An Analysis of Waste Minimisation Initiatives in the City of Cape Town, South Africa

by
Zandile Carol Nkala

Thesis presented in partial fulfilment of the requirements for the Master of Philosophy in Sustainable Development Planning and Management at the University of Stellenbosch

Supervisor: Prof Alan Brent
Faculty of Economic Leadership and Management
School of Public Leadership

December 2012

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Zandile Carol Nkala December 2012

Abstract

Mounting pressure on waste management has forced the City of Cape Town (CCT) to progressively move towards achieving an integrated waste management system (IWMS). This system presents a holistic approach of dealing with waste issues. The waste management hierarchy indicates that the 'cradle-to-cradle' approach of waste management is more ideal as compared to the traditional 'cradle-to-grave' approaches of waste management, example landfilling. However the challenges that have transpired in the rollout of waste minimisation initiatives highlight the need to continuously improve the system.

This thesis investigates the municipal solid waste (MSW) minimisation programmes initiated by the CCT Solid Waste Management Department. A systems approach that combined both quantitative and qualitative methodologies was employed in the analysis. A material flow analysis (MFA) model was used to trace the flow of waste through the waste management system. The benefit of applying the MFA approach for waste management problems has been highlighted in literature in terms of identifying potential recycling, and other, waste-treatment technologies, and predicting the outcomes of waste treatment and disposal initiatives. The main objective of this study was to apply an adapted MFA method in order to determine the progress of the existing waste minimisation programmes and to also determine the opportunities to utilise biodegradable and other recyclable components of the waste streams; thereby improving the IWMS of the CCT.

The MFA provided a conceptual understanding of the flow of waste materials in the CCT. The mass assessment of waste minimisation facilities, such as the Bellville compost plant and Athlone material recovery facility and refuse transfer station, unveiled that there is still a large amount of biodegradable and recyclable municipal solid waste that ends up in landfills regardless of the waste minimisation facilities available. However, it is still immature at this stage to conclude the success of the Think Twice campaign, since this is a fairly new initiative that relies on the response rate of the public. There are challenges associated with the recyclable waste recovery rates such as public awareness, proper advertising, operational problems that still need to be addressed. The MFA results also showed the final sinks of the different waste types that are sent through the different waste minimisation facilities run by the CCT. The current institutional arrangements and

legislative environment have been greatly improved but there are still a number of challenges that need to be addressed.

The largest, overall challenge is devising a practical plan of 'closing the loop' in order to develop a circular economy. The concept of 'cradle-to-cradle' seems to be premised on extended producer responsibility and other stringent control mechanisms, which are currently believed, will yield negative consequences in the South African context. A lot more work needs to be done to achieve a genuinely integrated and sustainable solid waste management system.

Opsomming

Die Stad Kaapstad streef na ‘n geïntegreerde afval beheer sisteem (GABS) as gevolg van toenemende druk op die bestuur van afval. Hierdie stelsel bied 'n holistiese benadering tot die hantering van afval-probleme. Die afvalbestuur-klassifikasie wys dat die “wieg-tot-wieg” benadering meer ideaal is as die tradisionele “wieg-tot-graf” benaderings van afvalbestuur, byvoorbeeld die bestaande sorteringsterreine. Die uitdagings wat voor-gekom het in die bekendstelling van afvalbeperkingsinisiatiewe het getoon dat daar ‘n voortdurende behoefte is om die stelsel te verbeter.

Hierdie tesis ondersoek die munisipale vaste-afvalbeperkingsprogamme wat deur die Stad Kaapstad se Departement Vaste-Afvalbestuur geïnisieer is. Beide kwantitatiewe en kwalitatiewe metodes is gebruik om die analises uit te voer. ‘n Materiaal vloei-analise model (MVM) is gebruik om die vloei van afval deur die afvalbestuur-sisteem te volg. Die voordeel van die toepassing van die MVM-model word uitgelig in die literatuur in terme van identifisering van potensiële herwinning en ander afvalbehandelings-metodes en die voorspelling van die uitkomste van afval-behandeling en wegdoen-inisiatiewe. Die hoofdoel van die studie was om ‘n aangepaste MVM-metode toe te pas om die vordering van die bestaande afvalbeperkings programme vas te stel asook om die gebruik van bio-afbreekbare en ander herwinbare komponente van die afvalstrome beter te kan benut en daardeur ‘n verbetering van die GABS van die Stad Kaapstad teweeg te bring.

Die MVM het goeie insig gebied in die vloei van afvalmateriaal in die Stad Kaapstad. Die massa-waardebepaling van afvalverminderings-fasiliteite, soos die Belville kompos-aanleg en die Athlone materiaalherwinningsfasiliteit asook die afval-oordragstasie, het onthul dat daar nog groot hoeveelhede biodegradeerbare munisipale vaste-afval in die stortingsterreine beland ten spyte van die afvalbeperkings-fasiliteite wat beskikbaar is. Dit is egter nog te vroeg om ‘n gevolgtrekking oor die sukses van die “Think Twice” veldtog te maak aangesien dit 'n redelike nuwe inisiatief is wat op die terugvoer van die publiek staatmaak. Daar is uitdagings wat verband hou met die herwinbare afvalhersteltempo’s soos byvoorbeeld: openbare bewustheid, goeie advertering asook operasionele probleme wat nog aangespreek moet word. Die MVM resultate het ook ‘n daling in die verskillende afval-tipes wat deur die verskillende afvalbeperkingsfasiliteite van die Stad Kaapstad

gestuur word, getoon. Die huidige institusionele reëlings en wetgewende omgewing het baie verbeter, maar daar is nog 'n aantal skuiwergate wat aangespreek moet word.

Die grootste algehele uitdaging tans is die ontwerp van ‘n praktiese plan om die skuiwergate te oorkom en om ‘n kringloop in die ekonomie te ontwikkel. Die "wieg-tot-wieg" benadering berus op uitgebreide produsente verantwoordelikheid en ander streng beheermaatreëls wat waarskynlik negatiewe gevolge in die Suid-Afrikaanse konteks gaan oplewer. Daar is egter nog baie werk wat gedoen moet word om ‘n geïntegreerde en volhoubare stelsel vir die bestuur van vaste-afval daar te stel.

Acknowledgment

The researcher would like to acknowledge and thank the following individuals for their assistance in the research:

Sincere thanks to my Supervisor Professor Alan Brent and Professor Mark Swilling for your guidance and advice.

The officials in the SWMD of the CCT for allowing me access to unpublished documents, data and for the willingness to share with me your experience and thoughts about the waste management system of the City.

I would also like to extend a heartfelt thanks to my loving family; Differ and Sihlelelwe for their support, prayers and encouragement. To our Heavenly Father, thank you for the strength and grace to press on even on difficult times.

Table of Contents

List of Acronyms

Cathode Ray Tubes	CRT
Cape Metropolitan Area	CMA
City of Cape Town	CCT
Extended Producer Responsibility	EPR
European Union	EU
Integrated Solid Waste Management	ISWM
Integrated Waste Management	IWM
Integrated Waste Management Facilities	IWMF
Material Flow Analysis	MFA
Material Recovery Facilities	MRF
Municipal Solid Waste	MSW
Municipal Solid Waste Management	MSWM
National Waste Managment Strategy	NWMS
Refuse Transfer Stations	RTS
Solid Waste Managment Department	SWMD

List of Figures

List of Tables

Chapter 1

1.1 Introduction

Whether in an urban or rural setting waste forms part of our daily lives. The environment through its configuration and nature dictates the wellbeing of its inhabitants. That is why it is crucial to keep the environment free from nonbiodegradable waste types. Waste management therefore warrants attention in sustaining the health of the environment and its inhabitants. The fast growing populations , rising production and high consumption rates in urban areas create an urgent need for solid-waste disposal facilities (Crane et al, 2010).

Due to the increasing concerns around the sustainability of a healthy environment and conservation of natural resources, waste management practices are transitioning towards sustainable options. Governments around the globe now pursue integrated solid waste management plans which offer opportunities to suggest and implement a combination of waste minimising technologies. It has taken developing countries longer to realise the need for a transition from conventional waste management. This is due to the fact that developing countries have been focusing on other issues such as poverty, hunger, unemployment and other socio-economic issues (Medina, unpublished).

Waste generation encompasses activities in which materials which are identified as not valuable are either thrown away or gathered for disposal. Waste generation globally is becoming uncontrollable and difficult to manage because of the diverse nature of waste (White et al, 1995 in Engledow, 2007). Waste management systems have a number of challenges such as: poor service delivery, absence of improved waste management strategies, increased budgets and lack of enforcement of waste management laws (Ball and Fiehn, 2005). Landfilling is becoming an unattractive option for waste disposal due to shortage of airspace in existing landfills and the difficulty of obtaining new landfill sites especially in municipal areas. This trend however still follows the `end of pipe’ approach to the waste management problem which continues to prove that it is not meeting the zero waste targets.

Jewaskiewitz (2008) defines integrated waste management as an intelligent combination of processes to solve waste problems by maximizing recycling and energy production. According to Ling and Yuen (2010), integrated solid waste management (ISWM) is a system approach for comprehending the what, why and how of solid waste management. Tchobanoglous et al (1993) explains ISWM as the selection and application of suitable techniques, technologies and management programs to achieve specific waste management objectives and goals. ISWM basically entails collection, transportation, prevention, reducing generation of waste, reusing, separating, recycling and finally landfill disposal.

In the year 2006 the solid waste management department (SWMD) of the CCT moved away from the generic waste management activities which only entailed, waste collection, cleaning and disposal and moved towards the implementation of an integrated waste management system. This led to the city winning the presitigious Cleanest City award in 2006/2007, Crane et al (2010). This was the second time that the city won this award, the first award was awarded in 2003. However, large tonnages of waste still go straight to the landfill. Waste minimisation through recycling is the norm in post industrial waste streams (industrial sector) and this trend is not common from consumer sources (at households and town centres). This is a problem because landfill waste disposal is not sustainable.

