipment are operational and 8% are non-operational.

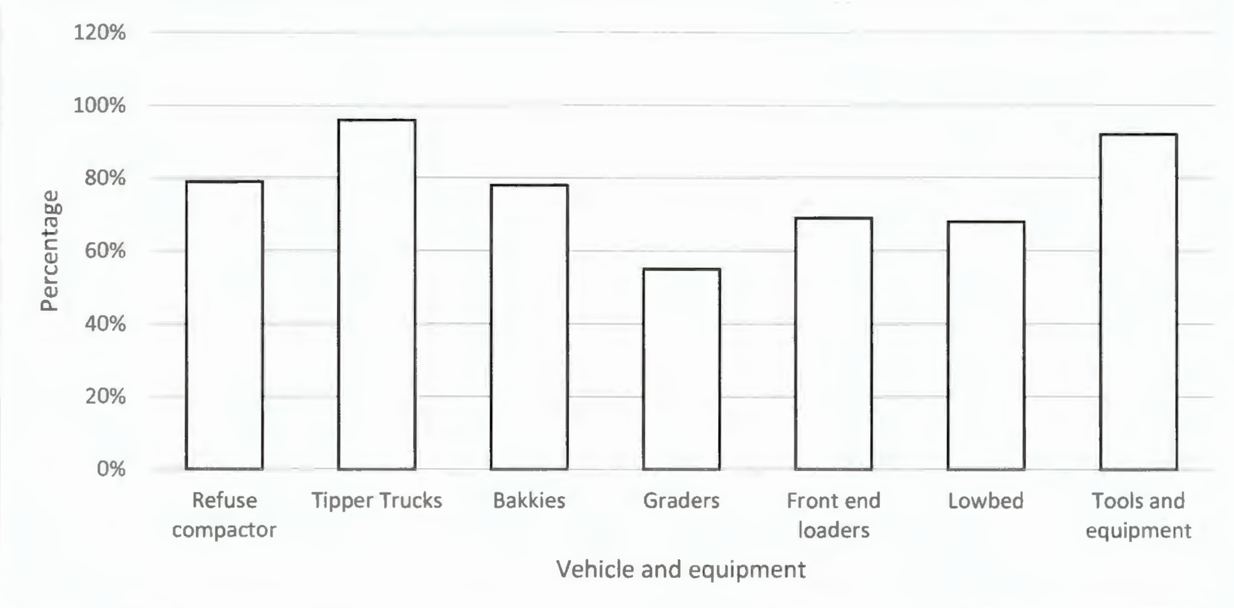


Figure 57. Operational status of vehicles and equipment for Welkom

Plate 1 Bell L2606D Front end-Loader used for clearing ad hock dumping (Klerksdorp)

Plate 2 Nissan UD 85 Chassis Tipper used for dumping waste (Welkom)

Plate 3 Illegal dumping next to a 6m^3 Skip container (Witbank)

Plate 4. 6m^3 Skip container used in the CBD and for rentals (Klerksdorp)

Plate 5 Nissan UD 85 Chassis Skip Loader used for commercial and private rentals (Welkom)

Plate 6 20m^3 Nissan UD 290 Refuse Compactor used for Domestic collection (Carletonville)

Plate 7 Nissan UD 80 Chassis Roll in Roll of Vehicles (Carletonville)

Plate 8 Unapved road in Greenspark, Carletonville LM

Plate 9 Broken down grader (Witbank)

Plate 10 Waste collection receptabes-(Welkom)

The assessment of vehicles that are being used in the waste management shows that the challenges currently being faced by the municipalities are: The vehicles and equipment are too old; No tracking devices are installed thus making the vehicles prone to theft; No planned vehicle maintenance programmes seem to be in place and no pre-trip inspections are done. The municipalities are however to implement a fleet management system; Develop a planned maintenance system, procure a service provider for fleet management system and install a costing system. All waste collection vehicles and equipment are rented on a full maintenance lease basis eliminating the risk of not having vehicles available for waste removal and improving collection services. Rear End Loading (REL) mobile compacters are used for domestic and commercial waste collection and roll on roll offs (RoRo) and skip loaders are used for mass containers at businesses and rentals by the public.

4.4 Key Findings

On the basis of these results, the several issues stand out. There seems to be a miss alignment in the structure of the waste directorates as some personnel are distributed across sub-divisions that have nothing to do with waste management. The common amalgamation of waste management with electricity, water and sanitation undermines the accumulation of specialist skills within waste directorates. The organisational set up of waste directorates shows staff shortages at middle level management causing a delay in the chain of command. The budget allocated towards waste services is very insignificant when compared to the overall budget of the local municipality. Budgetary constraints further causes a delay in service delivery. The operational status of the vehicles utilised in the waste system is just above average when compared to the amount of the waste being generated and the areas of responsibility, the status is low.

4.5 Summary

Currently the local municipalities are experiencing huge challenges in respect to governance, institutional and financial capacity. These challenges have impacted negatively on service delivery and sustainability. Factors and challenges in this respect can be attributed to rapid urbanisation and the economic growth of the mining and the industrial sectors thus placing enormous pressure on the bulk infrastructure and over-utilisation of networks resulting in an accelerated rapid deterioration of service infrastructure. A culture of non-compliance has developed amongst staff and this has led to the interference of labour unions into managerial activities and decision-making therefore affecting work discipline. This has resulted in the deterioration of command and control especially at senior levels together with an entitlement culture amongst staff. This culture of non-compliance is also dominant amongst groups in the community, with non-payment for services, illegal activities and a high crime rate dominating. Dysfunctional service delivery and a lack of equipment and tools of the trade, especially vehicles, have resulted in continued dysfunctional operations and non-compliance leading to successive disclaimer audit findings. There is a pressing need for the local municipality to provide quality services to the community so as to avoid public unrest. The basic services that have to be provided are potable water, sanitation, refuse removal, electricity, roads and storm-water, street lighting and environmental health. These services directly affect the quality of the lives of the people in the community. The non-provision of water and non-collection of refuse can easily lead to unhealthy and unsafe living environments. Poor services can also make it difficult to attract investments to an area therefore limiting economic growth and job creation. On the basis of these results, Objective 2 of the study has been addressed.

CHAPTER 5: WASTE MINIMISATION PROGRAMMES

5.1 Introduction

Chapter 5 of the study looks at the programmes that have been identified, implemented or initiated at the different municipalities. These programmes are aimed at maximising and aiding already established mechanisms in minimising the amount of wastage from entering the waste stream and ultimately landfill sites. These programmes are applied throughout the entire waste chain and should largely be applied at the different phases of the waste hierarchy to ensure its effectiveness and efficiency.

5.2 Materials and methods

5.2.1 Research Design

In addressing objective 3 of this study, a programme evaluation was developed that specifies key performance areas (KPA) and used to measure the performance of these programmes. These were linked to actual waste minimisation programmes that were initiated and implemented in each of the study areas.

5.2.2 Population

Each local municipality was found to have its own programmes in place but the more common characteristics were selected for the design of a standard table used in the evaluation of these programmes.

5.2.3 Data Sources

Data for this subject matter was derived from the waste directorates of each study area. This was further reinforced with data obtained from:

- the Integrated Development Plan (IDP);
- the Integrated Waste Management Plan (IWMP);
- Annual Reports (AR);
- Local Economic Development Plan (LEDP).
- Waste management plans of the respective directorates.

5.2.4 Instruments and Collection

Each of these programmes was selected and evaluated based on the key specific areas. The results were captured and recorded into applicable formats.

5.3 Results and Discussions

5.3.1 Financial Management Strategies Programmes

Financial management strategies are programmes that have a lot of capital injected into them and are usually long term financial commitments. A series of processes are involved in authorising such projects and they benefit entire regions. They are commitments usually undertaken at higher command levels. Table 10 shows the most significant financial management strategies programmes that to date have been identified for all the four municipalities. Firstly is the on-going review of the computerised financial system. The integration of such a computerised systems and the purchase of the required hardware and software within the local municipality ensures that captured information is accurate, relevant and prompt. This will in turn will facilitate the smooth running and effective management of the municipality. Second is the upgrading of the "Venus" software that is being currently used at the municipalities, to the "solar" software and this will greatly improve the operating systems. This software is used to generate the required job cards and improve responses in tackling outstanding issues. Thirdly is the development of a generally recognised accounting practices (GRAP) compliant and medium term revenue expenditure framework (MTREF) budget. These programmes are also aimed at reviewing and updating asset, budget and accounting policies and procedures.

The objectives of such programmes as indicated in Table 10 will be to regularly ensure that the financial and other staff members receive the required training they require to ensure a cost effective and efficient service to the municipality and its customers. It will improve budgetary controls and timeline of financial data. Building capacity of the budget and treasury office to ensure that financial information for reporting purposes is generated timeously. It will also include the monitoring and reporting on budget variances. It also provides for the development and implementation of a debt capacity policy. This policy will ensure that any loan or debt taken by the municipality will be done in responsible manner and that the repayment and servicing of such debt will be affordable. It can be depicted from Table 10 that Klerksdorp, Witbank and Welkom have committed R1.7 million in developing and renewing their financial systems. This will enable faster responses to job cards. These areas have also committed R3 million for a development of a generally recognised accounting practices compliance and a medium term revenue expenditure revenue medium term expenditure (MTREF) budget. The areas of Carletonville and Welkom have allocated R890 000 to enhance budgetary control and timeline financial data. Klerksdorp has allocated R1.6 million rand to the implementation and development of a debt capacity policy.

Table 10. Financial management strategies programme

INPUT		KEY PERFROMANCE AREA (KPA)	VALUE (R 000')	OUTCOME
KLERKSDORP; WITBANK & WELKOM INITIATED PROGRAMMES	Review of the computerised financial system	• Integration of the computerised systems. • Acquisition of the required hardware and software. • Ensure information is accurate, relevant and prompt.	R 1.7M	• Smooth running and effective waste management.
	Development of generally recognised accounting practices compliant and medium term revenue expenditure revenue budget	• Develop and implement a uniform budget reporting framework tractable with National Treasury's Municipal Budget and Reporting Regulations. • Reviewing and updating prescripts regarding asset, budget and accounting policies and procedures; Training and development of financial and other staff.	R3M	• Ensures financial and other staff members receive required training. • Ensures a cost effective and efficient service to the municipality and its customers.
CARLETONVILLE & WELKOM	Enhance budgetary controls and timeline of financial data	• Building capacity of the budget and treasury office.	R890'	• Ensures that financial information for reporting purposes is generated timeously.
KLERKSDORP	The development and implementation of a debt capacity policy	• Ensure that any borrowings taken by the municipality will be done in responsible manner.	R1.6'	• Repayment and servicing of such debt will be affordable.

The importance of these programmes is that they inject much needed financial capital to improve responses along the waste chain. They address the issue of institutional red tape as challenges are speedily addressed. The implications of such commitments are that response times to immediate challenges are speedily resolved resulting in an improved service delivery and a decrease in waste backlogs.

5.3.2 Asset Management Strategies and Programmes

These are programmes that are focused in the improvement of fixed and movable assets such as the vehicles used in the waste directorates for waste collection. The goal is to ensure that sufficient back-up collection equipment are available at all times as well as supporting equipment for the street cleansing service, illegal dumping service and for landfill. The need to ensure the availability of collection equipment will however need to be addressed by the actions of the relevant local municipality. The local municipalities can now purchase and maintain their own landfill equipment to a minimum that includes a garbage disposal vehicle, waster cart, and tipper truck and front end loader. Table 11 tabulates the financial commitment in ensuring that assets utilised along the waste chain are well maintained.

Table 11 Asset management strategies and programmes

	INPUT	KEY PERFORMANCE AREAS (KPA)	VALUE (R'000)	OUTCOME
Klerksdorp	implementation of an integrated asset management system	Investigation, identification and implementation of a suitable integrated asset management system.	R 895 000	Capture of all assets into a system, the maintenance of this system and the production of a complete register
Witbank	Re-assess and update of asset and risk insurance protocol and the renewal of the insurance portfolio	Entails the identification of risk in partnership with insurers and head of departments.	R 1. 5M	Incorporates the review of the existing insurance portfolios and the reformations of the insurance policy as per the renewal terms,
Carletonville and Welkom	Allocation to repairs and maintenance and the renewal of existing infrastructure assets	Uncontrolled increase in renewal infrastructure backlogs will negatively impact on the financial sustainability, reliability and quality of municipal services	R 650 M	Adequate budget provision for asset maintenance over its useful life. Maintenance of assets according to an infrastructural asset and maintenance plan
Klerksdorp	Replacement and renewal of aging vehicles and equipment	Ensure on-going health and municipal infrastructure	R 750M	Ensuring all asset owned and controlled are insured except where specifically excluded by policy

The Klerksdorp, Witbank, Welkom and Carletonville municipalities have financially committed to the application of an integrated asset management system and the re-assessment and updating of an asset and risk insurance protocol and allocations to repairs and maintenance of the existing infrastructure. The equipment currently on site is not adequate and is difficult to maintain due to procurement procedures. Landfill equipment should not be out of commission for longer than two days since the landfill site is operated on a daily basis whilst waste volumes are continually increasing over time. All indications are that outsourcing the operation of the landfill is more cost effective and that the site will be better managed from an operational point of view. There are various examples where municipal landfills are successfully operated by private contractors. The following are some of the more significant programmes that have been identified: Implementation of an integrated asset management system; Identification and implementation of a suitable integrated asset management system. This will also include the capture of all assets into a single system, the maintenance of this system and the production of a complete asset register in terms of generally recognised accounting practice document 17 and 102 and any other accounting standards requirements; Reviewing and updating of asset and risk insurance protocols and renewing the insurance portfolios. Risk identification in conjunction with insurers and departmental heads. Re-assessing of existing insurance portfolio and the renewal of the insurance policy as per the renewal terms; Repairing and maintaining of existing infrastructural assets should be prioritised since an uncontrolled increase in renewal infrastructure backlogs will negatively impact on the financial sustainability and the reliability and quality of municipal services. Adequate budget provision for asset maintenance over its useful life and the maintenance of assets according to an infrastructural asset maintenance plan, Maintain a system of internal control of assets to safeguard them, Replacement and the renewal of aging assets according to replacement programme to ensure the on-going health and municipal infrastructure and ensuring all assets owned and controlled are insured except where specifically excluded by policy.