1.2 Research problem statement

The CCT has three landfill sites namely Bellville South, Coastal Park and Vissershok. The imminent closures of these landfill sites have led the CCT to prioritise waste management issues. The Bellville South landfill will close in June 2013, while Coastal Park is envisaged to close between 2019 and 2022. Vissershok South is a low hazardous waste disposal site (H:h) envisaged to close between 2014 and 2016. Vissershok North landfill is envisaged to operate in the next two years. There is a privately owned landfill in Vissershok close to the state owned site that handles industrial hazardous waste (H:H). It is estimated to close in the next 9 to 13 years (Wright-Pierce, 1999). The lifespan of the remaining municipal landfill sites is between 8 and 11 years excluding the private landfills. This is less than the international benchmark of 15 years banked landfill (Akhile Consortium, 2011).

As the three currently operating landfills continue to fill up, sites for new landfills are difficult to acquire. For instance, sites in Atlantis and Kalbaskraal were identified as equally suitable sites for the construction of the new regional landfill site. However the application for either of the sites that was lodged under the Environmental Impact Assessment (EIA) Regulations promulgated under the Environmental Conservation Act, 1989 (Act No. 73 of 1989) (ECA) was rejected. The landfill application is under appeal in terms of section 35 (3) of the ECA. It is not yet clear when the issue will be resolved. Atlantis is 50km away, while Kalbaskraal is 53km away from the city and these long distances will also have negative impacts on the cost of transportation, traffic flow and the carbon footprint. Additional transfer stations will be required to transport waste over these long distances.

The CCT SWMD runs waste minimisation programs however, there are private waste minimisation companies, Non-governmental organisations, communities that are also running waste minimisation programs. For instance, Enviroserve is a private company that has been in the waste management sector for many years and has been active in reducing landfill waste through programs such as composting. It is not clear how much waste is diverted by similar organisations as they are not yet obligated by legislation to report their waste management data. The only legislation that refers to waste information is in chapter 6 of the National Environmental Management Waste Act, 59 of 2008. This law states that the Province must develop a waste information system. The Western Province is currently developing an Integrated Pollutant and Waste Information System (IPWIS) to which waste generators, waste management service providers, waste disposal facilities including recyclers, composting facilities, transfer stations in the Western Cape must submit their waste statistics. According to Muller (2011), the CCT is planning its own waste information system to which all stakeholders will report their data but they are currently waiting for Province to finalise the (IPWIS) system in order to avoid duplicate instructions. As a result, waste minimisation statistics from private companies is currently not readily available to the public as it is not mandatory for them to disclose their statistics to the municipality. This current arrangement makes it difficult to clearly determine the true potential that waste minimisation programs have in making a significant difference.

Waste minimisation data from the SWMD shows that 8.67% of total waste generated was diverted from landfill during the 2010/2011 financial year. This percentage combines all waste minimisation initiatives run by the SWMD. The CCT supports the Polokwane declaration to reduce waste generation and set a target to minimise waste generation by 20% and to reduce waste sent to the landfills by 10% by 2012. Waste minimisation initiatives in the CCT do not seem to be achieving the 10% diversion target as more waste still ends up in landfills despite the fact that the CCT has invested in waste minimisation initiatives and provided the required infrastructure. This research therefore seeks to unveil the progress of waste minimisation initiatives in the CCT to determine why waste minimisation initiatives underperform.

1.3 Rationale of thesis

Zumbuehl (2006) conducted research on *"Mass flow assessment (MFA) and Assessment of Recycling strategies for Cathode Ray Tubes for the Cape Metropolitan Area (CMA), South Africa"* whereby he carried out a material flow assessment of cathode ray tube computer monitors (CRT screens) and television sets of the CMA in order to determine the future management of CRT screens in South Africa. He then assessed the sustainability of recycling CRT glass using the Multi Attribute Utility Theory (MAUT).

On a slightly similar note, this study aims to trace the flow of solid waste material within the municipal boundary. The study therefore aims to, analyse the flow of solid waste material passing through the CCT integrated waste management facilities. These facilities include drop-offs, material recovery facilities, refuse transfer station, compost plant and landfills. The MFA will commence at the time solid waste is collected by the municipality or contract service providers up to the when it reaches landfills.

According Engledow (2007), Zumbuehl (2006), Spamer (2009), Crane et al (2010), Swilling (2004) and various other authors, South Africa delivered a large number of research and academic literature on the subject of solid waste management.

However, there is very limited research has been conducted to trace the flow of municipal solid waste materials done in the CCT.

1.4 Research Objectives

Waste management in South Africa faces a number of challenges such as, the increase of waste volumes within growing urban areas, the increased complexity of waste streams, and growing pressure on the use of inefficient waste treatment systems due to financial constraints (NWMS, 2011). This research aims to test the use of MFA method in understanding the flows of waste. This research seeks to unveil the progress of waste minimisation initiatives in the CCT and to determine why waste minimisation initiatives are underperforming. This will be achieved through the analysis of the trends of waste minimisation initiatives in order to determine the main challenges of the waste diversion. Waste flow will be tracked to determine how much waste that is meant for recycling ends up in landfills by using MFA as a method.

The Objectives of the study is:

- To understand the flow of waste material through CCT municipality.
- To conduct a broad material flow analysis of SWM system mainly focusing on the flow of material through the CCT municipal waste minimisation infrastructures. This will be done in order to determine how much recyclable material is practically diverted to recycling companies and how much ends up in landfills. Tracing the flows and masses of recyclable material distribution will help unveil waste diversion in the CCT.
- To determine the performance and flows of recyclable components in the waste minimising facilities namely; the Think twice campaign, compost plant, drop off sites, MRFs and RTS.
- To analyse waste minimising facilities and projects in order to determine the challenges they are facing in developing a sustainable and efficient waste minimising system.

1.5 Study Motivation

In the year 2006, the SWMD adopted the ISWM plan which resulted in additions to the traditional municipal solid waste (MSW) management system that initially only comprised of cleaning, collection of waste and landfill disposal. The new additions to the traditional MSW system include waste recovery, climate change mitigation and recycling initiatives. Waste processing activities such as recycling of recovered waste is a non-municipal function. This means that after the municipality collected recyclable waste, the processing is not done by the municipality. The CCT has introduced a Draft Energy and Climate Change Action Plan in order to monitor methane gas emissions from fermentation of organic waste in landfills. The system was put in place in order to continue providing a more sustainable service delivery that reduces negative impacts to society, economy and the environment (Coetzee, 2010).

In addition to the various waste minimisation projects that have since been initiated, there are set targets aimed at achieving a 'zero' waste situation in the near future. The study is important as a means of determining how far the CCT has come in achieving its waste minimisation targets. This study will determine the general performance of the waste minimisation facilities that have been operating so far at the same time identify the current challenges.

1.6 Structure of the Thesis

The first chapter of the thesis provides an introduction of the study that mainly highlights the growing waste generation rates and need for waste minimisation initiatives to divert waste from landfill disposal. The second chapter covers the literature review which provides a discussion on system approach as a convenient way of managing municipal solid waste systems and also incorporating the sustainable development concepts. Advanced waste management systems such as integrated solid waste management (ISWM) and industrial ecology concepts are discussed. This discussion leads to the introduction of the MFA method as a useful tool to model the solid waste management system. In the waste management system a MFA gives a broad view and detailed analysis of the waste management system thus helping to navigate details of every facet of the system. Following this, a plan is adopted which demonstrates how the progress of waste minimisation initiatives is systematically analysed.

The third chapter describes the research design and methodology of the study. The methodology combines quantitative and qualitative methods of data collection. A framework developed by Bilitewski et al (2009) discussed in the literature review was used as a guide to discuss the case study. The MFA is used to model the CCT waste minimisation initiatives and serves as a quantitative method of data collection. Data used in the MFA was sourced from the SWMD minimisation division after being formally permitted by the management.

The case study results were presented and discussed in chapter four thereafter suggestions were made for further analysis of possible solid waste management initiatives. The last chapter presents conclusions and recommendations drawn from the study findings.

Chapter 2: Literature Review

2.1 Introduction

Solid waste generation has become problematic in modern societies. Devising proper waste management methods has become a priority in environmental and social policies of most developed and developing countries (Valle et al, 2004). Population growth, rising incomes, increasing industrialisation and a more sophisticated form of consumerism are leading to an increase in the amount of waste in cities around the globe (UN-Habitat, 2010). With waste being an inherent and inevitable feature of human society, it is bound to become a challenge to manage it with the increasing urban population. A vast body of knowledge has emphasised that the rise in income, material consumption and population growth have contributed to the increase of waste generation in cities globally (Ackermann, 2005; Crane et al, 2010; Engledow, 2007; Cointreau, 2006).

In this chapter the definition of the concept of sustainable development is given as well as a broader explanation on how it is applicable in the context of solid waste minimisation. A vast number of approaches of sustainable development have been researched by different scholars. The literature describes how the systems theory approach can be used as a means to achieve sustainable solid waste management.

2.2 Sustainable development (SD) in solid waste management

The most famously sited definition of SD is that of the Bruntland Commission of 1987 which states that SD is *"development that meets the needs of the present without compromising the ability of future generations to meet their own"* (WCED, 1987). The concept of sustainable development has gained a lot of attention globally resulting in numerous debates for and against this way of thinking. There are various definitions available on literature by authors such as Hattingh, 2001; Pezzoli, 1997; Sneddon et al, 2006; Meadows, 2004 and others.

Gallopin (2003) emphasises that the definition of SD determines that there should be an integration of economic, environmental and social concerns in order to achieve

SD goals. The definition of the National Environmental Act No. 107 (1998) combines Gallopin`s (2003) definition together with that of the Bruntland Commission as follows;

"Sustainable development means the integration of social, economic and environmental factors into planning, implementation and decision-making so as to ensure that development serves present and future generations".

The definition referred to above emphasises that the concept of sustainability highlights the interdependence between the environment, society and economy. The interdependence model in Figure 1 illustrates that the economy exists within a society because the economy is driven by the interaction of people. Even though society plays a crucial role in the development of economies it also exists within an environment which contributes in making it a very complex body. The environmental system is reshaped and greatly affected by anthropogenic activities (both society and economic activities). The environmental system is the overarching system that harbours both the social and economic systems. The concept of sustainable development highlights the integration of social, economic and environmental factors.

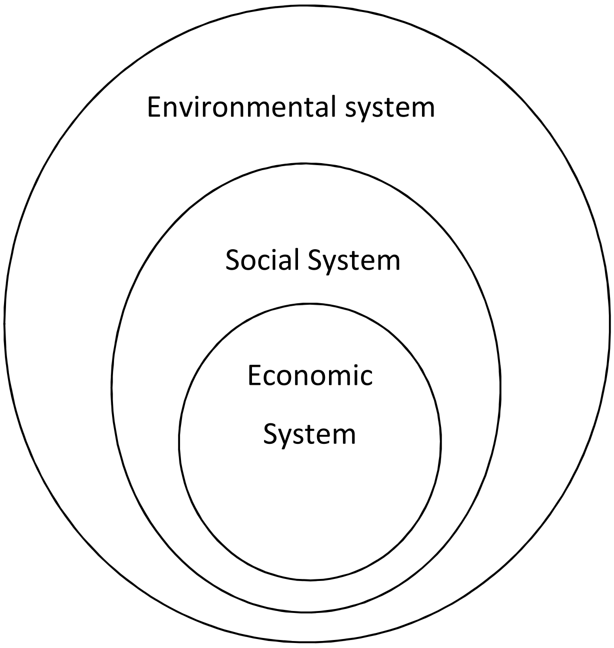


Figure 1: Interdependence model of Sustainability

According to Lehman (2010), waste was once seen as a burden in industries and communities. However, it has also been realised that landfill runoff and leacheate are a threat to the soil and ground water, and that methane gas discharges pose a threat to the atmosphere and contribute to environmental impacts in the form of global warming. This further illustrates the interdependence model of sustainability in the context of waste management that growing population, people`s attitudes and behaviour towards waste and the by-products of industrial activity (which are economic activities), produce astronomical amounts of waste on a daily basis. These are dumped into the environmental system which results in the reduction of landfill space and negatively affecting the environment. The arguments presented highlight that processes of development raise many issues that must be addressed such as poverty, inequality, environmental degradation and also the management of solid waste.

Yap and Zvauya (1999) say that the three interrelated 'spheres' in SD shown in Figure 1, namely anthroposphere (human centred i.e. economy and society) and ecocentric sphere (environment centred) are complex. In the context of solid waste management, there is evidence that balancing the needs of anthroposphere and ecocentric sphere is complex. For instance, when the government of South Africa enacted the regulations banning production of thin-film plastic shopping bags because they had low recyclable and economic value, the business and labour industry were greatly affected (Nhamo, 2008). This environmental (ecocentric) regulation resulted in a significant reduction of plastic bag litter but caused a loss in employment and revenue. Striking a balance between socioeconomic issues and environmental management continues to be a challenge.

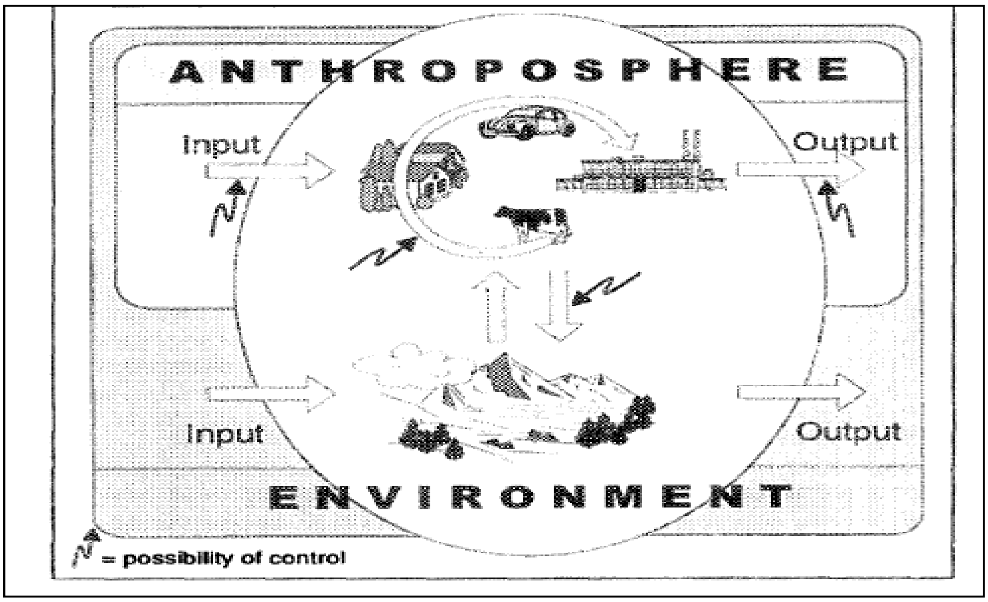


Figure 2: Illustration of the connection between Athroposphere and Environment

Source: Brunner et al (2000).

Sustainable development in solid waste management has been discussed in other international platforms such as the comprehensive plan for local Agenda 21 which presents a programme that seeks to address solid waste management through the use of a hierarchy of objectives. These objectives include the following: (a) minimising of waste; (b) maximising environmentally sound waste reuse and recycling; (c) promotion of environmentally sound disposal and treatment, and (d) extension of waste coverage. Agenda 21 simply laid a foundation for the much needed basis for action against the increasing quantities of waste streams which was left unchecked and that would result in a fundamental limit to natural resources (Meadows, 2004).

The European Council in 2001 adopted European Union Sustainable Development Strategy with the aim of promoting sustainable communities that are capable of ensuring environmental protection, social cohesion and resource efficiency. The New Waste Directive published by the European Commission (EC) has new definitions of waste which require that waste management technologies should improve in order to protect human health, environment, promote reuse and recycling, enhance waste prevention programmes and implement policy instruments such as extended producer responsibility (EPR) collectively. The main concept of the new legislation is to promote a holistic approach of MSW management practices. This implies that long term SWM systems initiatives should be chosen appropriately in order to ensure that they seek ways to enhance energy recovery, but do not increase the emissions of greenhouse gas (GHG) and environmental pollution.

2.3 Promoting Sustainability in Waste Management

In order to promote sustainability in waste management, fundamental strategies have been developed. Different countries in the world are using a combination of innovative approaches and tools to ensure that their waste management practices are sustainable. The main focus is shifting waste management towards the upper level of the waste hierarchy namely; to waste prevention and material recovery. Waste management contributes to SD as it aims to eliminate pollution of the environment by finding ways to treat waste and disposing it in sanitary landfills. Waste management also plays a critical role in improving the standard of living in societies as the communities become healthier and less prone to bad health conditions. It also economises the use of natural resources by diverting waste from landfills through waste minimisation initiatives such as recycling and energy recovery (Bilitewski et al, 2009). The ISWM and industrial ecology are examples of solid waste management approaches that contribute to sustainable waste management.

2.3.1 Integrated Solid Waste Managment (ISWM)

ISWM is a systems approach that recognises three important dimensions which are all pertinent in developing a sustainable solid waste management system, see Figure 3 (UNDP, 2010). The term “integrated” refers to the interlinking of the three dimensions and activities explained below:

- Stakeholders – organisations and people with an interest in waste management.
- Elements - technical components of waste management which refer to collection, reduction and waste recovery.

- Aspects – in order for a waste management system to be sustainable it needs to consider all the operational, legal, social, institutional and environmental aspects of the system.

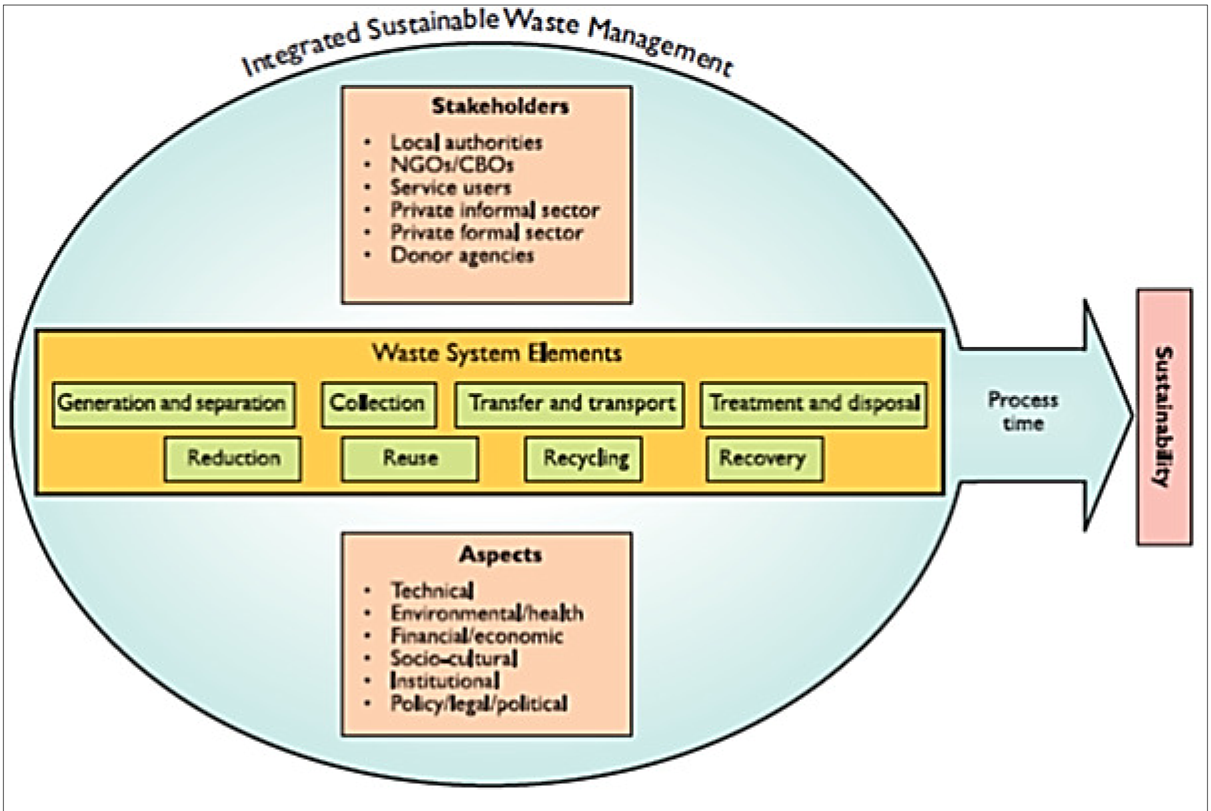


Figure 3: ISWM framework

Source: UNDP (2010)