5.3.3 Other Programmes

The following waste minimisation programmes as depicted in Figure 58 have been identified throughout the study areas and presented. These programmes are continuous programmes. They have no expiry date attached. All that is required is for them to be upgraded as regularly as possible by the responsible personnel of the waste directorates.

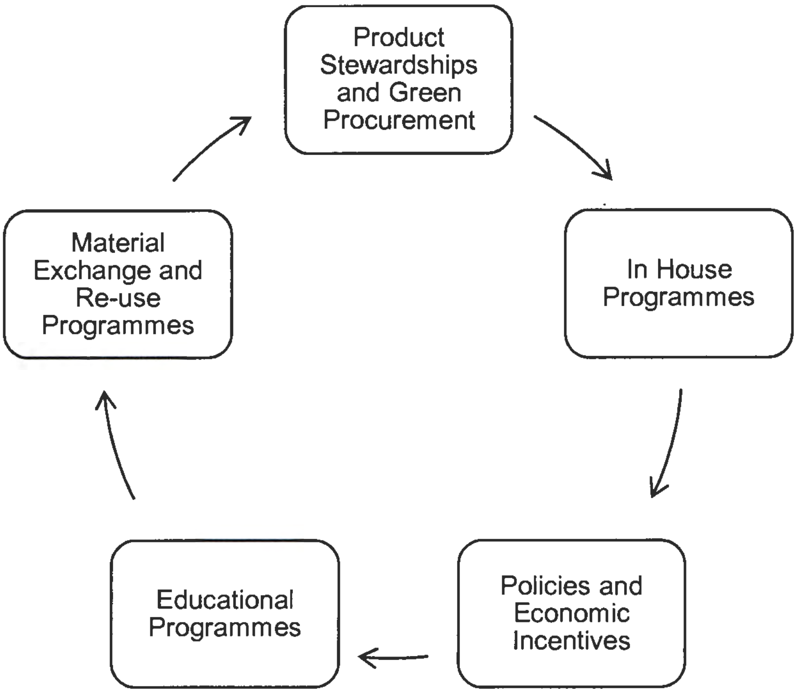


Figure 58. Other types of waste minimisation programmes

a) In-house Programmes

These programmes encourage governmental agencies and solid waste departments to reduce waste generation following the cred of practice what you want to preach. Valuable lessons can be learnt with such in-house programmes initiatives about day to day practicalities and the challenge around generating less waste in the first place. In-house programmes facilitate the economic and policy incentives that require or encourage consumers and businesses to practice source reduction. Such programmes are necessary to ensure success of waste minimisation programmes. Residential, commercial and industrial educational programs are packages suited for in-house programmes that increase public awareness and participation in source reduction programmes. Educational and on-site business and industry assistance programmes advise businesses how to use materials more efficiently and reduce waste generation. The areas in the study sites all have in-house programme.

b) Policies and Economic Incentives

The policies and economic incentives involves the development of an environmental management corporate agreement with the respective local industry and association to develop targets for recycling of products and waste reduction to landfill. They hold manufacturers responsible for their products throughout their life-cycle. Local government can press for extended producer responsibility at the state and national levels. If goals are not met, the responsible or concerned will push for institution of a regulatory framework. Local government can pass producer responsibility resolutions calling on producers to share the responsibility for their products and on state and national legislatures to shift the burden of managing discarded products and packaging from local governments to the producers of those products. To facilitate such programmes, local government may need to pass local ordinances banning use and/or sale of certain types of products and packaging that cannot be reused, repaired, recycled, or composted. It was observed that the Klerksdorp, Witbank and Carletonville areas have put emphasise on such programmes whereas Carletonville has none.

c) Educational Programmes

Educational programmes and outreach are very important. Educational and technical assistance programs provide residents and businesses with information about 'how' and 'why' to reduce, reuse, recycle, and compost. Public information campaigns which allow consumers to make smart choices when making purchases are effective options. Public education campaigns can also highlight the environmental and economic benefits of preventing, reusing, and recycling discards and connect the role these activities play in moving toward a sustainable economy. It is proven time and time again that money spent on education to promote savings and raising awareness of environmental issues, although seeming like a significant cost, can yields significant results in waste minimisation. The local municipalities have put continuous educational programmes in place. For instance in Klerksdorp, posters are put up and waste information published in the *Lentswe* newspaper and the local radio station. In Witbank the focus is on schools and regular awareness campaigns are initiated. For the Welkom and Carletonville local municipalities signs and posters are established in key areas.

d) Material Exchange and Re-use Programmes

This is initiated by establishing a materials reuse program to take unwanted but reusable materials and making them available to non-profit organisation, businesses and private individuals. Material can come from anyone in the area. The advantages of such programmes are that the materials are both cost effective and environmentally beneficial. For business advantages they include:

- Avoidance of paying disposal cost;
- Free up valuable space;
- Receive a tax rebate;
- Receive cash;
- Use less expensive material and packaging than buying new ones;
- Improves the corporate images of the respective organisations or company.

e) Product Stewardships and Green Procurement

Product stewardship and green procurement is the act of minimising the health, safety, environmental and social impacts of a product and its packaging throughout all lifecycle stages, while also maximising economic benefits. The manufacturer, or producer of the product has the greatest ability to minimise adverse impacts, but other stakeholders, such as suppliers, retailers, and consumers, also play a role. Stewardship can be either voluntary or required by law. It incorporates human health and environmental concerns into the search for high quality products and services at competitive prices.

5.4 Key Findings

On the basis of these results, the following findings are specified:

- The selected study areas do not seem to have precise and clear programmes that are solely and specifically aimed at minimising waste. Instead the financial management and asset management strategies are initiated to overhaul the entire out-dated municipal systems. As a result one of the drawbacks is that the waste management systems indirectly benefit although these are not direct programmes aimed at the waste management systems.
- Observations suggest that suitably qualified persons should manage in-house programmes and other programmes as these have a major impact in educating people about waste minimisation.
- The organisational set up of local municipalities does not give adequate space and autonomy to the waste directorate. This has an adverse effect on the recruitment, retention and development of specialist skills.
- Waste management does not receive adequate budgetary support from local municipalities and, this constrains the ability of waste directorates to up-grade current systems and to improve their record of service delivery.

- The status of operational equipment and vehicles at local municipality level indicates serious problems of maintenance. These problems relate to red-tape in the procurement systems for parts and spares and the low priority given to the recruitment of full time mechanics at municipal engineering workshops.
- Waste minimisation is a critical element of long-term government goals to protect the environment; yet, it does not receive much attention from senior management across local municipalities.

5.5 Summary

The findings indicate that attainable, viable and practicable waste minimisation and recycling programmes and initiatives are important and should be developed and implemented within the local municipalities. These functions and aspects can be outsourced, but it is envisaged that people be appointed within the areas to assist with the development of programmes and campaigns since they will be directly involved in the daily issues of waste management. It is also proposed that the local municipalities establish partnerships with contractors for the establishment of buy-back centres. Separation at source should also be investigated to establish its feasibility. Thereafter, pilot projects should be initiated in certain suburbs of the municipality and progressively extend it to the other suburbs. There is no single best approach but instead a variety of approaches are needed to reduce waste generation. Educational initiatives, at-home composting, unit-based pricing, and materials exchange and reuse programs are the most common waste minimisation programmes practiced in general. However, a growing number of local governments are expanding their programs to include on-site technical assistance to businesses, economic and policy incentives and in-house source reduction policies. Spending money to change the way the community thinks so that waste minimisation becomes a voluntary way of life for everyone always works out cheaper than money spent to enforce such practices on an ignorant community. On the basis of the results and the discussion thereof, objective 3 of the study has been adequately addressed.

CHAPTER 6: CAPACITY CONSTRAINTS IN THE WASTE CHAIN

6.1 Introduction

A typical solid waste management system in a developing country displays an array of constraints. These centre on low collection coverage; irregular waste collection services; crude open dumping; burning without air and water pollution control; the breeding of flies and vermin and the handling and control of informal waste picking or scavenging activities. The intensity of these constraints vary from area to area and across different countries. At a second level, the waste chain itself is both a physical-technical system (Mudau et al, 2013; Ruhiiga, 2016) and a social system. To this end, particular constraints relate to material flows along the chain and to the management and personnel components of service delivery. These constraints directly talk to concerns in public health, environmental and management. The factors constrain the development of effective solid waste management systems. These factors can be categorised into technical, financial, institutional, economic, and social constraints. Chapter 6 examines the constraints that affect local municipalities in the context of waste management.

6.2 Materials and Methods

6.2.1 Research Design

Addressing objective 4, which is to analyse capacity constraints in the municipal waste chain, in this study depends upon the results of the analysis of the data captured and extracted from Objectives 1, 2, 3 and 4. Included in the analyses of the constraints are the required generated results indicating the state of the waste chain in the study area, capacity, differences, similarities, limitations and strengths in the waste chain.

6.2.2 Population

The population of study for this section of the project is the Welkom, Klerksdorp, Witbank and Carletonville local municipalities. The constraints have been considered along the entire waste chain.

6.2.3 Data Sources

Data for this subject matter was derived from the waste management directorates of each study area. This was further reinforced with data obtained from the following sources:

- Integrated Development Planning (IDP).
- Integrated Waste Management Plan (IWMP).
- Annual Reports (AR) and
- The Local Economic Development Plan (LEDP).

6.3 Results and Discussions

6.3.1 SWOT Analysis

SWOT Analysis is an assessment of system viability based on its strengths, weaknesses, opportunities and the threats to it. Table 12 summarises the results of the SWOT Analysis as regards the identification of constraints in the waste streams for the local municipalities in the selected study areas. A Gap Analysis then follows – this helps in the grouping of the challenges being experienced.

Table 12. SWOT analysis to identify constraints within the waste streams

STRENGTHS	WEAKNESSES
Integrated spatial development • Land use management • Spatial planning **The provision of basic services** • Municipal services **Good governance** • Corporate governance • Broaden local democracy • Local government accountability **Financial viability and management** • Financial viability • Financial management	**Integrated spatial development** • Infrastructure master planning • Environmental management • Rural development planning • Human settlements management **The provision of basic services** • Physical infrastructure aging and backlog • Water and electricity losses **Financial management** • Procurement practice and system **Local economic development** • Economic development • Social development **Business management and leadership** • Strategic positioning to influence key stakeholders • Organisational culture • Stakeholder relations management & • Communication **Resource management** • ICT management • Record / knowledge management • Human resource management • Asset management • Office accommodation • Interdepartmental collaboration (lack of internal customer care) • Organisation performance management
OPPORTUNITIES	**THREATS**
• Alternative sources of funds	• Non-payment culture in community

• Inter- governmental relations framework / stakeholder alliances • ICT developments • Economic diversification in the municipality • Tourism opportunities • Mining related opportunities • Job creation opportunities • Agriculture development opportunities • Transport opportunities • Strategic partnerships • Availability of land for development • Carletonville Urban Renewal	• Inadequate resources to deal with increasing demands • Poverty % unemployment impacting negatively on available resources • Illegal connections leading to risks • Vandalism of infrastructure. • Long lead times on EIA's; Pollution (air, land, water) • HIV / AIDS pandemic; Fraud / corruption • Infrastructure backlogs • Declining mining sector • Electricity tariff escalation • Urban sprawl • High crime rate

6.3.2 Gap Analysis

Table 13 further describes the gaps that were identified as a result of the SWOT analysis. The weakness aspect of the SWOT analysis was selected and gaps identified as flagship objectives and target to improve the waste management services. This is further elaborated and tabulated in Table 13 which was simplified to highlight the more common characteristics for the local municipalities in the study areas.

Table 13. Gap analysis for the local municipalities in the selected study areas

Area	Objectives and Targets	Gap Analysis	Outcomes
All LM,s	Render a sustainable, equitable and cost effective refuse removal service to all domestic and business premises	Personnel to assist with roles and tasks as set out in the waste management section structure.	Ensure that recruitment procedures are followed when interviewing new candidates. Staff employed should have all the relevant qualifications required. Criteria and job descriptions to be reviewed.
All LM,s	Improve refuse collection in informal settlements.	Lack of service and or sustainable initiatives.	Detail evaluation of existing waste collection relating to the proposed collection system in the informal areas. Alternative collection systems and methodologies to be investigated.
All LM,s	Decrease the volume of illegal dumping.	A lack of proper public dumping/disposal facilities.	Implement proper public dumping/disposal facilities for residents to dispose of various waste types.
Carletonville	Ensure that a proper mass container rental system is implemented	Rates currently charged for mass container service is not market related.	Evaluate proposed collection system for informal areas. Purchase additional equipment if required, based on the outcome of the evaluation. Consider utilising SMMEs and one-person-contractors for primary and secondary collection.

Carletonville	Implementation of recycling initiatives at both domestic and commercial service points.	A proper recycling plan and programme is lacking, this also includes aspects such as composting.	Develop a proper recycling action plan and programme. Establish a formal partnership with recycling companies. Discuss implementation of the proposed plan with the preferred company. Benchmark with other municipalities on waste reusing Programmes and/or involve the public/ communities.
All LM,s	Decrease illegal dumping	Lack of enforcement of by-laws and legislation. Lack of Formalised service to the informal areas in particular is creating illegal dumping in those areas.	Implement proper public dumping/disposal facilities for residents to dispose of various waste types. Conduct a proper investigation into the need for such facilities. Determine best locations for such facilities. With the new By-laws in place, the introduction of active enforcement must be done. Implement formal collection services to informal settlement areas.
All LM,s	Comprehensive street cleaning service.	Only CBD and surroundings receive street cleaning service	A plan of areas which require street cleaning needs to be developed. Based on this, the required personnel to provide the more comprehensive street cleaning service should be allocated.

*LM's....Local municipalities

6.3.3 Technical Constraints

Table 14 represents the technical constraints facing each of the selected study areas. From analysis on Table 14 we can deduce that the Klerksdorp municipality has approximately 120 442 households and 219 available vehicles to collect waste. The ratio for this area is thus one vehicle for every 549 households or one vehicle for every 1920 people. This results in a weekly refuse removal rate of 89% for the Klerksdorp Local Municipality. This refuse removal rate is worked as the number of times the refuse is successfully collected at the specified times. In times of general picketing, vehicle breakdown or any other foreseen and unforeseen circumstances this rate then drops.

For the Carletonville local municipality 102 624 households are relying on 132 vehicles for their waste removal. This gives a ratio of one vehicle for every 777 households or one vehicle for every 1625 people. This results in weekly refuse removal rate is at 79.7% for Carletonville Local Municipality.

The Witbank local municipality has approximately 119 874 households being serviced by 149 vehicles giving it a ratio of 804 households for every one vehicle or one vehicle servicing 2796 people. The weekly refuse removal rate is 67.2% for Witbank.

The Welkom local municipality has a rate of one vehicle for every 1079 households as 194 336 households are relying on 180 vehicles giving a ratio of one vehicle for every 2375 people and a weekly refuse removal ratio for this area is at 86.3% for Welkom.

Table 14. Technical constraints in the study area

Area	Households	Vehicles	Ratio	Population	Vehicles	Ratio	Weekly refuse removal
Klerksdorp	120 442	219	1: 549	420 545	219	1: 1920	89%
Carletonville	102 624	132	1: 777	214 553	132	1: 1625	79.7%
Witbank	119 874	149	1: 804	416 625	149	1: 2796	67.2%
Welkom	194 336	180	1: 1079	427 640	180	1: 2375	86.3%

The significance of this section is that it gives an understanding on the transportation segment of the waste system. It is evident that vehicles play a crucial part in the waste system and ultimately in waste minimisation. The result of an efficient transportation system for the collection, sorting and diversion of waste is that waste is able to be minimised at a fast pace while at the same time providing effective service delivery to the local municipality. A lacking transportation system gives little or no priority to waste minimisation as the focus is on collection and landfilling. This is due to the fact the pressure is being placed on the drivers and on the waste management directorates. As a result the vehicles are constantly breaking down, hence the low weekly refuse removal rates and the turn over time for their service and repairs is time costly.

6.3.4 Financial Constraints

Figure 59 represents the overall budget for the local municipality versus the allocated budget towards the waste management services. The values from Figure 59 represent the 2014/2015 financial year and has been selected to describe the significance of the budget meant for waste services. We can appreciate that the allocated budgets towards waste management services in the municipalities are small compared to the overall budget of the municipality. For the Klerksdorp local municipality, 16% of its overall budget is allocated towards waste management. For the Carletonville local municipality 13% of its budget is allocated towards waste management. For the Witbank local municipality 6% of its overall budget is allocated towards waste services and 8% of the Welkom local municipality budget is allocated for waste management services. The budget allocated for waste management services is utilised towards human resources management (e.g.

salaries, education and development of personnel) vehicles, tools and equipment, maintenance of the landfill sites and permits.

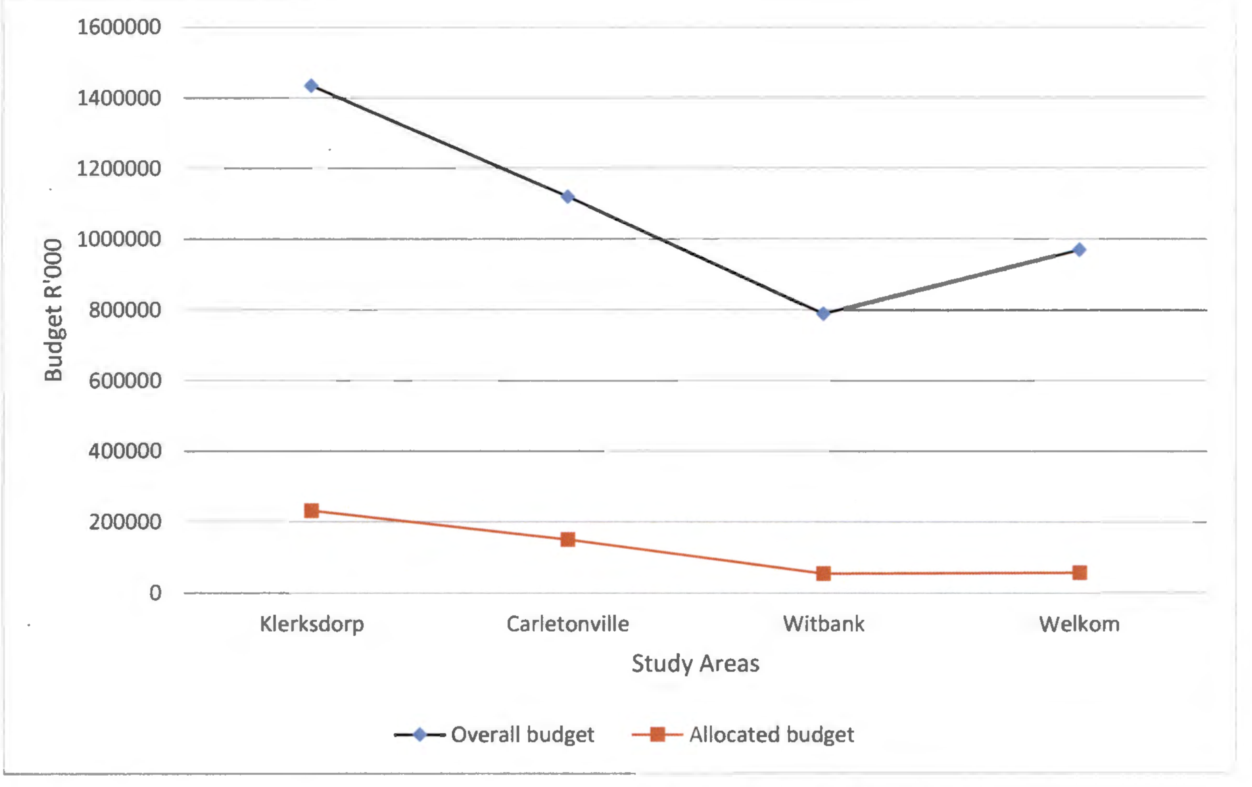


Figure 59. Overall budget vs the allocated budget in study areas in 2014/2015.

The significance of section 6.3.4 is to highlight the fact the budgets play a very important role in the entire waste chain. The allocation of funds to waste services enables the effective and efficient operation of that system. The implication of a low budget is that challenges cannot be resolved timeously. Investments in resources such as the development of personnel by providing educational opportunities, the servicing of vehicles and equipment, the purchasing of new equipment and asset and the recruitment of qualified and experienced personnel and the initiation of suitable waste minimisation programmes cannot take place. Lower budgets allocated towards waste services have an impact in minimising waste because resources cannot be effectively transferred or relocated.

6.3.5 Institutional Constraints

Figure 60 represents the current organogram for the waste management directorates which fall within the community services structures. This structure consists of community services (e.g.

library services and parks and recreational services), waste management services and traffic safety services. The constraints fall within the command and control channels, where the waste management directorates have to report to the community services general or manager. And so the challenges arise when proper support in terms of resources required for waste management services has to be obtained.

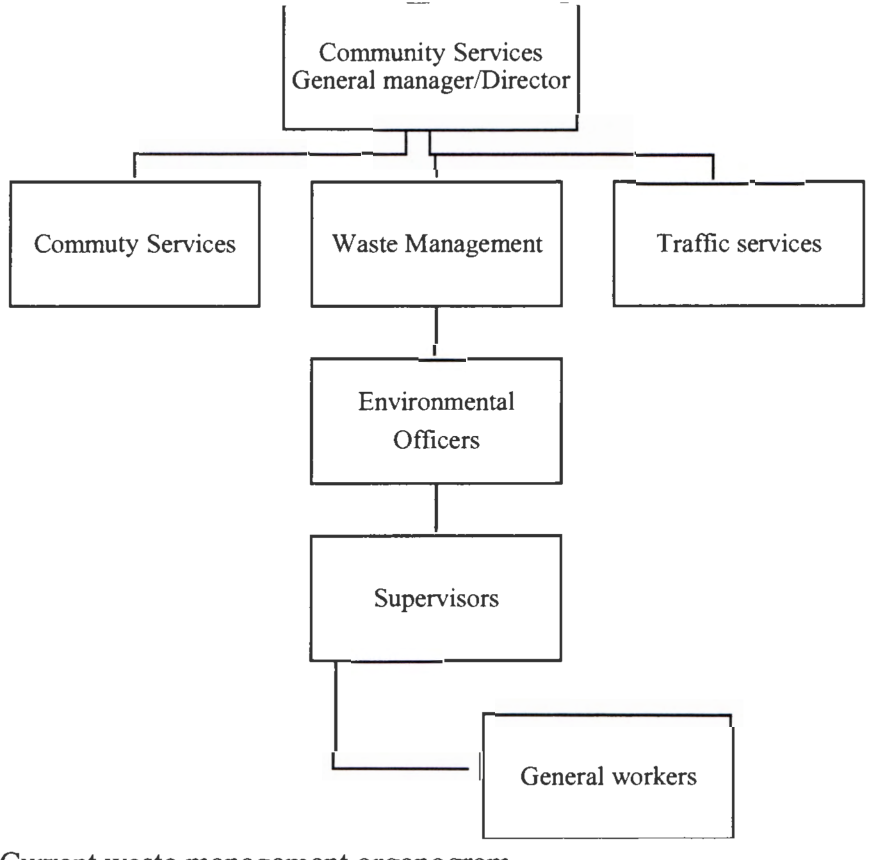


Figure 60. Current waste management organogram

The importance of this section 6.3.5 is that it provides a view of the current organogram for the waste directorates reporting and management systems. The limitations of such an organogram is that reporting is to none subject matter experts. The implication is that challenges being experienced cannot be satisfactorily addressed and resolved. This usually is the result when higher management and senior management don't have the necessary skills and understanding to deal with challenges pertaining to a different environment from what they know. There are often no clear roles and functions of the various departments defined in relation to solid waste management and also no single person or committee designated to coordinate their projects and activities. It should be also noted that legislation is only effective if it is enforced. Therefore, comprehensive legislation, which avoids the duplication of responsibilities, fills in the gaps of important regulatory functions, and is enforceable is required for sustainable development of solid waste management systems.

6.3.6 Economic Constraints

Economic and industrial development play key roles in solid waste management. Obviously, an enhanced economy enables a better financial climate for allocation of funding for sustainable solid waste management in a sustainable manner. However, secondary cities have weak economic bases and hence insufficient funds for sustainable development of solid waste management systems. Local industry could be encouraged to produce relatively inexpensive solid waste equipment and vehicles to reduce and in some cases totally eliminate the need for importing expensive foreign equipment for solid waste management. Such local industry can also supply associated spare parts, lack of which is often responsible for irregular and insufficient solid waste collection and disposal services. However in secondary cities, the lack of industry manufacturing solid waste equipment and spare parts and a limited foreign exchange for importing such equipment and spare parts are the rule rather than exception.

Waste recycling activities are affected by the availability of industry to receive and process recycled materials. For instance, the recycling of waste paper is possible only when there is a paper mill within a distance for which the transportation of waste paper is economical. The weak industry base for recycling activities is a common constraint for the improvement of solid waste management in developing countries.

6.3.7 Social Constraints

The social status of solid waste management workers is generally low in both secondary cities and metropolitan areas. There exists a negative perception work which involves the handling of waste or unwanted material. People employed in such industry tend to have low esteem because of the work they do. Because of insufficient resources available in the local government sector, collaborative projects often have attempted to mobilize community resources and develop community self-help activities. Results of such collaborative projects are a mixture of success and failures. Failed projects with inactive communities usually did not provide people in the community with economic as well as social incentives to participate in activities. The social incentive is based on the responsibility of individuals as part of the community for the improvement of the community, and is created by public awareness and school education programmes. The lack of public awareness and school education about the importance of proper solid waste management for health and well-being of people severely restricts the use of community-based approaches in developing countries. At dump sites, transfer stations, and street refuse bins, waste picking or scavenging activities are common scenes. People involved have not received school education and vocational training to obtain knowledge and skills required for other jobs. They are also affected by limited employment opportunities available in the formal sector. The existence of waste pickers/scavengers often creates an obstacle to the operation of solid waste collection and disposal services. However, if organised properly, their activities can be effectively incorporated into a waste recycling system. Such an opportunistic approach is required for sustainable development of solid waste management programmes in developing countries.

6.3.8 External Waste Factor Constraints

External factors have an impact on waste management systems. External factors are the issues that arise from outside the local government institutional activities as shown in figure 61.

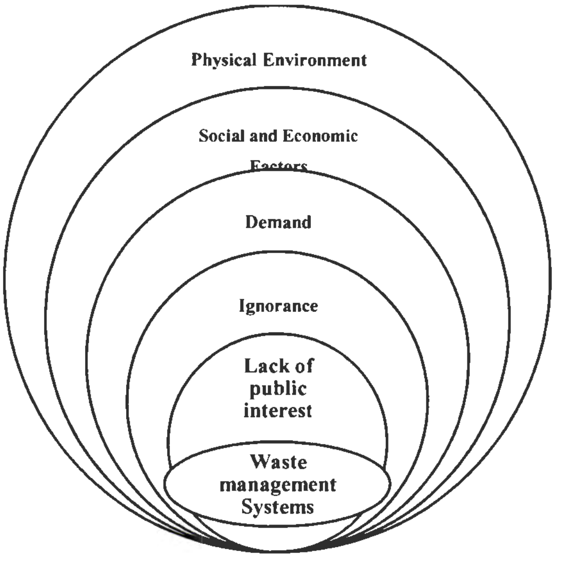


Figure 61. External factors influencing the waste system

a) Public Interest

Interest is one of the fundamental driving forces that push individuals to take action and pursue particular goals. The lack of public interest in waste management denotes the absence of a desire to comply with the municipal waste management by-laws. People who lack interest tend to be very negative and have excuses for not attending waste awareness campaigns. People who have interest tend to be positive and are very eager and energetic in giving attention to waste awareness issues. It was observed that most people in the study area have no interest whatsoever regarding waste. This was evident when the turnaround to waste outreach programme was poorly attended. The organisers at the Welkom local municipality has anticipated approximately 200 people when only 50 arrived. It has also been observed that a lack of emphasise on waste minimisation is being placed by the municipalities.

b) Ignorance

The level of ignorance for waste minimisation, the concept of re-uses, reduce and recycle, displayed by people is very discouraging. There is a basic awareness of waste service and waste management but a lack of adherence to it. For example, there is official signage in particular locations clearly marked; 'Do not dump – Offenders will be prosecuted'. Yet, dumping continues at that very site. Even though there is a lack of awareness amongst people in the selected areas, there is a national drive for waste minimisation and recycling. Ignorance is a very critical factor because even if funds are allocated for awareness, nothing will materialise in ignorance.

c) Demand

The specific factors affecting system performance include the demand for a specific action and the system's response to the demand. Urban growth is outstripping municipal capacity and it is one of the major problems resulting in inadequate waste management. Achieving equity in service level to previously disadvantaged communities is also recorded as a persistent problem. Therefore the demand for waste services by the increase in population has far exceeded the ability to provide services.

d) Social and Economic Status

The drive for providing waste service to communities is dependent on their social and economic status. For example in Klerksdorp and Witbank it was observed that priority is being given to more affluent residential neighbourhoods. Such neighbourhoods hardly struggle with their refuse collections. However it was observed in the Welkom and Carletonville areas that less priority is given to the poorer communities. These communities always have a backlog and a pile up of waste in their areas.

e) Physical Environment

When waste is not being collected in a specific area, residents tend to find the nearest open area and dump their waste there. This is how many areas tend to have illegal dumping sites. It was observed in the Henneman area that a lack of service from the waste directorate has caused the sporadic opening of illegal dumping sites. In Klerksdorp dumping illegally also take place in the closest available land. Normally garden waste and construction waste make up the bulk of illegal waste in these areas.