According to Spamer (2009) ISWM acts as a framework that includes all policies, techniques and practices related to the management of waste. Concern about the environment and resource depletion led to the development of the ISWM and the development of a series of steps presented in the form of a hierarchy. An example of the waste management hierarchy is shown in Figure 4. The hierarchy acts as a guide of how to make waste management more sustainable by moving up through the hierarchy of options (see Figure 4). In the hierarchy, the first priority is to avoid production of waste in the first place, however if it is produced, it must be reduced (or minimised). The next step is to reuse and recycle as much as possible with landfilling as the last option which should only be considered after all the other options have been exhausted (Wilson, 1996). These five levels of desirability aim to reduce the amount of solid waste sent to landfills, therefore the presentation of landfill disposal at the base of the hierarchy as shown in Figure 4 illustrates that landfill disposal is the least desired method of solid waste management.

Wilson (2007:200) highlights that “the waste hierarchy can be viewed as the first step towards stopping the current way of ‘end of pipe’ concept of MSW management towards an integrated concept”. On the other hand, Zeng et al (2010) criticises the presentation of landfills in the hierarchy, by arguing that its presence still provides an unsustainable option of waste disposal therefore giving a little consideration on the application of SD. This implies that, the landfill option should not be present in the hierarchy if the aim is to develop a more sustainable waste management system. Similar debates emanate from the fact that landfills are identified as potential environmental and health hazards. Decomposing waste in landfills produces methane gas which is considered to be a greenhouse gas.

- Avoidance – refers to actions taken to prevent generation of waste in the first place for instance cleaner production in industries.
- Reduction – refers to decreasing the amount of solid waste generated, for instance, imposing tax on plastic bags
- Re-use – refers to recycling material by means of using its original purpose or similar purpose without fidling with its physical form, for example the use of soft drink bottles to collect water.
- Recycling/treating – refers to remanufaturing material by means of using them as resource or as a component used in the manufacture of a new product, for example reused plastic can be recycled to make lower grade plastic or melted down plastic which is turned into pallets and used to manufature plastic containers, chairs or toys.
- Landfilling – refers to the transfer of waste material to landfill sites as a final form of disposal.

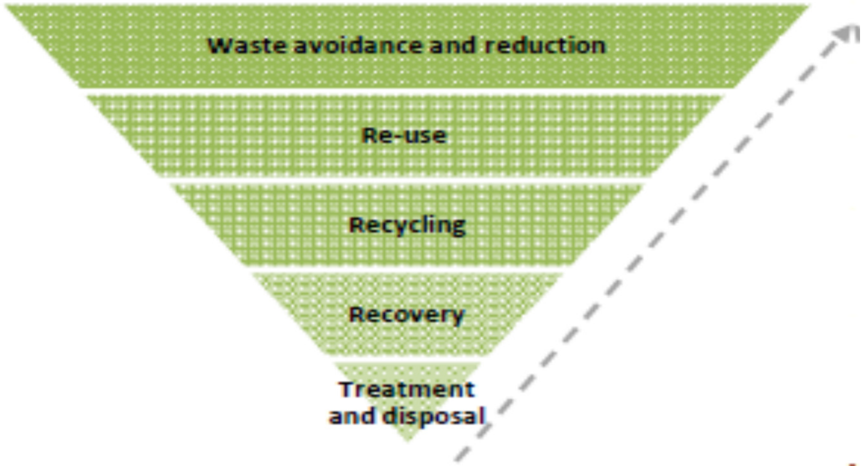


Figure 4: Waste Management Hierarchy

Source: National waste management strategy (2011)

A number of developing countries such as South Africa, Brazil, and India have also adopted an ISWM system and aim at significantly reducing waste flows to landfills. Developed countries have become pioneers in the field as they have gained more experience on waste minimisation over the last decades. The principles of the waste management hierarchy shown in Figure 4 were developed in the 1970s in the Netherlands and were incorporated into Dutch legislation in the 1970s (Oelofse and Godfrey, 2008). This internationally accepted waste hierarchy was first implemented into policy by the European community in 1975 (Oelofse and Godfrey, 2008). The widespread adoption of the hierarchy indicates the intensity of waste problems and the desire to reduce, reuse and recycle generated waste. Markel et al (2008) highlighted that at present, in developing countries and a number of developed countries, the waste management hierarchy shown in Figure 4 tends to be inverted as most waste is disposed at landfills. This implicates that, landfill waste disposal - labeled as the least favourable method of waste management in terms of the waste management hierarchy, serves as the main waste sink in some countries as a significant proportion of waste is disposed of at landfills. Contributing factors is that waste minisation initiatives such as incineration can be an expensive capital investment and poses environmental health risks to most communitites globally (Oliveira and Rosa, 2003 in Troschinetz and Mihelic, 2008). In addition to that, countries such as Swaziland cited that, lack of financial resources and capacity has delayed the implementation of a national waste managemnt strategy (Keran and Jewasikiewitz, 2006). These factors leave the landfill disposal option as the most affordable means for waste management in most developing countries. On the extreme side, Botswana has been successful in implementing a basic waste management system in terms of legislation, infrastructure development and planning.

2.3.2 Industrial ecology

According to El-Hagger (2007) industrial ecology is the study of industrial systems that mimic the operation of natural systems. In a natural ecosystem the available resources and energy are used by organisms in the system, for example plants, animals and human beings living in the environment have a symbiotic relationship. This implies that they are interdependent to each other because waste matter produced by animals can be used to enrich the soil with nitrates in order to nourish plants. This circulation of material and energy forms a complex web. In industrial ecology, the basic concept is the diversion of products and materials destined for disposal by remanufacturing them. This creates an industrial symbiosis[1]. According to Lyons et al (2009), Lyons (2005), the argument presented by industrial ecologists

[1] Industrial symbiosis is an analogy to the behaviour of natural ecosystems where there is a physical exchange of material, energy and water flows circulating in a complex web of exchanges.

is that production and consumption systems should mimic natural systems in order to significantly minimise the impact of waste on the environment and its inhabitants. The element of interest in solid waste management is closing the loop by moving from the concept of 'cradle to grave' and 'end of pipe' waste management to a holistic resource management of 'cradle to cradle'. The industrial ecology approach exhibits a high degree of both open loop and closed loop system.

- According to Cheng (2011) a closed loop system is a system that allows the flow of material within the same boundary. In the context of waste management this system is portrayed when a company's waste material generated from one process is recycled internally to be used for another process or to make another product (Institute of Waste Management Southern Africa, 2007).

- Open loop system refers to a system whereby waste material from one boundary moves to another boundary where it is used as an input for other processes or where it is recycled. Such systems are observed in waste exchange programmes whereby waste from one company is used by another company for recycling purposes (Institute of Waste Management Southern Africa, 2007).

Yap and Zvauya (1999) argue that the conflict between industry and the environment root from the fact that the conventional production systems are linear. Therefore there seems to be a need to redesign these systems so that they imitate the cyclical environmental system. Imitating the cyclical patterns of nature will require redesigning of the linear industrial system. However, Pezzoli (1997) also argues that contemporary development methods need to move away from the 'open loop system to that of a 'closed loop system' in order to promote urban resource ecologies that can learn to self-contain their waste system and practice more internal recycling of waste. The problem with this concept is that not all industries have the ability to recycle their own waste materials by exchanging waste within the same boundary. The open loop system on its own creates a larger recycling economy amongst industries which allow innovative strategies through stakeholder involvements, to redesign and recycle waste material.

McDonough and Braungart (2002) present ideas for the designing of industrial recyclable products as a way of shifting from the current norm of production for disposal. They also invented the term, “technical nutrients” for materials that can circulate back into the creation or use of other products. These nutrients can be waste material or by products of manufacturing processes that can be recycled into new products or used as inputs in the manufacture of other products. Pinderhughes (2004), shares the same line of thought when he argues that there is a need to create a new material economy that will promote the redesigning of industrial products so that waste from one process can be used as raw material for another when they reach their useful stage in the metabolism cycle. The main theme for their idea is:

“a product – its production, use, and recycling can be designed to support nature`s living system, rather than being a burden to the environment” (McDonough and Braungart, 2002:100).

A number of cities are accustomed to what Girardet in Doughty and Hammond (2004) called linear metabolism – whereby the city consumes its inputs and thereafter pollute (see Figure 5a). He associates this system with unsustainability and argues that a more desirable system would be one called ‘circular metabolism’ (see Figure 5b). In a circular metabolism, inputs are efficiently used up and the waste materials resulting from this are reused or recycled back into the similar or same product thereby re-entering the metabolic cycle[2].

[2] See images borrowed from Girardet in Doughty and Hammond (2004)

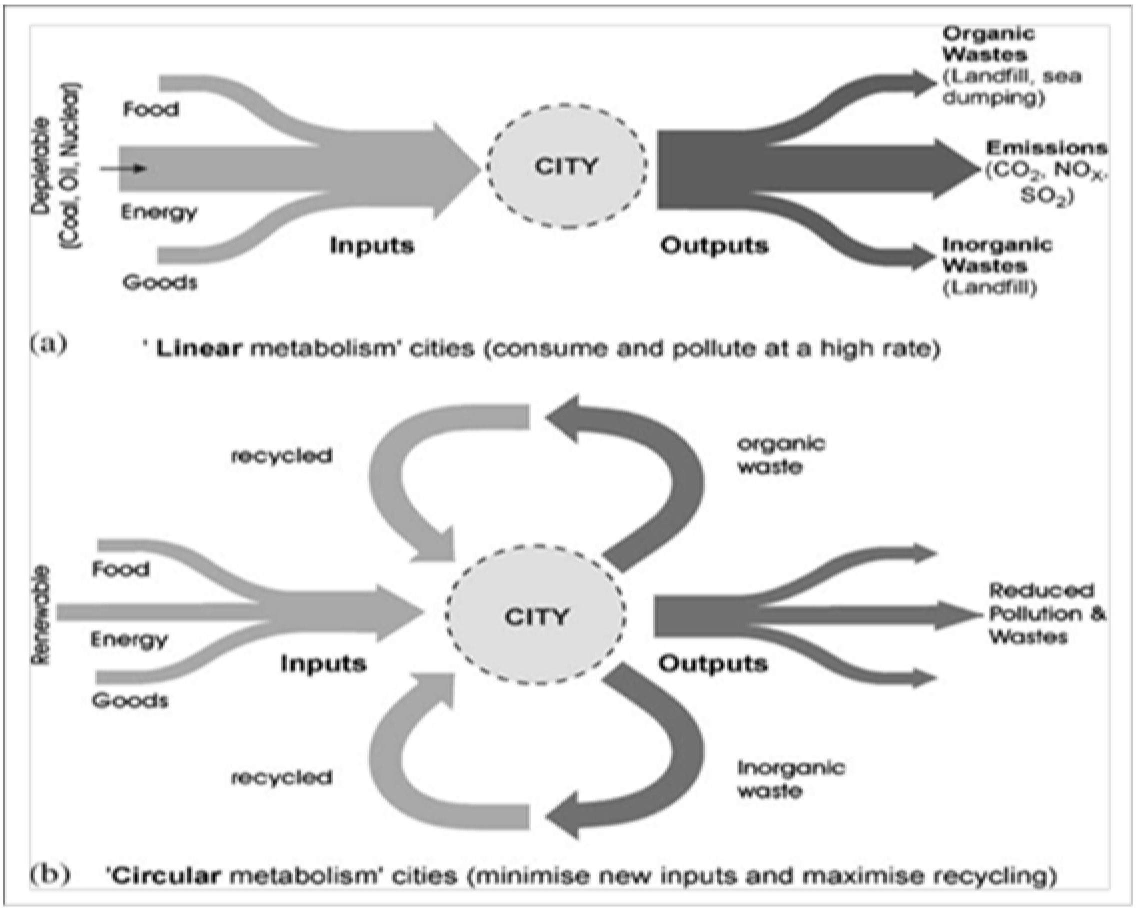


Figure 5: Illustration of linear and circular metabolism cities

Source: Girardet in Doughty and Hammond (2004)

According to Yong (2007) the principles of the 3 R's namely; reduce, reuse and recycle would be the starting point in the focus of circular economy initiatives. The two crucial benefits of the principle are firstly the reduction of waste flow and tonnages and lastly reduction of the amount of natural resource extraction. The Governments of China, Japan and Germany enacted the philosophical concept of circular economy in their waste laws in order to ensure resource utilisation, waste disposal and recycling. Oelofse and Strydom (2010) argue that recycling is still in its teething pro-environmental consciousness stages in South Africa. This means that recycling and separation at source is limited. This implies that "closing the loop" is happening at a low rate as waste materials that have potential economic value end up disposed of in landfills. Baud et al (2004) argues that the reason behind this trend is that the policies that govern initiatives of waste prevention and landfill diversion are still weak in most developing countries. However, the increase in waste flow and reduction of landfill spaces make it imperative that developing countries focus their attention on the waste problem as well. Preliminary findings of waste research done by the CSIR suggest that there is a need for potential triggers of recycling initiatives in South Africa to take the form of command-and-control instruments. Many economists believe that developing countries are not yet ready for such instruments due to the lack of finances, market developments, institutional capacity and many other issues related to development stages (Godfrey and Nahman, 2007).

The growing awareness of landfill environmental impacts compelled the European Union policy makers to enact the Landfill Directive in 1999. The Landfill Directive set targets for progressively reducing the amount of biodegradable waste landfilled from 1999 to 2016 (EEA, 2009). It is interesting to note that the European Environmental Agency (EEA) member states adopted different instruments in attempt to encourage waste minimisation such as:

- Producer responsibility – this is mainly a voluntary initiative where the industry takes responsibility in the minimisation of waste. This instrument In short, works in the principle of the 'producer must pay' where producers take responsibility of waste produced beyond the point of sale. In Germany and Sweden this principle led to a 15% decrease of packaging waste.
- Landfill taxes – this is an example of an economic instrument whereby weight related tax is imposed for landfilling. It mainly introduced high landfill taxes in order to stimulate the necessity for waste authorities to build waste minimisation infrastructure at a high pace and also in turn changed the disposal method of industries (Lasaridi, 2009). Its main objective is to improve the use of other waste management initiatives such as composting and recycling instead of landfilling. The introduction of landfill tax in Estonia for example, significantly reduced waste landfilled from 95% in 2000 to 60% in 2006 (Eurostat data in EEA report 2009). In Demark, household waste disposal was reduced from 63% to 32%.

- Legislative requirements – these are requirements that are imposed nationally or regionally as a follow up to the EU waste policy. In Australia and the Netherlands, this instrument led to 33% diversion of biodegradable waste.

EEA member states all use different choices of waste management systems and recovery options. These are influenced by the waste generation and the scale of the waste system. This strategy has improved the effectiveness of the landfill policy. Even though there are limits to recycling and remanufacturing of waste material, there are many advantages, for example the demand for virgin raw materials is reduced and the volume of waste going to landfills is minimised (Lyons, 2005). The largest, overall challenge is to develop a practical plan of 'closing the loop' in order to develop a circular economy. The concept of 'cradle-to-cradle' seems to be premised on stringent control mechanisms, which may yield negative consequences in the context of developing countries. This is mainly due to the fact that waste minimisation initiatives are expensive to run and maintain. Most developing countries do not have the financial ability to manage such projects.

2.4 Systems approach to review solid waste management system

Franchetti (2009:27) describes the systems approach as a;

"Problem solving philosophy that focuses on a holistic view of an organisation by analysing the linkages and interactions between the elements"

According to Gallopin (2003), a system is a set of interconnected functions of elements or subsystems. The function of a system depends on many other functions or variables resulting from the environment of the system which is affecting it. Similar to this is a solid waste management system which is comprised of various variables that have an effect on the overall operation of the system itself. Gallopin (2003) further argues that the systems approach can offer an analytical viewpoint of the concept, because the systems view is a way of thinking in terms of connectedness and context. This line of thought carries the same theme as SD that the integration of economic, social and ecological perspectives is vital, in order to assemble issues that seem disconnected and that should be viewed in a holistic manner (Hattingh, 2001; Swilling and Annecke, 2004; Gallopin, 2003).

The origins of the systems approach were premised on the study of complex systems. According to Cilliers (1998), complex systems are not constituted by merely a sum of components, but of the intricate relationships that exists among these components. He further describes complex systems as a set of characteristics that have to interact dynamically as well as elements that influence and should be influenced by other factors. Interactions are non-linear, they have a fairly short range, and there are loops in interactions. Finally it seems that complex systems are open systems. According to Piers et al (2011) MSW management systems have similar characteristics as a complex system in which the procedural aspects such as waste collection, composting, anaerobic digestions, incineration, recycling are sub-systems linked with one another. This means that, waste sourced from households may pass through various operational points within waste minimisation facilities therefore forming a complex web of interactions.

Figure 6 shows a web diagram developed by Troschinetz and Mihelcic (2008) that illustrates the complex relations of all the factors that influence the sustainability of municipal solid waste management (MSWM) systems in developing countries. In their study the collaborative nature of the factors revealed their important contribution to the development of a sustainable MSWM. The network of relationships between Government policy, Government finances, waste characterization, waste collection and segregation, household education, household economics, MSWM administration, MSWM personnel education, MSWM plan, local recycled-material market, technological and human resources also reveal the complex nature of MSWM systems. According to Fiehn and Ball (2005:19) "*Waste and its management is a complex system of interrelated activities which require the input from a number of sectors, involves a wide spectrum of waste types and requires that collection, storage, handling, recycling, treatment and disposal be conducted in various different ways".* These intricate relationships require a consideration of social, economic and environmental factors.