Plate 11. Illegal dumping in Klerksdorp

Plate 12. Illegal dumping at Welkom

6.4 Summary

According to the weekly waste collection rates presented earlier, waste collection is generally effective in the local municipalities in the selected areas. However, in the same areas, service provision strains are showing. None of the municipalities has a 100% service record due to various inefficiencies and cost constraints. The causes of these inefficiencies and cost constraints should be addressed. Waste collection should be further investigated in smaller communities and farmland to consider sustainable waste removal systems that could be applied to these communities where waste removal services cannot be rendered. Little or no effort is made to reduce or recycle waste in the municipalities. Recycling centres are available at some landfills but these are not being utilised. There is however a need for recycling stations when the large numbers of waste pickers on landfill sites are taken into consideration. Due to the distances to the landfill sites in the municipalities, waste transportation is an area of concern and historically waste has not been transported long distances. Transportation vehicles are in most cases not in good condition and are in need of repair or replacement. Consequently a few, often inefficient landfills are developed in each town. Given that the resource requirements for managing landfills have been increasing with increased public awareness and legislative changes, these resources should be re-visited to achieve maximum efficiencies with regards to waste disposal. On the basis of the results, objective 4 of the study has been addressed.

CHAPTER 7: DESIGN OF A WASTE TO LANDFILL MINIMISATION CHAIN

7.1 Introduction

Chapter 7 addresses objective 5 of the study, which is to design a waste to landfill minimising model. Section 7.2 presents the key findings of the study with a key focus on the municipal waste chain and the minimisation of waste along the chain. The processes in the waste chain, the interfaces between them and the limitations as identified through data analysis in Chapters 3-6 are focused on. Section 7.3 presents the underlying theoretical base of the model whereas Section 7.4 presents the current waste minimisation models. The input elements for the proposed model is described in section 7.5 and the regression analysis is presented from Section 7.6 through to Section 7.7. The proposed integrated waste process model is describe in Section 7.8 with applicable equations attached.

7.2 Key Findings of the Study

Data analysed and results are presented in Chapters 3-6. For the purpose of building the model, the key findings so far are:

- There are inherent challenges of the design in the MWM systems.
- Prioritisation of needs by waste directorates is not appropriate for an effective waste minimisation programmes.
- There are severe constraints in the internal institutional structure of the municipal waste management systems.
- There is insufficient managerial and technical capacity in the individual municipal waste directorates.
- High costs associated with the transportation of recyclables from the rural areas to the city centres, where the recycling companies are situated, are prohibitive.
- Metropolitan areas have put adequate facilities and initiatives in place in support of their programmes in minimising waste. These areas have even gone to extremes by imposing landfill bans at certain interval, something that is lacking in the secondary cities.
- Relevant waste minimisation models - lack of location specific models that addresses the local municipalities of secondary city's needs.

- Models imported from other locations do not necessarily fit the specific requirements of secondary cities in South Africa. This is the point which this study wishes to address and the results of which will be outlined in chapters seven and eight of the study.
- More waste is being generated and the amount being disposed or ending at the landfill site is greater than what is then what is being recovered and recycled.
- Domestic waste is the dominant form of waste stream in the study areas which also includes waste from local business is the most dominant form of waste stream at all four sites
- Variations in the waste stream of each of the four sites should inform the priorities decided upon with respect to modelling minimisation.
- The carrying capacity of the landfill site not being able to sustain any future waste disposal as some of the sites are reaching their lifespan and their carrying capacity.
- There seems to be a misalignment in the structure of the waste directorates as some personnel are further allocated to serve in areas such as cemeteries, parks and municipal facilities. There is a gap in middle management causing a delay in the chain of command.
- The budget allocated towards waste services is insignificant compared to the overall budget of the local municipality. Budgetary constraints further cause delays in service delivery.
- The operational status of vehicles utilised in the waste system is very low taking into account the amount of the waste being generated and the areas of responsibility.
- The selected study areas do not seem to have precise and clear programmes that are solely and specifically aimed at minimising waste. Instead the financial management and asset management strategies are initiated to overhaul the entire outdated municipal systems.
- Observations suggest that suitably qualified persons should manage in-house programmes and other programmes as these have a major impact in educating people about waste minimisation.

7.3 Model Underlying Theoretical Base

A system may be closed or open depending on its type. The waste management system, is an open system that is both physical and social. This means its physical components can be treated like any other system that is natural or man-made (Marshall, 2013). The elements in this context can be identified, measured, manipulated and re-engineered to cause predetermined system outputs at the end. Its social identity brings in the human element in terms of people, firms, organisations, settlements, information flows and how these changes in time and space. The social component is far more difficult to control within a system's environment because the behaviour of the players does not often follow natural laws as is common in sciences such as Physics and Chemistry. Using a platform of rational behaviour, the probability of certain outcomes can still be predicted in terms of general patterns. This calls for a flexible and multi-dimensional systems theory that must be responsive to these two contradictory behavioural characteristics (Drack, 2010). Both systems dealt with in the field of environmental science are space bound and change with time, and the space-time-continuum allows for the possibility of integrating the social and the physical components of the waste chain in practice. A waste chain as a physical-social system is made up of processes and the interfaces that separate different processes as waste moves from generation to final disposal (Ruhiiga, 2016).

7.4 Current Waste Minimisation Models

The first attempt at the classification of waste management models was by Macdonald (1996) where fifteen models were characterised into nine types. The problems were characterised according to their approach to time, cost minimisation, problem solving, measuring environmental impacts and economic analysis. Bojrklund (1998) further introduced some new types of models onto the environmental performance and technology selection which include characteristics such as input-output analysis, multi criteria optimisation and multi criteria analysis. Morrisey and Browne (2004) tried to classify the models and they introduced three categories which are cost-benefit analysis, life cycle analysis and multi-criteria analysis. The methodology in all these models does not give separate sets of solutions. Stypka (2007) proposes three categories of models which are White, Grey and Green models. The distinctive feature of each model is its approach to a problem. The assumptions of White models are that all input data are absolutely correct and therefore, use different optimisation procedures for a solution. Grey models rely on probability by applying different mathematical tools. Green models adopt the concept of sustainable development and seek solutions through life cycles analysis (LCA), decision support systems and multi-criteria techniques to solve problems. Learning classifier system models focus on environmental impact, neglecting social and economic consequences of the analysed solutions. The life cycle analysis models from the green approach appeared to be the best choice when seeking the best sustainable development solutions for waste management, although there is no dominant municipal solid waste management model.

7.5 Input Elements for Proposed Model

The proposed integrated waste process (IWP) model is built around inputs, processes and outputs all housed within waste minimisation techniques that reduces the amount of waste as it moves down the waste stream.

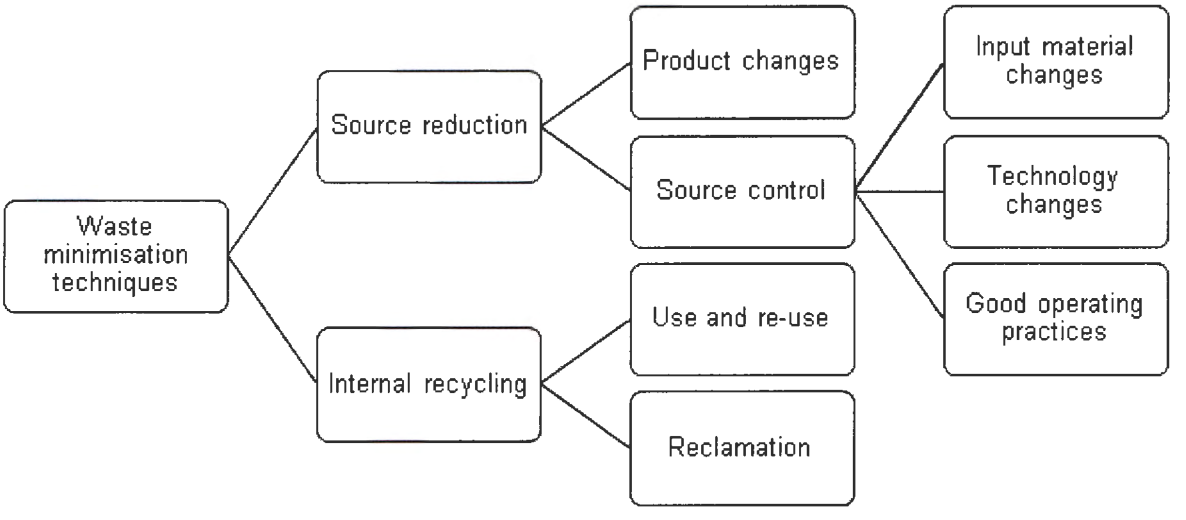


Figure 62. Input elements for the proposed model

7.6 Analysis

In modern sciences, regression analysis is a necessary part of virtually almost all data reduction processes. In regression analysis is based on the relationship, called the regression function, between one variable Y (the dependent variable) and several other called the X (independent variable). The following equation is utilised: $Y=X_1+X_2+X_3+X_4+X_5$

Y...Dependent variable (predicted by a regression model), Y*...Dependent variable (experimental value)

X_i (i=1, 2,..p)..ith independent variable from total set of p values, b_i (i=1, 2,..p)..ith coefficient corresponding to X_i

b_0...intercept or constant, k=p+1...total number of parameters including intercept (constant), n..number of observations, i=1,2,..p..independent variable index, j=1,2,..n..points' index

If a regression function is linear in the parameters it is termed a linear regression model otherwise it is nonlinear. Therefore the proposed model is a mathematical linear model.

7.6.1 Descriptive Statistics

Table 15 shows the descriptive statistics obtained from the study area. This includes the amount of waste disposed (Y), the amount of waste generated (X1), the amount of waste recovered and recycled (X2), the amount of waste being treated (X3), the amount of waste thermally treated (X4), and the amount of waste in storage impoundments (X5). (Waste =tonnes)

Table 15. Regression statistics output

Summary statistics (Quantitative data):							
Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum (tonnes)	Maximum (tonnes)	Mean (tonnes)	Std. deviation
Y	8	0	8	13916.000	663692.000	311208.875	247232.670
X1	8	0	8	829158.000	6325470.000	2884271.125	2281061.473
X2	8	0	8	10516.000	37083.000	19415.875	9322.671
X3	8	0	8	13902.000	659115.000	192467.500	214888.929
X4	8	0	8	1260.000	32186.000	10690.250	12551.554
X5	8	0	8	425.000	6501.000	2267.750	2036.630

7.6.2 Regression Outputs

Table 16 represents the regression outputs for the independent and dependent variables for the study areas. The multiple $R = 0.74$, the $R^2 = 0.55$. The adjusted $R^2 = -057$. Therefore the standard error for the variable is equal to *2855897.14*. This has been done observing 8 variables.

Table 16. Regression statistics output

Regression Statistics	
Multiple R	0.743060683
R Square	0.552139179
Adjusted R Square	-0.567512873
Standard Error	2855897.144
Observations	8

7.6.3 Correlation Matrix

Table 17 describes the correlation matrix for the dependent and independent matrix. The lowest values at set at *(X^1, X^2)* with the highest values set at *(X^4, X^4)*.

Table 17. Correlation matrix

Correlation matrix:						
	X^1	X^2	X^3	X^4	X^5	Y
X^1	1	-0.723	0.613	0.907	0.434	0.847
X^2	-0.723	1	-0.310	-0.611	-0.111	-0.475
X^3	0.613	-0.310	1	0.828	0.211	0.625
X^4	0.907	-0.611	0.828	1	0.405	0.745
X^5	0.434	-0.111	0.211	0.405	1	0.194
Y	0.847	-0.475	0.625	0.745	0.194	1

7.6.4 ANOVA

Table 18. Analysis of variance

Analysis of variance (Y):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	377868166610.014	75573633322.003	3.023	0.267
Error	2	49999784386.861	24999892193.431		
Corrected Total	7	427867950996.875			
Computed against model Y=Mean(Y)					

7.6.5 Model Parameters

Table 19 represent the parameters of the proposed model. The lower bound (95%) is set at -184.8 where the intercept value is set at *-1522574.5*. The upper bound (95%) is set 122.5 where the intercept is set at *998751.9*.