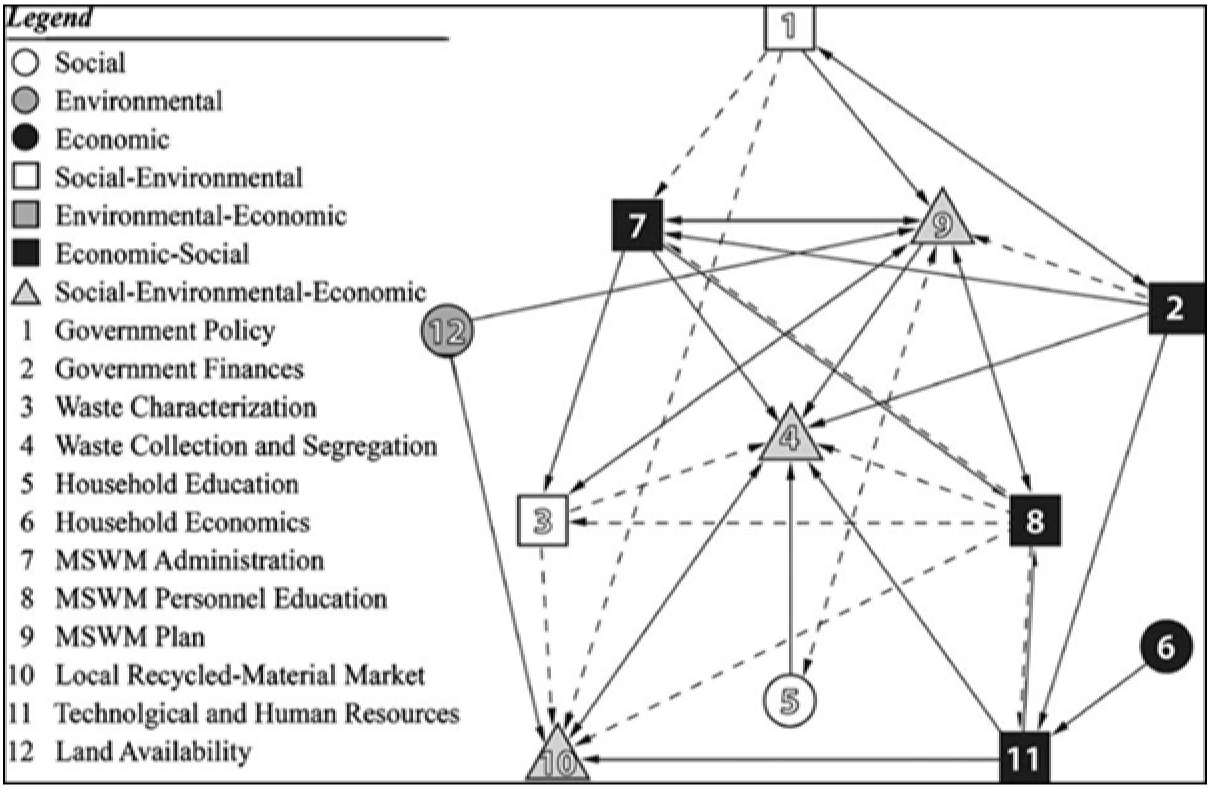


Figure 6: Illustration of information flow between factors and relevant stakeholders whose interlinkages help form a sustainable MSW system.

Source: Adapted from Troschinetz and Mihelcic (2008)

The complexity of a system often makes it difficult to decode as to where to begin to solve problems and further develop sustainable systems because various factors influence the performance of that system. This is mainly because the problem of one subsystem is interconnected and overlaps with other problems within the system. Since systems have boundaries it makes it easier to study subsystems thereby helping in determining the linkages and interconnections that make up the whole system as illustrated in Figure 6 (Cilliers, 1998).

Troschinetz and Mihelcic (2008) further highlight the importance of institutional interconnections, flow of information and interconnections of the three sustainability dimensions (social, environmental and economic) of MSW in systems in developing countries. For example Figure 6 highlights that in waste collection and segregation, residents need to be educated on how to separate waste, government needs to manage finances associated with waste management and provide guidance and policies, and there is also need for labourers and equipment to implement the projects. With regard to sustainable development, the collaboration web shows that factors that are thought to be one dimensional such as local recycled material market (number 10 in Figure 6 deemed as economic) is in fact multidimensional due to the other necessary critical interactions that are required in order for this factor to reach its goal. This means that the other input factors from various institutions are multidimensional. The collaborations web serves to increase the awareness of institutional relationships and activities that are associated with the development of a sustainable MSWM system and describe why it is important to take cognisance of them when studying the waste management systems.

2.4.1 Sustainable development view of the solid waste management system

The systems approach has long been used in the study of waste management where engineering models have been used to explore insightful illustrations of material exchange, input-output matching, stakeholder participation and many other dynamics that form part of the system (Cheng, 2011). Over the decades, waste management has become very complex because of the different dynamics that influence the performance of the waste management system. The efficiency of an ISWM system can be deduced from the definition of SD discussed in section 2.2, that its efficiency relates to how it affects the economy, society and environment. Bilitewski et al (2009) presented a systematic approach of how to analyse a solid waste system and still take the three pillars of SD into consideration. In his model he indicates the importance of analysing the legal framework, economic and socio-economic factors and local conditions.

- Legal framework conditions refer to regulations regarding the collection, treatment and disposal of waste, the reduction of GHG gases emitted by decomposing waste, the energy utilisation potential of waste types and climate protection
- Economic and socio-economic factors review costs/ revenue of waste service, taxes, funding and potential job creation.
- Local framework conditions deals with population, geographic area of case study and infrastructure.

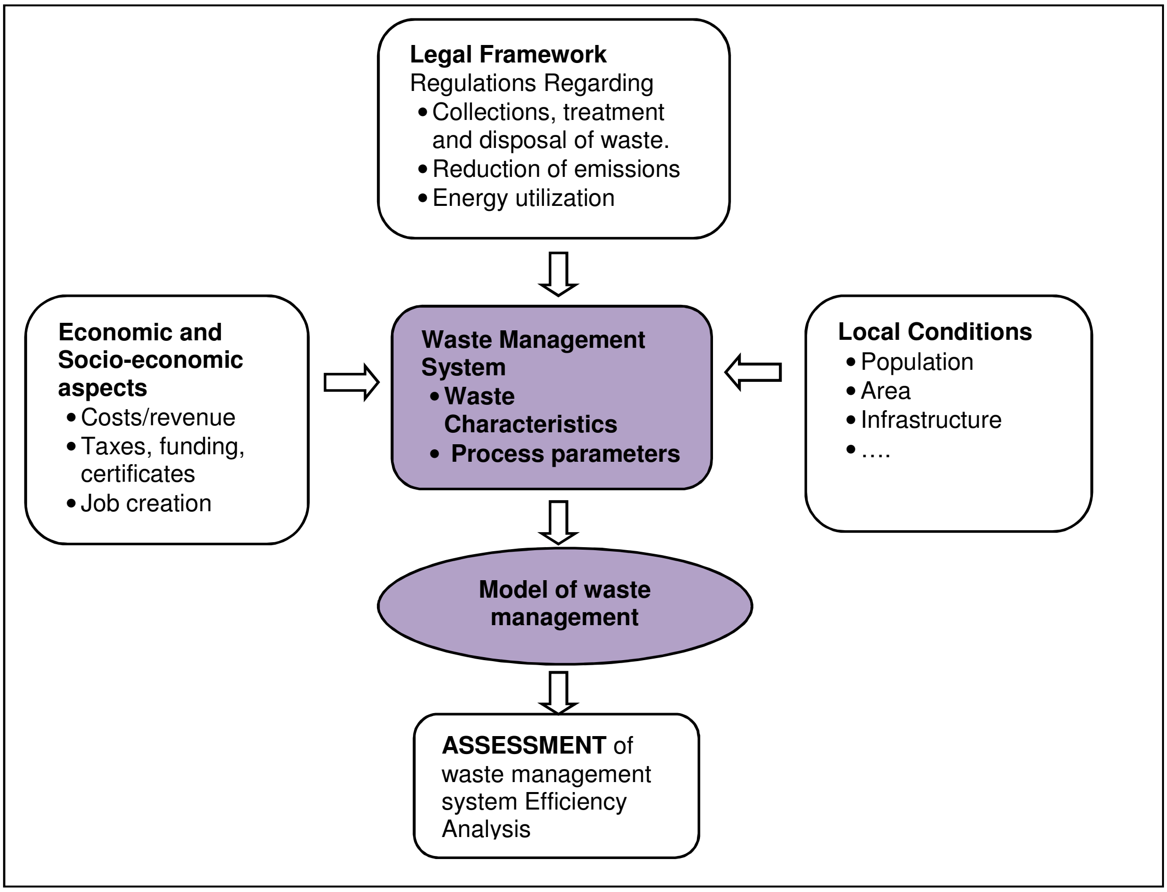


Figure 7: Factors influencing the Waste Management System

Source: Bilitewski et al (2009)

Figure 7 graphically presents the main factors that have a significant influence on the performance waste management systems. The modelling stage refers to a stage where systems analysis methods such as Life Cycle Assessment (LCA), Material flow analysis (MFA) and Risk Assessment tool (RA) can be used to analyse and assess the quantitative performance of the operations of the system through the different stages namely; collection, transport and treatment facilities. The model assists in assessing the flow of major waste materials in the municipal waste stream to determine the inventory levels of the waste flowing within the system. *"Thus potentials for optimised resource productivity through energy and secondary raw material waste stream can be identified"* (Bilitewski et al, 2009:3).

The efficiency of the waste management system in terms of economic, social and environmental sustainability can be deduced by using different sets of indicators.

The modelling of the system can help to identify the sustainability of the ISWM system and dealing with the large scale complexity within the systems.

The MFA has rapidly developed into a sophisticated tool of analysing systems in the field of sustainable development and has become one of the most reliable methods in quantitative detection of waste management systems (Swilling and Annecke, 2004; Bilitewski et al, 2009). Brunner et al (2000) suggest that, the MFA is able to provide an overview of a system by combining the anthroposphere[3] with the environment. According to Brunner et al (2000: 312) the objectives of a material flow analysis are; (*a) to analyse materials flows (b) use data to analyse the stocks and (c) control flows in view of set goals*. In an ISWM system the complexity of disposal systems continuously arise as various processes to treat waste such as composting, incineration and waste-to-energy initiatives are implemented. The links and increasing re-feeds of waste materials as inputs into the different waste minimisation and disposal facilities increases the connections and the complexity of the system (Bilitewski et al, 2009) as demonstrated in Figure 8.

[3] Means, portion of environment in which humans interact.