Table 19. Model parameters for proposed model

Source	**Value**	**Standard error**	**t**	**Pr > |t|**	**Lower bound (95%)**	**Upper bound (95%)**
Intercept	-261911.286	292996.728	-0.894	0.466	-1522574.459	998751.886
X1	0.193	0.083	2.316	0.147	-0.165	0.550
X2	9.330	10.370	0.900	0.463	-35.290	53.950

X3	0.554	0.648	0.855	0.483	-2.234	3.342
X4	-18.641	20.157	-0.925	0.453	-105.369	68.088
X5	-31.158	35.716	-0.872	0.475	-184.831	122.515

7.6.6 Equation for the Proposed Model

Equation: $Y = X^1 + X^2 + X^3 + X^4 + X^5$

Therefore: $Y = -261911.28 + 0.19*X1 + 9.32*X2 + 0.55*X3 - 18.64*X4 - 31.15*X5$

7.6.7 Standardised Coefficient

Table 20 represent the standard coefficient of the proposed model where the lower bound (95%) is set at -5.349 at X^4 with a value of *-0.946* and the upper bounds (95%) set *5.076* at X^1 with a value of *1.776.*

Table 20. Standard coefficient of the model

Standardized coefficients (Y):						
Source	**Value**	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
X1	1.776	0.767	2.316	0.147	-1.524	5.076
X2	0.352	0.391	0.900	0.463	-1.331	2.034
X3	0.482	0.563	0.855	0.483	-1.942	2.905
X4	-0.946	1.023	-0.925	0.453	-5.349	3.457
X5	-0.257	0.294	-0.872	0.475	-1.523	1.009

Figure 63 is a graphical representation and should be read in conjunction with Table 20. It can be observed that variables *X4* and *X5* fall below the point of o and that *X1, X2* and *X3* fall just above the point of 0. However, all the variables are within the upper and lower bounds. Table 21 represents the summary of the variable predictions and the residuals. Re-enforcing this table are Figure 64, 65, 66 and 67.

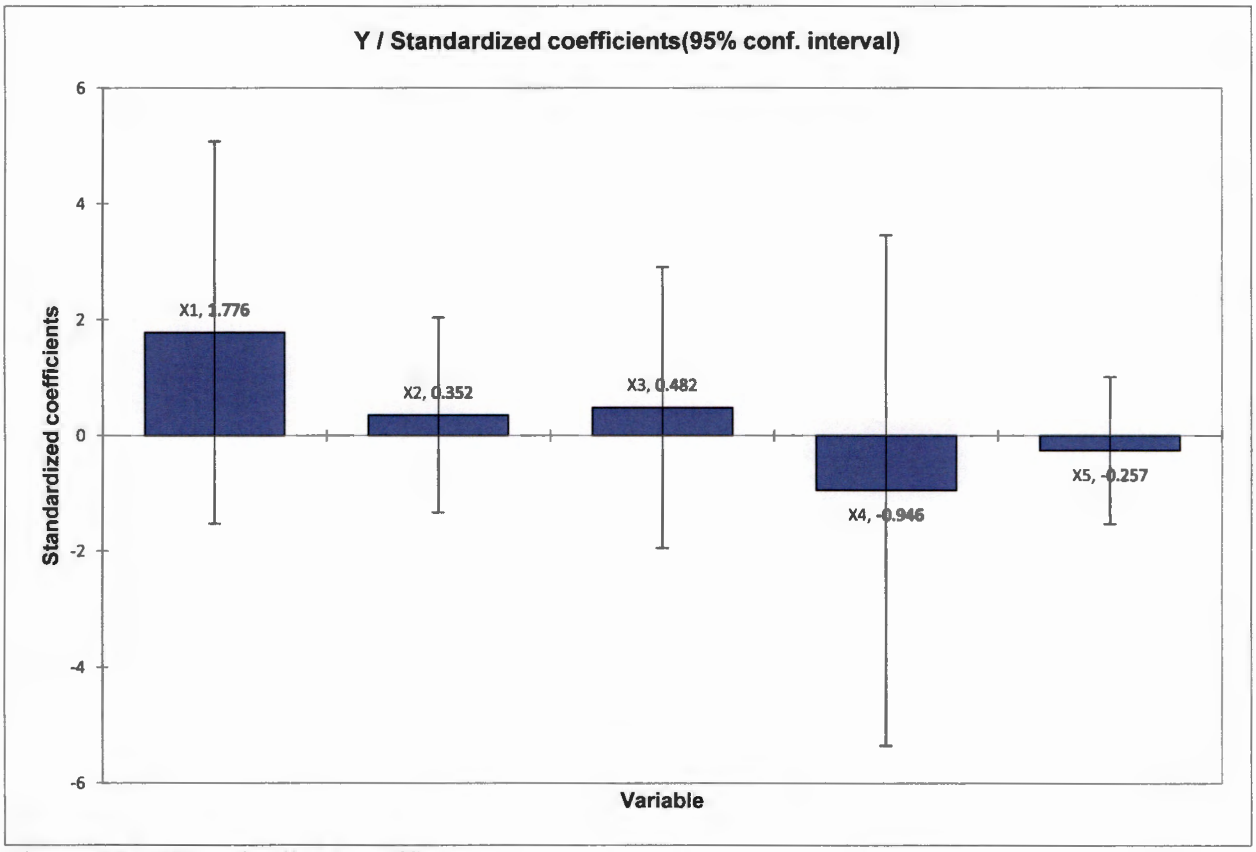


Figure 63. Y/Standardised coefficients

Table 21. Predictions and Residuals

Predictions and residuals (Y):

)bservatio	Weight	Y	Pred(Y)	Residual	Std. residual	ɜv. on pred. (	bound 95% (	bound 95% (	ɔn pred. (Ob	ɹnd 95% (Obs	ɹnd 95% (Obs
Obs1	1	13916.000	152317.883	-138401.883	-0.875	93778.300	-251177.574	555813.340	183832.156	-638648.046	943283.812
Obs2	1	149172.000	160451.657	-11279.657	-0.071	99832.282	-269091.982	589995.297	186992.986	-644114.223	965017.537
Obs3	1	254486.000	195844.426	58641.574	0.371	150871.328	-453302.504	844991.355	218545.303	-744480.121	1136168.972
Obs4	1	142979.000	15641.521	127337.479	0.805	125035.574	-522343.131	553626.172	201578.240	-851679.644	882962.685
Obs5	1	170870.000	238463.337	-67593.337	-0.427	148540.226	-400653.670	877580.344	216942.598	-694965.324	1171891.998
Obs6	1	432575.000	481422.792	-48847.792	-0.309	152653.598	-175392.629	1138238.214	219779.465	-464211.923	1427057.508
Obs7	1	663692.000	602438.374	61253.626	0.387	151325.898	-48664.417	1253541.164	218859.361	-339237.452	1544114.199
Obs8	1	661981.000	643091.010	18889.990	0.119	156766.067	-31418.937	1317600.957	222655.546	-314918.481	1601100.502

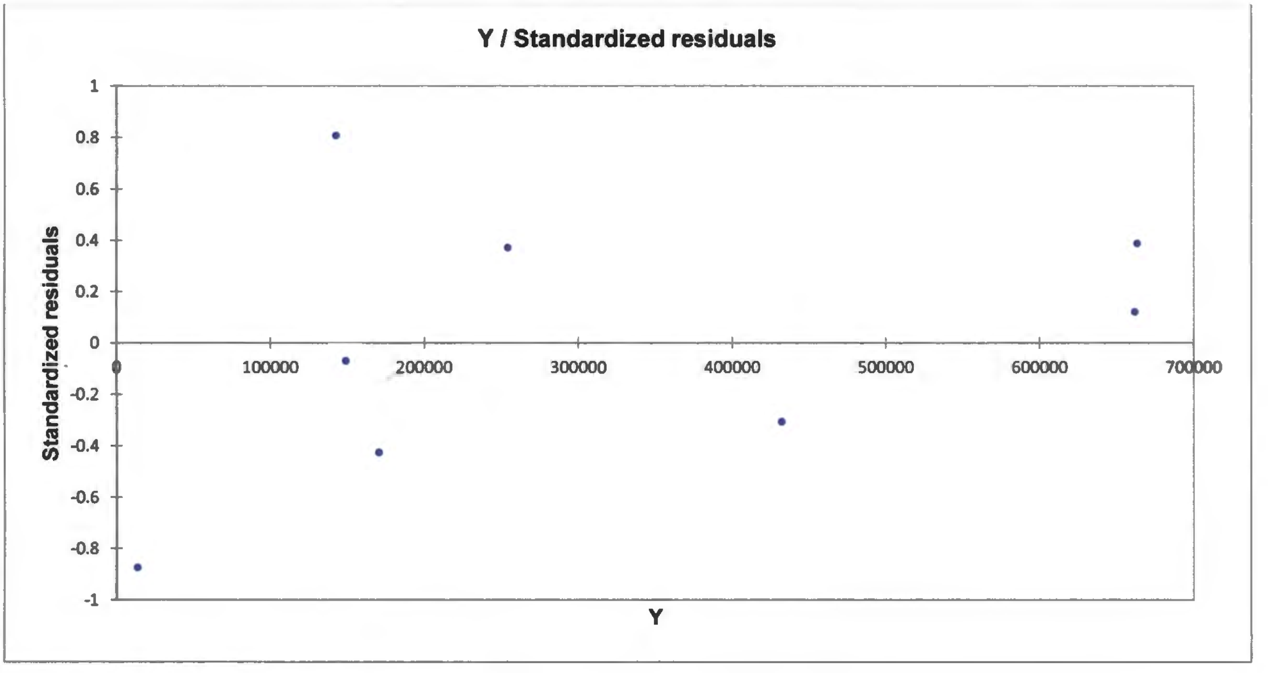


Figure 64. Y/Standardised residuals

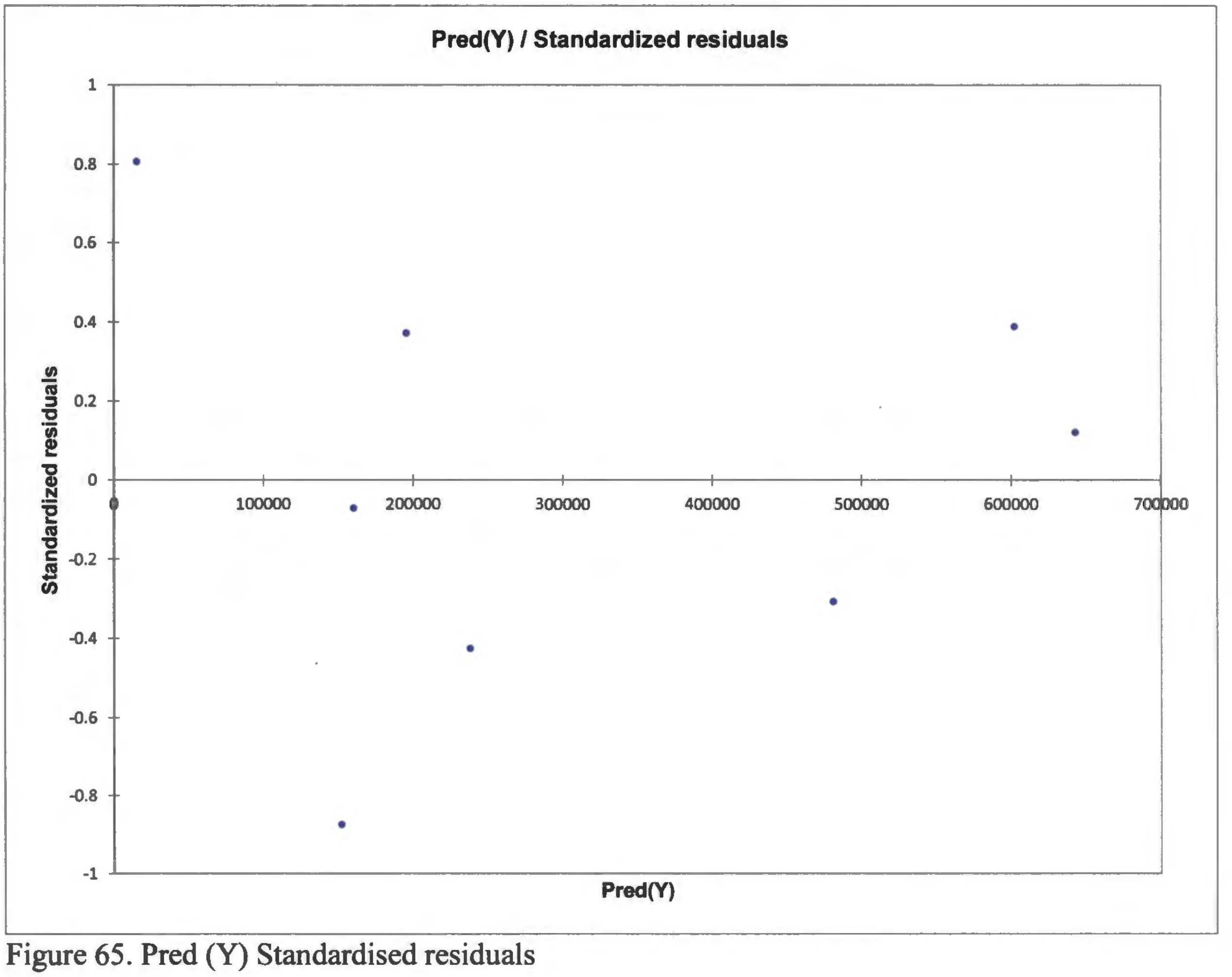


Figure 65. Pred (Y) Standardised residuals

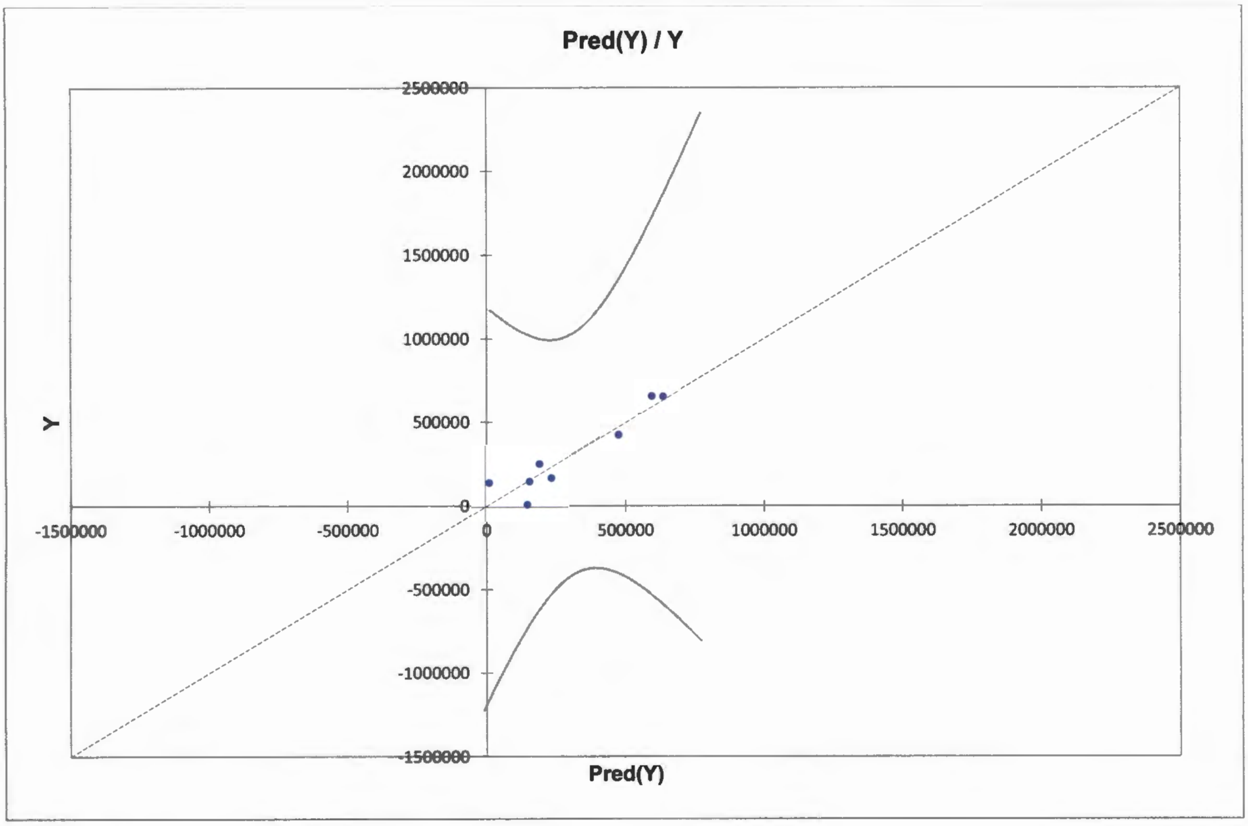


Figure 66. Pred (Y)/Y

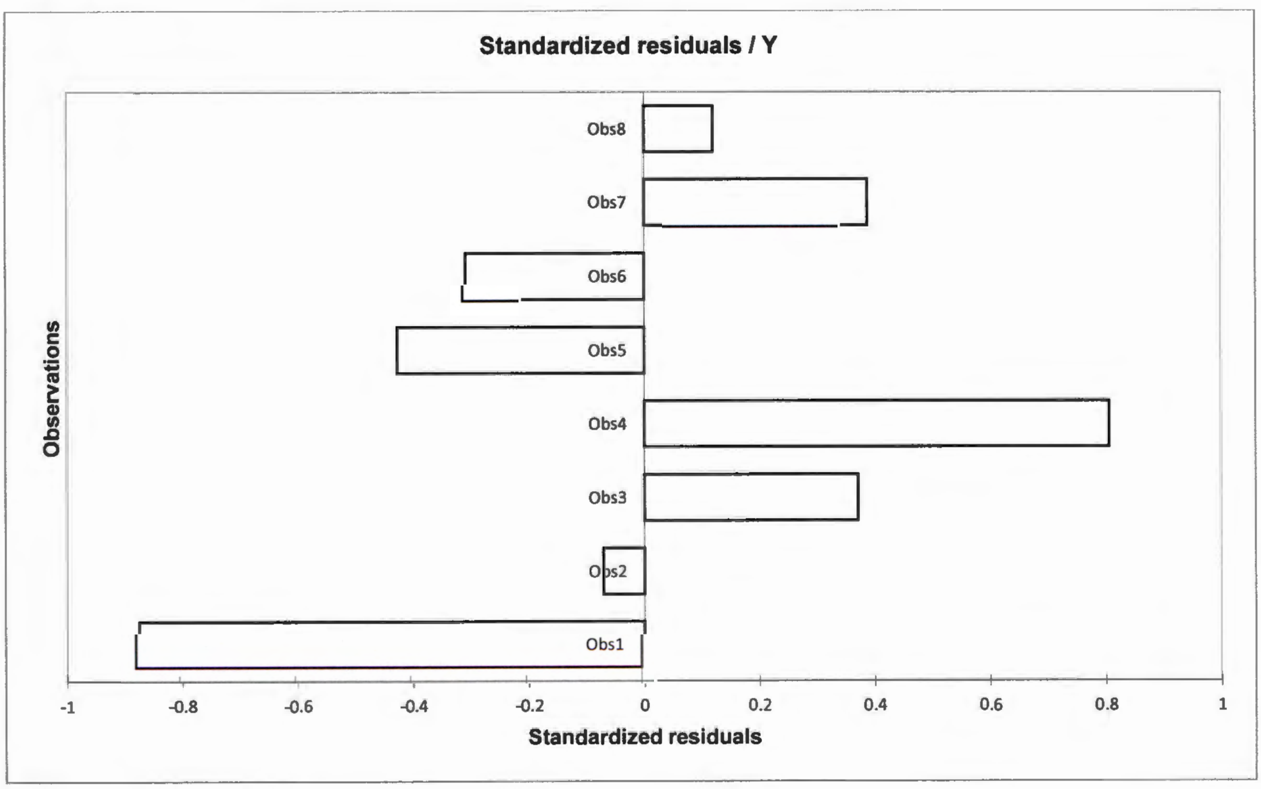


Figure 67. Standardised residuals/Y

7.6.8 Hypothesis Testing

Test interpretation:

H_0: The difference between the mean is equal to 0.

H_a: The difference between the means is different from 0.

As the computed p-value is lower than the significance level alpha=0.05, therefore rejecting the null hypothesis H_0, and accept the alternative hypothesis H_a. The risk to reject the null hypothesis H_0 while it is true is lower than 0.92%.

Table 22. Confidence level table

95% confidence interval on the mean:	
104517.194,	517900.556 [
Difference	311208.875
t (Observed value)	3.560
|t| (Critical value)	2.365
DF	7
p-value (Two-tailed)	0.009
alpha	0.05

7.7 Assumption of the Proposed Model

The following are assumptions of the proposed model:

- Reducing the number of illegal and mismanaged operating landfill sites and working towards regionalisation of landfill will decrease the impact of waste disposal on the environment.
- Regional waste disposal sites are one of the targets that the NEMWA has identified and needs to be implemented.
- Depending on the size of the community being served and the types of waste being generated, materials recovery facilities may be established at the transfer stations. This would effectively recover material closer to source and reduce the quantity of waste to be transported and disposed of, thus reducing costs along the waste management chain.

7.8 The proposed Integrated Waste Process model (IWP)

The proposed model in figure 68 is hereby termed the Integrated Waste Process model or IWP. It is built upon the knowledge of existing waste management conditions on the ground and can be utilised to assit the process where traditional models are not cabable of minimising waste along the waste chain.

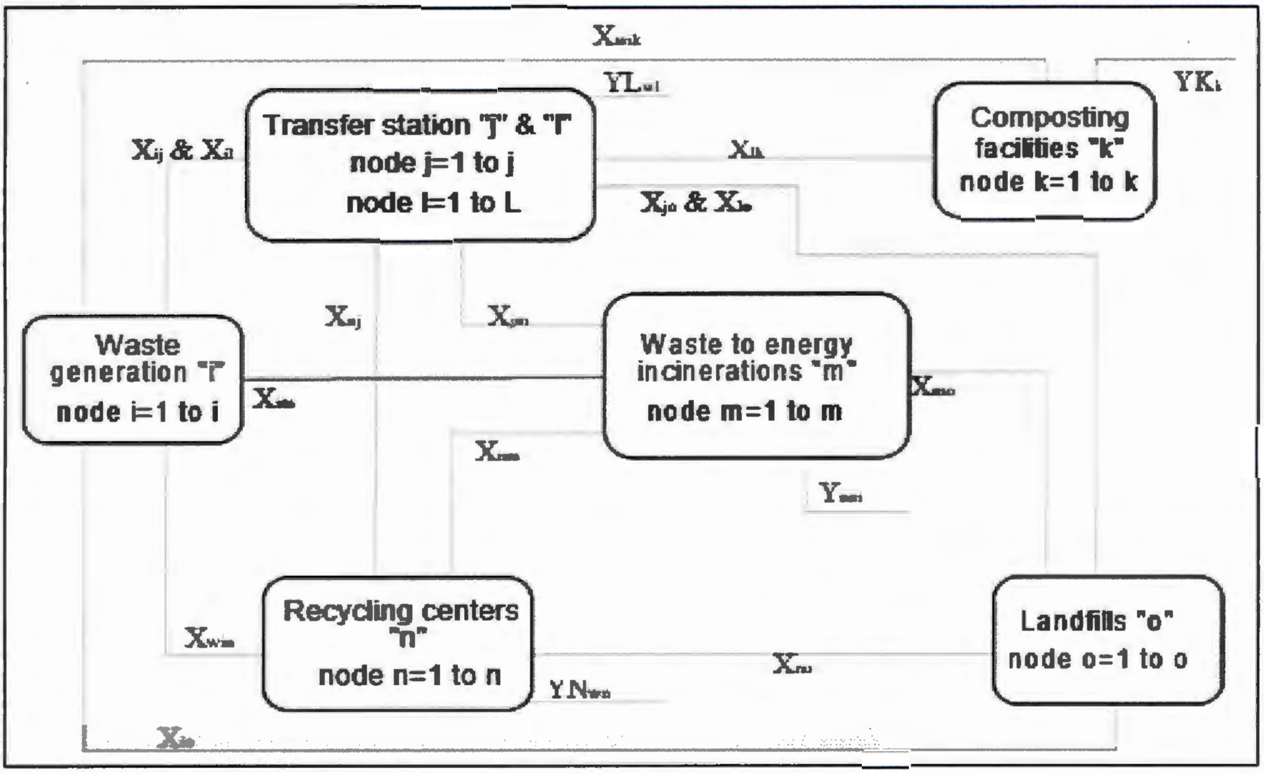


Figure 68. The IWP model

The model has six nodes, one representing waste generation and the remainder the five sets of processing and disposal facilities. The notations in the model represent time, waste source and facility types as the origin and destination and waste types. More specifically, time is identified by t, and waste generation nodes by the index i,. Transfer stations are identified by the indices j and l,. At transfer station l mixed waste is separated for recyclable material, while at j they are not. Therefore waste is transported from waste generation node i to transfer stations j and l at time t is labeled X_{ijt} and X_{ilt}. Composting facilities are identified by the index k, *kÎK*, and waste shipped from i to k is denoted X_{ikt}. Recycling facilities are identified by the index n, *nÎN*, and the types of waste are identifying by w. Hence, waste shipped from i to n is denoted X_{wint}. Incinerator facilities are identified by the index m, *mÎM*, and wastes shipped from waste generation nodes to incinerator facilities are denoted X_{imt}. Finally, landfill facilities are identified by index o, *oÎO*, and the amounts of waste shipped from i to n are denoted X_{iot}. The labelling of waste shipped among facilities will use the same pattern. The waste that is processed in recycling and composting facilities is identified by w. The types of waste consist of paper, glass, plastic, aluminium, and yard waste. Mass balances account for the conservation of mass in the system. At generation sites, all waste must be sent to either processing or landfill sites. At processing sites (incinerator, recycling, and transfer station/material recovery facility), all incoming waste must equal its residue after processing (adjusted for its conversion rate) plus unprocessed waste sent to landfill or other facilities. At composting sites, all incoming waste equals outgoing waste. At landfills, all incoming waste is absorbed by the landfill.

At waste generation node i:

Waste is generated at point sources representing neighbourhoods. Decisions at such nodes include the share of waste for recycling, the level of promotion, the participation rate and the amount of waste sent to the facilities. At the source, all waste generated is distributed to facilities existing in the waste management system, as represented by equation (Davis et al, 2009).

$$WG_{it} = S_j X_{ijt} + S_{wk} X_{wikt} + S_l X_{ilt} + S_{w,n} X_{wint} + S_m X_{imt} + S_o X_{io}t \quad (1)$$

where WG_{it} is the amount of waste generated in neighbourhood *i* at time *t*. The decisions at the neighbourhood level involve determining the share of waste allocation to each facility, including the share of sorted waste sent to recycling centres. The total amount of recyclable waste $S_{w,n} X_{wint}$ in neighbourhood sent to recycling centres depends on the community participation rate CPR_{it} and maximum share of recycling material $MXSRC_i$. Hence, the total amount of recyclable waste cannot exceed the product CPR_{it}. WG_{it} . $MXSRC_i$. This requirement yields equation:

$$S_w S_n X_{win}t = CPR_{it} \cdot WG_{it} \cdot MXSRC_i \quad (2)$$

The model allows the local municipality, in this case, the waste management directorate, to influence the community participation rate through a recycling promotion, including public education, fliers, and advertisement. The promotion level $COPL_{it}$ is measured by the amount spent per person in community *i* (R/person). It is assumed that the higher the promotion, the higher the cost, and the higher the participation rate. However, the level of participation depends on how a community reacts to the promotions. The same level of promotion may or may not induce the same participation rate in two different neighbourhoods. The success of the recycling promotion, besides being influenced by the level of promotion, is also determined by the awareness of the community. Presumably, two neighbourhoods with different levels of education and income, for example, will have different responses. In the model, the responsiveness factor is represented by a ideally, a should be determined through a survey and analysis in each community, as each community has its own level of awareness to minimising activities (Chertow, 2009).