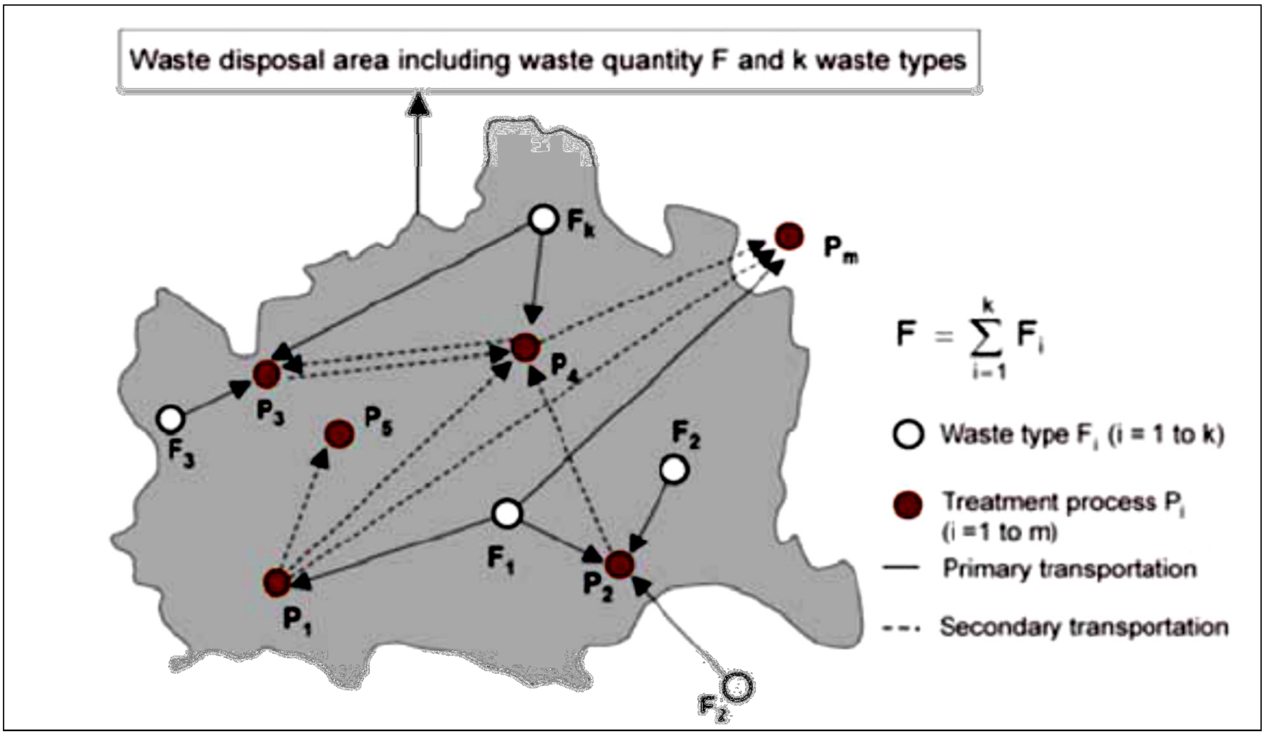


Figure 8: Complexity of waste management system

Sources: Loschau (2006) in Bilitewski et al (2009)

2.4.2 Material flow Analysis (MFA) as an ISWM model

MFA is defined as a "*systematic method of the flows and stocks of materials within a system defined in space and time*", Brunner and Rechberger (2004:23). The MFA model is defined by a system boundary and material flows between different processes within the system. Udodes et al (1997) in Scholtz and Tietje (2002:270) emphasise that MFA is,

"*a tool for integrated chain management because it investigates a chain or a network of economic and ecological processes rather than a single component ,..... it further investigates the total mass, volume or energy of material or bulk material*"

Brunner (2002) highlights that the use of the MFA tool is very common in developed countries, such as Germany, Italy, Sweden, and Denmark. According to Moriguchi (2007), these countries are able to easily initiate MFA studies because they have national statistical offices that are responsible for data collection and compilation of MFA accounts. A number of scholars have innovatively applied the use of MFA in various studies and manipulated the conventional approach to suit their case studies. For example scholars in the United States of America in Hawaii did a study to consider issues of import, export, and consumption of waste in order to complement the design of conservation and recycling efforts in that particular state (Eckelman and Chertow, 2009). They used the MFA as an innovative means to study exports, imports and consumption as an aid to develop long term strategies for reducing the generation of waste that could complement local conservation and recycling efforts. Gurauskiene and Stasiskiene (2011) conducted a regional agent based MFA in electronic waste management systems in Lithuania as a measure to reveal potential points for improving and providing a broader view of the system.

MFA research in developing countries is not very common. However, a few developing countries are beginning to make use of MFA such as China where the MFA approach was applied to study the extraction of domestic resources such as coal, heavy metals and mineral flow (Moriguchi, 2007). In South Africa, Zumbeuhl (2006) carried out a simplified MFA study for cathode ray tube computer monitors and televisions for the Cape Metropolitan Area. These studies provide the author with a broad reference of work in the use of MFA as it has been widely used in waste management studies across the globe in determining the flow of waste material in order to reveal points for improvement.

The use of MFA in waste material flow is also very common in the field of industrial Ecology. For instance, Brunner and Rechberger (2004) used MFA to calculate the amount and composition of wastes by accounting for the process of waste generation and treatment. Binder and Mosler (2006) carried out a MFA to analyse the consumption and waste flows of recyclable goods in Santiago de Cuba households. Moriguchi (2007) used MFA to analyse the flow of material resources, products and wastes in his study of primary and secondary resource flows in China. The Japanese Government also launched an economy wide material flow accounting system to develop a measurement of material flow of resources in 2003. Eckelman and Chertow (2009) performed an island-wide MFA in Oahu state of Hawaii USA as an innovative means of considering consumption, input and exports resulting to develop long term strategies for diminishing the generation of waste.

Findings of the study revealed opportunities for using domestic waste as a substitute for imported resource such as fuel and construction material. These results further helped them to develop the long-term sustainability strategy for the island.

Barles (2009) argues that piloting the use of an MFA at a city scale can help to elucidate urban functioning and enable better understanding of material flows. According to Brunner and Rechberger (2004:2), MFA is an "*excellent tool in waste management decision support*". Eckelman and Chertow (2009), also highlight that the benefit of applying a MFA for waste management problems is that one is able to identify the upstream and downstream flows of waste materials. Brunner and Rechberger (2004) further argue that the MFA approach is able to identify potential recycling and other waste-treatment technologies, and predicting the outcomes of waste treatment and disposal initiatives.

According to Pieres et al (2011) after systems such the MSW management system has been created and implemented, it is vital that the system's performance is evaluated in order to determine how improvements could be made. The MFA provides a broad view and detailed analysis of the waste system which help to navigate details of every facet of the system. It also highlights areas that allow high amounts of waste streams to flow into large pool of waste namely landfills. The CCT is currently using an ISWM system which aims at reducing waste landfilling. A detailed analysis of this system using an MFA will highlight and navigate areas in the system that goes against the "zero waste" policy. This can help in determining solutions to improve the system's performance.

2.5 Conclusion

Adopting the systems approach in analysing the complex MSW management system provides an insightful approach of determining its sustainability. The use of the MFA offers a means to understand the system's operation and performance. However, the study does not extend to follow the flow of substances such as environmentally hazardous elements such as heavy metals, which are produced by some of the decomposing waste in landfills. The performance of the currently existing waste minimisation facilities will be presented in the MFA method in the case of CCT

SWMD in Chapter 5. The case study uses the MFA framework to describe, trace waste flows and evaluate the MSW system. The evaluation uses empirical evidence to measure the amount of waste passing through the municipal waste management boundary and to determine how much of that waste is diverted from landfills. The case of the CCT SWMD provides an understanding of the local waste management system and discusses the challenges currently faced by the waste minimisation project as a whole.

Chapter 3: Research Methodology

3.1 Introduction

According to Mouton (2001:56) a research methodology "*focuses on the research process and the kind of tools and procedure to be used*". The literature outlines the framework of the research by describing the factors that affect the performance of an ISWM system. This chapter comprises the research design that was used to address the research objectives with reference to the MFA framework described in Chapter 2. It further defines the MFA as a quantitative model of determining the performance of the ISWM system. Data and information relevant to analyse the ISWM of the CCT and analysing the flow of waste are used in the quantitative part of this study. The chapter also describes the methodology that was used to conduct the study. The weaknesses and strengths of the methodology were taken into consideration during the selection of research design and data interpretation was used in this research.

3.2 Research Design

The research design was mainly composed of a triangulation mixed method approach. In this method both qualitative and quantitative data were collected. The two data sets were then merged and results were used to interpret and understand the ISWM system of the CCT. Creswell, (2005:514) states that "*the rationale for this design is that each of the forms of data collected supply strengths to offset the weaknesses of the other*". The qualitative data provides in-depth observations and explanation to quantitative data that does not provide adequate information about the setting. Both these approaches were used to solicit information on the waste flow and the general challenges and successes of the waste minimisation initiatives in the CCT. In order to understand the operations of SWMD the researcher conducted a case study on the CCT waste minimisation initiatives. The literature review highlighted the fact that the legal framework, local conditions and socio-economic issues have an influence in the performance of the ISWM. The socio-economic factors and local conditions of the CCT were briefly discussed and formed part of the qualitative analysis of the study.

The quantitative data analysis was assessed using the MFA as a modelling method. The combination of these study approaches helped the researcher to meet the research objectives. Figure 9 describes the research design and steps followed to conduct this study.