At transfer station node j:

At these facilities, there is no weight reduction or waste separation. The mixed waste from neighbourhoods and other facilities is simply transferred from smaller collection trucks to bigger trucks. The mixed waste from this facility may be sent to incinerators, composting facilities, and landfills. The mass balance in this facility is given by the equation (Chertow, 2009):

$$S_i X_{ijt} + S_n X_{njt} + S_m X_{mjt} = S_k X_{jkt} + S_m X_{jmt} + S_o X_{jot}, \quad (3)$$

At transfer station/material recovery facilities, mixed waste is separated into recyclable material, combustible waste, and landfilled waste. After separation of the total waste S_wYL_{wlt}, the recycled waste is given by (Chen et al, 2012):

$$RVL_{wt} [(S_i X_{ilt} + S_n X_{nlt}] \quad (4)$$

At incinerators (waste-to-energy) facilities node m:

A change in quality and quantity takes place at these facilities. Waste may arrive from generation sites, transfer stations, and recycling facilities. It is first shredded in one particular facility before it is burned and converted to energy. The shredder facility is located adjacent to the incinerator, and is not considered as a separate node. The ashes and by-products from this process and the excess waste are shipped to landfill sites. Hence, the decision is to determine the share of incinerated waste. The output of these facilities is electricity sold to the local municipality. All mixed waste sent to these facilities are separated for combustible waste. Then, the combustible waste is shredded before it is burned in the incinerator. The amount of the ashes is computed by

$$RD . [S_iX_{imt} + S_lX_{lmt} + S_jX_{jmt} + S_nX_{nmt}] . ASHCF_m \quad (5)$$

Where RD is the fraction of waste that can be incinerated, and $ASHCF_m$ is the waste-to-ash conversion factor of incinerator m, and the amount of non-combustible waste is computed by

$$[1 - RD]^2 . [S_iX_{imt}+S_lX_{lmt}+S_jX_{jmt}+ S_nX_{nmt}] \quad (6)$$

Both ashes and the non-combustible wastes are sent to landfill facilities. Equation 6 represents the total amount of waste leaving the facilities, X_{mot} that consists of ashes and non-combustible waste.

$[1–RD] . [S_iX_{imt} + S_lX_{lmt} + S_jX_{jmt} + S_nX_{nmt}] + RD . [SiX_{imt} + SlX_{lmt} + SjX_{jmt} + SnX_{nmt} . ASHCF_m] = So\ X_{mot}$ (7)

At recycling facilities node n:

While waste may have already been sorted at the source, there typically is a need for additional processing at the recycling centre, to separate waste into recyclables and non-recyclables. Therefore, the decisions made at these centres are the share of the recycled waste and the destination of the non-recyclable waste, either to landfills, transfer stations, and or incineration. Recycling centres only receive sorted recyclable material *w* (glass, paper, plastic, and aluminium) directly from the waste sources. At these facilities, the recyclable waste YN_{wnt} is processed to remove contaminated materials before the recycled material can be sold. The total recycled waste is computed by

$$RVN_{wn} . (S_{w,i}\ X_{wint}) \quad (8)$$

where RVN_{wn} is the recovery rate of recyclable material w at recycling centre n.

7.8.1 Goals of IWP

The first goal of IWP is to protect the health of the urban population, particularly that of low-income groups who suffer most from poor waste management services. Secondly, it aims to promote environmental conditions by controlling pollution such as water, air, soil and cross media pollution and ensuring the sustainability of ecosystems in the urban region. Thirdly, IWP supports urban economic development by providing effective waste management services and ensuring the efficient use and conservation of valuable materials and resources. Fourthly, IWP aims to generate employment and incomes in the reduction of waste and lastly IWP aims to increase the lifespan of landfill sites by lowering waste volumes that are landfilled.

7.8.2 Principles of IWP

The principles of IWP are thus to:

- minimise waste generation;
- maximise waste recycling and reuse, and

- ensure safe and environmentally sound disposal of waste.

It is necessary to establish sustainable waste minimisation efforts which meet the needs of the entire urban population, including the poor. The essential condition of sustainability implies that waste minimisation efforts should be absorbed and carried by the society and its local communities. These efforts should be appropriate to the particular circumstances and problems of the city and locality, employing and developing the capacities of all stakeholders, including the households and communities requiring service, private sector enterprises and workers, both formal and informal, and government agencies at the local, regional and national levels. Waste minimisation should be approached from the perspective of the entire cycle of material use, which includes production, distribution and consumption as well as waste collection and disposal. Whilst immediate priority should be given to effective collection and disposal, waste reduction and recycling should be pursued as equally important, longer-term objectives.

7.8.3 Interest Groups

A wide range of individuals, groups, firms, institutions and organisations can and should be concerned about waste minimisation as service users, service providers, intermediaries and regulators. The implications of the model are far reaching.

a) Households, Communities and other Service Users:

Residential households are mainly interested in having effective and dependable waste collection service at a reasonably low price. Disposal and minimisation is not normally a priority demand of service users, so long as the quality of their own living environment is not affected by dump sites. Only as informed and aware citizens do people become concerned with the broader objective of environmentally sound waste disposal (Chung, 2010). In low-income residential areas where most services are unsatisfactory, residents normally give priority to water supply, electricity, roads, drains and sanitary services. Waste is commonly dumped onto nearby open sites, along roads or into drains and waterways. Pressure to improve solid waste collection arises as other services become available and awareness mounts regarding the environmental and health impacts of poor waste collection service. Poorly served residents should form community-based organisations (CBO) to upgrade local environmental conditions, improve services and/or petition the government for service improvements. CBO's which may arise in middle and upper income neighbourhoods as well as in low-income areas may become valuable partners of the government in local waste management. When sufficiently organised, community groups have considerable potential for managing and financing local collection services and operating waste recovery and composting activities. Other service users including small and large scale industrial and commercial establishments and institutions are similarly interested in reliable and affordable waste collection service. Commercial establishments are particularly concerned to avoid waste related pollution, which would inconvenience their customers. Industrial enterprises may have a strong interest in reducing waste generation and can play an active role in managing waste collection, treatment and disposal in collaboration with government authorities and/or specialised private enterprises.

b) Non-Governmental Organisations:

NGOs may help increase the capacity of people or community groups to play an active role in local in waste minimisation by contributing to people's awareness of waste minimisation; organisational capacity and the formation of community-based organisations (CBO); channels of communication between CBO and government authorities; CBO's voice in municipal planning and implementation processes; technical know-how of locally active CBO, and access to credit facilities. NGOs may also provide important support to informal sector waste workers and enterprises, assisting them to organise themselves, to improve their working conditions and facilities, increase their earnings and extend their access to essential social services such as health care and schooling for children.

c) Local Government:

Local government authorities should generally be responsible for the provision of waste minimisation, solid waste collection and disposal services. They become the legal owner of waste once it is collected or put out for collection. Responsibility for waste management is usually specified in bylaws and regulations and may be derived, more generally, from policy goals regarding environmental health and protection. Besides their legal obligations, local governments are normally motivated by political interests. User satisfaction with provided services, approval of higher government authorities and financial viability of the operation should be important criteria of successful waste minimisation efforts from the local government perspective.

The authority to enforce bylaws and regulations, and to mobilise the resources required for waste minimisation is, in principle, conferred upon local governments by higher government authorities. Problems often arise when local government's authority efforts to raise revenues is not commensurate with their responsibility for service provision. Besides waste minimisation, municipal governments are also responsible for the provision of the entire range of infrastructural and social services. Needs and demands for MSWM must therefore be weighed and addressed in the context of the needs and relative priorities in all sectors and services. To fulfil this waste minimisation responsibilities, municipal governments should establish special purpose technical agencies, and are also authorised to contract private enterprises to provide waste management services. In this case, local authorities remain responsible for regulating and controlling the activities and performance of these enterprises. Effective waste minimisation depends upon the cooperation of the population, and local governments should take measures to enhance public awareness of the importance of minimising waste, generate a constituency for environmental protection and promote active participation of users and community groups in local waste management.

d) National Government:

National governments are responsible for establishing the institutional and legal framework for MSWM and ensuring that local governments have the necessary authority, powers and capacities for effective solid waste management. In many countries, responsibility is delegated without adequate support to capacity building at the local government level. To assist local governments to execute their MSWM duties, national governments need to provide them with guidelines and/or capacity-building measures in the fields of administration, financial management, technical systems and environmental protection. In addition, national government intervention is often required to solve cross-jurisdictional issues between local government bodies, and to establish appropriate forms of association when effective waste management calls for the collaboration of several local bodies.

e) Private Sector Enterprises:

The formal private sector includes a wide range of enterprise types, varying from informal micro-enterprises to large business establishments. As potential service suppliers, private enterprises are primarily interested in earning a return on their investment by selling waste collection, transfer, treatment, recycling and/or disposal services. Operating in various forms of partnership with the public sector, they may provide capital, management and organisational capacity, labour and/or technical skills. Due to their profit orientation, private enterprises can, under appropriate conditions, provide MSWM services more effectively and at lower costs than the public sector. However, private sector involvement does not, in itself, guarantee effectiveness and low costs. Problems arise when privatisation is poorly conceived and regulated and, in particular, when competition between suppliers is lacking. Private sector waste collectors may be contracted directly by individual households, neighbourhood associations or business establishments. More often, they operate under contractual agreement with municipal authorities. In this case, the authorities commonly retain responsibility for user fee collection. This arrangement ensures more equitable service access; when private enterprises depend on the direct collection of user charges they have little incentive to provide services in low-income areas where revenue potentials are weak.

f) Informal Private Sector

The informal private sector comprises unregistered, unregulated activities carried out by individuals, families, groups or small enterprises. The basic motivation is self-organised revenue generation; informal waste workers are often driven to work as waste collectors or scavengers by poverty and the absence of more attractive employment possibilities. In some cases, informal waste workers belong to religious, caste or ethnic minorities and social discrimination is a factor which obliges them to work under completely unhygienic conditions as waste collectors or sweepers. Their association with an activity which the public perceives to be filth-related tends, at the same time, to perpetuate discrimination against them. Informal waste workers usually live and work under extremely precarious conditions. Scavenging, in particular, requires very long working hours and is often associated with homelessness. Besides social marginalisation, waste workers and their families are subject to economic insecurity, health hazards, lack of access to normal social services such as health care and schooling for children, and the absence of any form of social security. The waste collection, transfer, separation, recycling and/or disposal activities of informal waste workers constitute economically valuable services. Informal waste workers work, normally, on a .self-employed. Basis or as informally organised groups; in some cases they may be hired directly by households and/or neighbourhood groups. In general, however, the marginalised and unstable social and economic circumstances of informal waste workers make it quite difficult to integrate their contribution into the MSWM system. As an initial step, informal workers require organisational and technical support to promote their social rehabilitation and alleviate the unacceptable socio-economic conditions in which they live and work. Through the formation of co-operative societies or micro-enterprises, it is often possible to considerably increase the job stability and earnings of informal sector workers, and to enhance the effectiveness of their contribution to waste management.

7.8.4 Limitations of IWP

The following limitations of the IWP are noted:

a) Limited or lack of markets:

Problems are experienced with markets for recyclables particularly glass, newspapers and magazines, paper and cardboard. For example the Welkom, Carletonville and Witbank areas are disadvantaged by the inaccessibility of recycling companies, that is most of the major recyclers are located in the Gauteng area which results in high transportation cost. Government does not encourage recycling since it does not specify the purchase recycled commodities through its procurement procedures.

b) Fluctuating prices for recyclables:

Prices have also fluctuated significantly and as a result many recycling ventures have gone under. For example, in one instance the number of recyclers has decreased from 700 to 300 and there are significant stockpiles of recyclable commodities which have not been sold.

c) Lack of competition:

There is also concern about the lack of competition in the recycling field, which may result to monopolistic practices. There is a need to create new markets for recyclables, over and above the existing large recyclers such as SAPPI, Mondi and Collect-a-Can. The need for government control was raised.

d) Unsustainable waste minimisation projects:

A number of unsustainable recycling projects had been started in, but shut down after a relatively short lifespan. It was suggested that recycling initiatives should be registered with an appropriate authority and an EIA should be undertaken.

e) High transportation costs:

The high costs associated with the transportation of recyclables from the rural areas to the major city centres, where the recycling companies are situated, are prohibitive.

f) Lack of skills:

There is a lack of skills and capacity at the local municipality level in the area of waste management and specifically waste minimisation, recycling and re-use. Environmental health departments can possibly assist with appropriate training by utilising their health inspectors to assist with the process of waste management. Public/private partnerships with industry and the larger recycling companies should be explored.

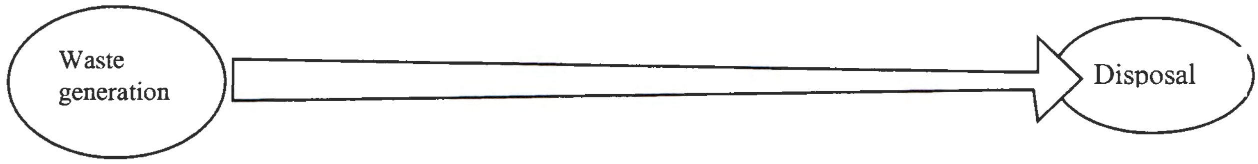
7.8.5 Empirical Testing

The IWMP model was run through field trials at the local municipalities of the selected study areas. These are Klerksdorp, Witbank, Welkom and Carletonville local municipalities. The data for waste generation consisted of the amount of waste that was generated for 2015. The results are shown in Table 23. This data was provided by the:

- waste directorate of each municipality;
- the South African Waste Information Systems (SAWIS);
- the South African Waste Information Centre (SAWIC);
- and the Department of Environmental Affairs.

Table 23. Empirical Testing Results from IWP model

TESTING AREAS	Initial input Waste generation Node: i	Transfer station Node: j Node: I	Composting facilities Node K	Waste-to – energy Node: m	Recycling centres Node: n	FINAL OUTPUT Landfills Node: o
Klerksdorp	1201474	18347	9725	99975	39158	135269
Witbank	1773059	62589	48972	101291	987569	673929
Welkom	4322357	45987	69879	2311148	89745	1805598
Carletonville	2285819	69879	87899	1236548	789850	101643



The arrow indicates the point from waste generation and the movement of waste along the waste chain to the point of disposal. As depicted from Table 23, the amount of waste is being minimised as it moves along the waste chain. At each node the set of mathematical equations as described in section 7.8 calculates the quantity of waste entering the node and the quantity of waste exiting the different nodes. The final output is the quantity of waste that can no longer be utilised and this should be a lesser amount for the landfill. Therefore the model cannot just be used to predict the final amount of waste being disposed, but can also provide solution as to which nodes along the waste chain minimises the largest amount of waste. From table 23 it can be deduced that the waste-to-energy conversion facilities account for the greatest minimisation of waste. This waste is used to convert energy for the local municipality and as a result the national electricity gridline is not under pressure. This is also a source of environmentally friendly renewable energy. Investments should be made for such facilities as they have the potential to not just supply electricity, but to create a green economic industry. The implications of which can create jobs. It can also be deduced that the composting facilities comprise the least amount of waste being minimised. It has been observed that the local municipalities in the study are have no capacity in this regard. Therefore the model has provided solutions for policy makers and uses of this model as to where interventions can be applied to fast track the minimisation of waste.

7.9 Summary

This chapter has presented the proposed waste integrated minimisation model. This is a mathematical model and aims to minimise the amount of waste moving through the waste chain. Regression analysis is described in this chapter and the hypothesis testing is applied. The assumptions of the model are made and the model described. The goals and principles of which the model is based on are presented. The stakeholder's involved in waste minimisation are also mentioned and the limitations of the model are widely described. On the basis of the findings it is relatively safe to assume that objective five of the study has been addressed.

CHAPTER 8: CONTRIBUTION, CONCLUSION AND RECOMMENDATONS

8.1 Introduction

This study was undertaken in order to design a waste-to-landfill minimisation model within a selection of secondary mining cities. The permitted landfill site for the Klerksdorp, Carletonville, Witbank and Welkom local municipalities were selected for this study and informational backgrounds for each of the selected sites was described in Chapter 1 of this thesis. The research problem was advanced in Chapter 1 and this was further strengthened and reienforced with a set of objectives together with a hypothesis to guide the study. The scope and significance of the study have been highlighted and the paradigm context and conceptual framework of this study have been described. An overview of literature exposed certain knowledge gaps which were addressed in Chapter 2 of the study. Based on the research design, a specification of variables were presented, populations of interests identified and procedures carried out. Instruments for the collecting of data were then designed and tested to ensure validity and reliability. The study used schedules and observational formats and the primary data collected was subjected to statistical analysis followed by hypothesis testing using the Excel™ platform for hypothesis testing. From the data analysed and results captured in Chapters 3-6, it was discovered that local municipalities have serious challenges and constraints in their waste management systems. The significance of the finding was discussed in each of these chapters and further reinforced with the implications it had on the waste chain. The design of the intervention offers potentially exciting methods on how to reduce the waste from the point of generation to the last point of disposal.

8.2 Contribution of the Study

8.2.1 Methods

This study has made a significant contribution to waste minimisation modelling in the following:

- Developing a set of equations that indicate possible interventions at points along the waste chain from generation to disposal. This is different from most modelling efforts which are built around final outputs of generation-recycling-disposal. The result is that the IWP modification model is made up of a series of equations that show embedded reductions in waste volumes downstream from generation to disposal

- Conceptualising the waste hierarchy in the form of a continuous chain makes it possible to use a process as a critical cog in the downstream movement of waste from generation to disposal. The internal linkages through feedback loops brings to the fore the role of integration.
- Highlighting technical, managerial and human resource constraints that face the waste chain creates opportunities for targeted interventions. This is because the diversity of constraints that are location specific allows for interventions that are not necessarily standardised, an approach common across local governments.
- The IWP developed here is not unique to mining towns; it has potential for application across secondary cities because of the inbuilt flexibility in its inputs.

8.2.2 Policy

This study findings have a potential impact on policy making with regard to waste reduction, waste minimisation and final disposal. In theory, the South African approach through a series of acts, guidelines and regulations emphasizes landfilling as the last option. The findings of this study indicate that in reality, landfilling remains the most popular option. Indeed, the idea that waste management means waste collection and transportation to landfills is still entrenched at local government level.

8.2.3 Key Findings in Relation to Knowledge Gaps

Finally, successful recycling initiatives (including pilot studies) require four key elements to be in place:

- The buy-in and participation by the key stakeholders that are affected by or may impact in the initiative such as separation at source, delivery to drop-off centers and buy in from workers.
- The availability, proper design, operation and maintenance of the logistical systems and infrastructure required to receive, collect and transport the recyclables to facilities such as igloos, buy back centres and agents with transport.
- The appropriate industries to process the recyclables that are recovered e.g. recyclables and composting; and
- A market for the recycled products e.g. recycled paper and composting.

All these elements need to be in place to ensure reasonable success for the recycling initiative. Should one or more not be in place or should it be in doubt, great care should be exercised in deciding on the practical implementation of such an initiative.

8.2.4 Knowledge Gaps Addressed

Utilising the IWP model enables the minimisation of waste streams from the point of generation to the point of landfilling. Each interface of the waste chain is subjected to reducing its waste load. In perspective, each phase of the waste chain therefore sheds off waste and as a result the amount of waste being disposed of is insignificant when compared to that at the point of generation. The applications of such a model are that the lifespan of landfill sites are further increased. The model has positive implications for the environment and the socio-economic impacts on the population of the local municipalities.

8.2.5 Limitations of the Study

One limitation of the study is brought forward and this is it's inadequacy in the state of data on waste volumes. The data of the different waste volumes that gets landfilled is based on estimates. The refuse vehicles enter the site and get weighed at the weighbridge. A series of calculations follow where the difference of the truck entering and leaving the landfill is calculated. Therefore estimates of the different waste streams are made as the refuse trucks do not have such data on board. The problem with such data is that all calculations are based on estimated and not on pure confirmed values. The impacts that such inadequate data has on the study is that all analysis performed were based on estimates that have been officially recorded by the relevant local municipalities.

8.3 Recommendations

8.3.1 Stakeholders Roles and Responsibilities

In order to promote and enable sustainable recycling as a means to minimise and reduce waste, all stakeholders in the complete recycling chain need to be appropriately involved. These stakeholders comprise the following groupings –

- Waste generators such as households, retailers, business, industries and the service sector).

- Waste collectors and reclaimers such as the local municipalities, private waste management service providers and the informal sector.
- Waste brokers such as entrepreneurs who buy and sell recyclable materials.
- Waste converters and recyclers, who buy recyclable material and alter it into a form that is readily useable by a manufacturer such recycled plastic pellets to be used by plastic extruders, compost using composting plants.
- End-use markets which are consumers and businesses who purchase recovered and converted materials to make new feedstock.
- Waste disposal entities who dispose of waste residues remaining after the recyclable have been removed and these included the private sector and municipalities.
- Policy makers from the three centres of government, non-governmental organisations, community, consumer groups and research institutions.

In order for recycling to become successful, stakeholders need to be made aware of the crucial need for and the environmental benefits of sustainable recycling. Businesses throughout the recovery chain need to realise the inherent value in recyclable material, as well as the impact of waste on the environment. Individuals need to realise that responsible management of recyclable materials in all facets of their daily lives will ultimately affect the standard of living of generations to come. Notwithstanding these project requirements, it is recognised that recycling is more cost-effective if a number of materials are separated and collected at the same time, than to have a process only for the collection of one material, and this has be taken into consideration in the further prioritisation of waste streams.

8.3.2 Provision of Services

Provision of waste collection services has been fragmented across the study areas. Local municipalities are mainly responsible for waste collection and disposal, and where capacity lacks it's the responsibility of district municipalities. At a municipal level the primary obstacle to a sustainable waste management service is the lack of 'in house' capacity to run the service in an efficient and effective manner as well as the lack of knowledge to move the service from an 'end of pipe' scenario to a waste minimisation approach. The primary intervention that is recommended in this vein is the strengthening of municipal human resource capacity. To further augment the waste minimisation approach cooperation is required between the waste producers and the local municipalities; this can be reinforced by by-laws (Coffee, 2009).

Furthermore, the provincial and national government should act in a supportive and complementary role to the local municipalities by providing policy guidance; developing legal deterrents against illegal dumping of wastes and the use of open dumps, coupled with adequate capacity for enforcement; and providing assistance with standards for segregation, storage, treatment, and disposal of each category of waste. In terms of addressing the backlogs so as to provide the majority of the people of South Africa with a sustainable solid waste service it is recommended that the backlogs in the secondary cities be addressed first as they account for 54 % of the total backlog in the country. The cost of addressing these backlogs will be less than addressing the backlog in other smaller and predominantly rural areas where waste transport costs will be prohibitive resulting in an unsustainable service. A detailed survey needs to be undertaken to identify what percentages and areas receives waste collection services. Once this is established an action plan needs to be drawn up for providing those services to un-serviced areas. The action plan needs to be implemented and carefully monitored to ensure the needed service is rendered to the community.

8.3.3 Rural Waste Management

Rural areas are generally not serviced by municipalities due to the remote locations of some areas. Waste produced in these areas are disposed of by community members either by means of on-site burning and burying or establishing small, poorly managed communal waste disposal sites. The quantities of waste produced in the rural areas have been said to be too low to initiate recycling projects. The following initiatives can be considered encourage recycling projects in rural areas: Involvement of local schools and establishing green and eco clubs at rural schools and providing incentives to encourage continuous involvement. The training of community members on recycling in their areas to reduce the quantities of waste going into pits and being burned. Composting and gardening projects will yield desirable benefits to communities. A detailed survey needs to be undertaken to identify what waste disposal methods are used in the rural areas and also what alternative options can be used in the rural areas which will be effective and financially viable for local authorities.

8.5.4 Landfill Licenses and Compliance Monitoring

From information gathered during this study, it was found that of the operational landfill sites in few are licensed. However, of the permitted landfill sites majority are not operated according to licence and permit conditions issued. Management of landfill sites appears to be the biggest problem in the local municipalities which is attributed to the lack of resources at municipal level. The key problems identified that need to be rectified include the following: Fencing and access control to landfill sites; illegal reclamation on waste disposal sites; Burning of waste in open trenches; inadequate or no equipment on site which is needed for operations of the landfill sites; and no compliance monitoring taking place in the province. Activities that are not allowed according to their authorisations are taking place and no legal enforcement actions are taken to rectify these activities. Compliance auditing need to be undertaken by DEDEA officials on a predetermined and fixed basis to ensure that licence conditions are adhered to at all times.

8.5.5 Development of a Location Specific Minimisation Strategy

Waste minimisation and avoidance are seen as the most important tiers in the waste management hierarchy and it is of vital importance that these activities are encouraged as far as possible. Recycling in the smaller and more rural municipalities has been unsuccessful due to the lack of interest and because it's not seen as a viable option as an income generator. Distance from markets has been identified as another reason for the poor recycling rates in these areas. A local recycling strategy needs to be developed which emphasizes that recycling opportunities are available within the province and with the appropriate coordinator or community champions in place, recycling can be effective. This strategy should also be the cornerstone for local municipalities to base their own local recycling strategies on and should provide them with tools that they may need to implement this strategy. Recycling companies in the bigger centres should be approached to assist with the needed infrastructure and it will be the coordinator or community champions' responsibility to ensure that the quantities of recyclables are adequate and are collected on a regular basis. At-source separation should be encouraged to increase the value of recyclable material and also to eradicate the dangerous scavenging and recovering of material taking place at the waste disposal facilities.

8.5.6 Education, Development and Training:

Each local municipality must compile a register of existing recycling initiatives in their area, and identify who is doing what and methods used and their markets. After this exercise is completed an investigation should be done to establish what the challenges are in the respective areas and how this could be overcome. Recycling investigations and initiatives should be undertaken by an official appointed for that specific function. This responsible person will be held accountable for all waste related projects in the area and may be the waste officer to be appointed by the municipality according to the NEMWA requirements. Once initiatives have been identified it needs to be work-shopped to community member to get their support behind whatever project it is in order for it to be successful. Without community backing a project and without the necessary training of community members, waste related projects may not be Public awareness campaigns can take the form of having competitions encouraging recycling and also municipalities providing incentives for reducing waste generated. Provincial government should supply the district and local municipalities with the needed support which includes supply of contact details of possible formal recyclers, institutions to provide financial aid and alternative recycling methods that may be available.

8.4 Conclusion

The key to sustainable recycling is finding a balance between securing the supply of recyclable material and promoting the demand for products that are made from these materials, while appraising the social, environmental and economic impacts. Formalised structures relying on government interventions to enhance market conditions to promote recycling and policy instruments that have been implemented include directive-based solutions, economic instruments, voluntary agreements, and education and information activities. These have resulted in an increase in the level of recycling but have not significantly impacted on the total quantity of waste generated and ultimately disposed of. Life cycle analyses of some wastes such as plastics and paper identify the incineration of waste with energy recovery as providing the greatest environmental benefit and most cost-effective solution. In the Klerksdorp municipality the drive for incineration is generally favoured over landfilling of waste. It has been observed that a formal structure for waste incineration has been developed. Although the design of an environmentally and economically effective recycling system is dependent upon local conditions, a number of lessons may be learnt from the study conducted and these include: Prior to the implementation of a recycling programme, a detailed evaluations of the economic, environmental and social impacts of recycling needs to be undertaken. These are generally location specific and should include an assessment of the life cycle costs associated with recycling, as compared with alternatives methods of disposal. The markets for recycled commodities need to be stimulated to promote more profitable recycling and create jobs. Furthermore, a local waste and location specific forum should be constituted comprising stakeholders of all sectors of the recycling chain, for discussing mechanisms to promote recycling and monitor their effectiveness. The co-ordination for the implementation of policy measures aimed at integrating recycling within waste management planning, increasing public awareness of the benefits and methods of recycling, and stimulating ongoing adoption of market-driven recycling initiatives should be undertaken

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APPENDIX A

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CERTIFICATE
OF
APPROVAL OF RESEARCH PROPOSAL AND TITLE REGISTRATION

This is to certify that: Kenny LR - 18035345

Whose proposal is titled: Design of waste-to-landfill minimization model for South African mining towns

Was considered by the Faculty Research Committee on the 04 March 2015 and approved.

Proposed Qualification: PhD Environmental Science

Supervisor (s): Prof TM Ruhiiga

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Appendix B

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21 November 2016

This serves to confirm that I have read and edited the PhD Thesis of KENNY, Leon Rodney (student number 18035345) entitled:

"A design of a waste-to-landfill minimisation model for South Africa's mining towns."

The candidate corrected the language errors identified to the satisfaction of the supervisor.

The document presentation is of an acceptable academic and linguistic standard.

Thank you

Prof T.M.Ruhiiga

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Supervisor

....

Prof D.A. Isabirye

Language Editor

Faculty of Agriculture, Science and Technology