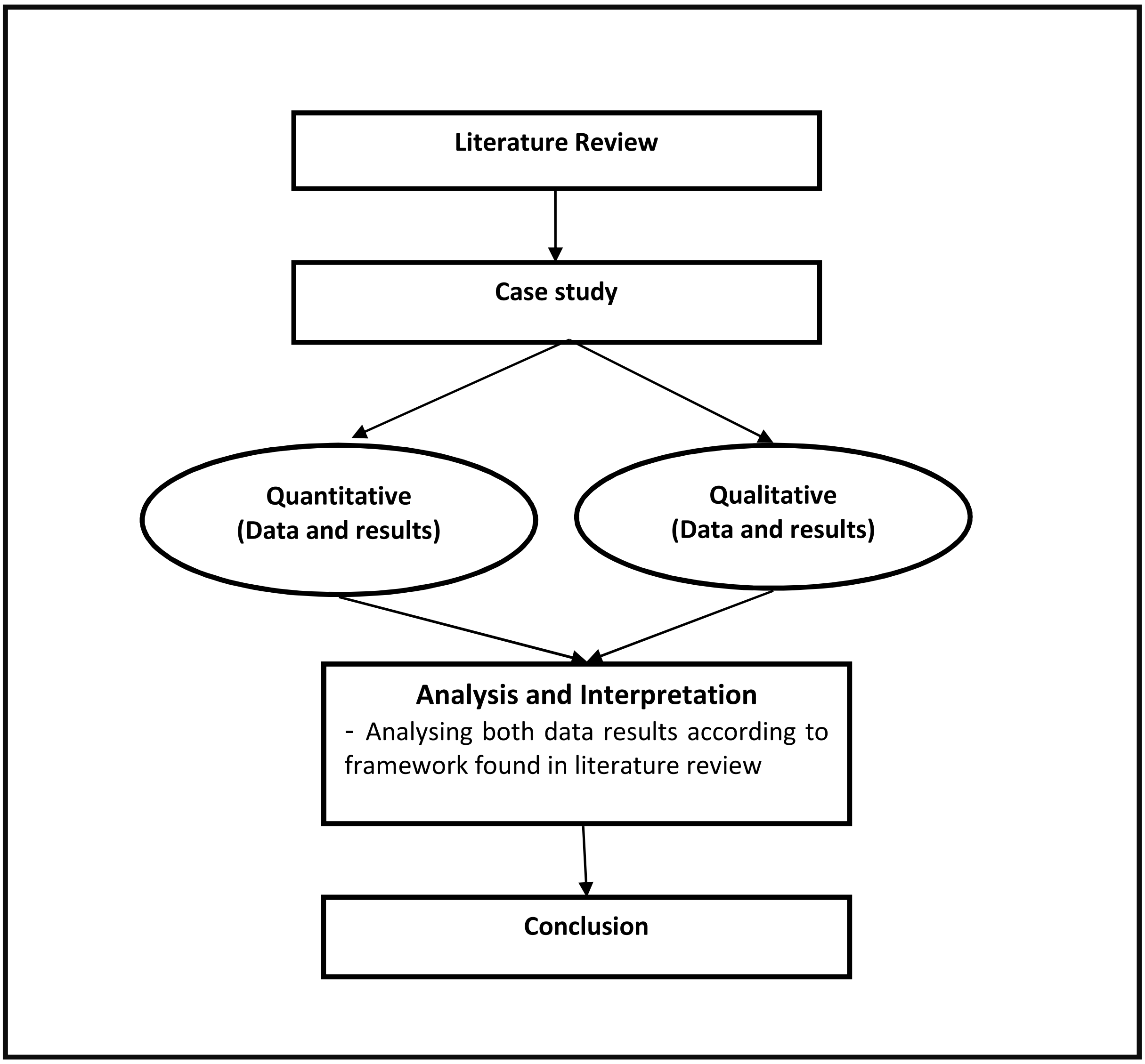


Figure 9: Research Design

3.3 Research Methodology

Combinations of qualitative and quantitative research methodologies were used in this study as a means to achieve the objectives of the study. This section will cover different types of overlapping methods used to conduct the study.

3.3.1 Qualitative Data Collection

The main objective of the study is to trace the flow of solid waste material throughout the waste minimisation facilities managed by the CCT. The literature review discusses important factors of the ISWM. The framework presented in that discussion guided the researcher in finding current information in the local conditions, the socioeconomic factors, and legislation and general problems encountered in waste minimisation system in the CCT. In addition to that, the qualitative data was collected alongside the quantitative data in order to solicit the weakness and strengths of the quantitative data. This assisted in providing background information and to give explanations of the quantitative results and consolidating the two sets of data in order to meet the research objectives listed in chapter 1 section 1.4.

Semi-structured interviews and, primary and secondary source literature were used as methodologies to access information. Semi-structured interviews are open-ended in nature in order to allow the respondents to answer questions in their own words in a narrative form. The researcher was permitted official access to information by the Head of SWMD of CCT. Involvement in an MFA study that was commissioned by the SWMD disposal unit allowed the researcher access to vital information and permission to conduct unlimited site visits. The researcher was able to network with other relevant people who shared information about operational issues pertaining to the waste minimisation initiatives and the challenges they are currently facing. The researcher also realised that respondents were not keen on answering documented questionnaires as they tend to be laborious. The operational challenges opened discussions on controversial aspects of the waste management system which the respondents did not wish to be quoted on. Some respondents complained about the general designs of the waste minimisation facilities and departmental political issues that hindered a fully integrated waste management system. These discussions were conducted via personal interviews, electronic mail and telephone discussions. The main discussion topics comprised of the description of the waste minimisation initiatives and the current challenges. According to Mouton (2001) open ended questions allow the available respondents to provide extensive information and share personal experiences and insights about the research topic.

According to Creswell (2005), primary source literature refers to literature reported by individuals who originated the research on the particular subject or direct sources of information such as official email correspondences and verbal discussions through appointments. Secondary source literature refers to literature that summarises primary data such as, former research conducted by Zumbuehl, 2006 and Engledow, 2007, municipal annual reports, consultant`s reports, official departmental documents, raw data, website publications and monthly data reports. All these sources provided recent data to meet the research objectives and also validate information that was acquired in the verbal discussions with staff members. The researcher also used self-reported data collected during interviews and site tours.

3.3.2 Quantitative data collection

The MFA has been chosen to model the ISWM system of CCT in order to meet some of the research objectives. The literature review introduced the MFA as a method of modelling the ISWM system. In this section, the steps of a MFA are described using a framework designed by Bilitewski et al (2009), Bainbridge (2009) and Brunner and Rechberger (2004). This study is only concerned about the flow of waste material through the waste minimisation initiatives of the CCT. This means that certain extensive mathematical MFA steps will not be done. There are reservations in using this model as detailed data was not available. Waste data obtained from the SWMD will be used to determine the flow rates. The framework presented in Figure 10 describes and summarises the important steps and parameters that will be used to model the waste management system in this study. However the first two steps of the model overlap with qualitative data collection.

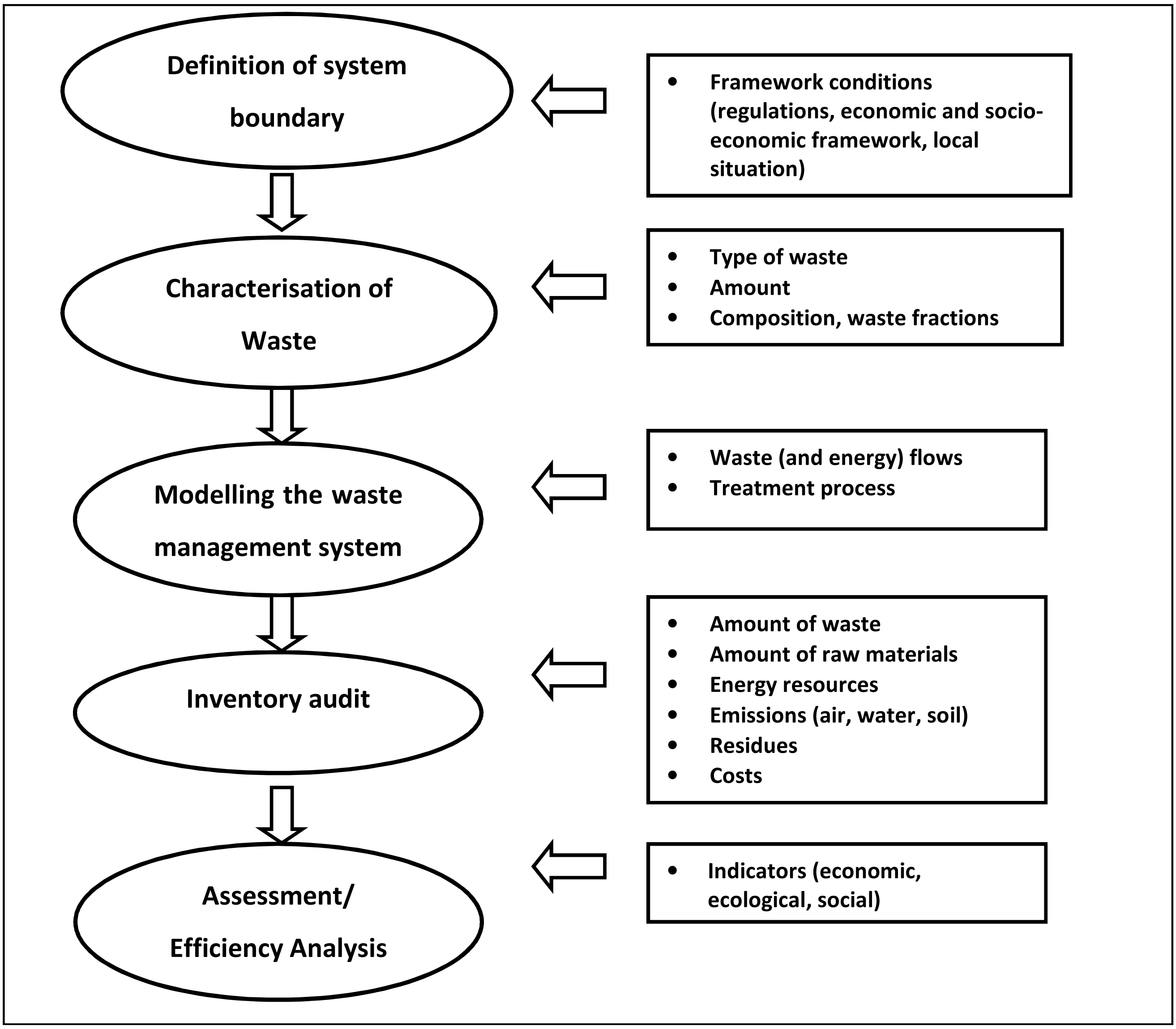


Figure 10: Summary of important MFA steps used to describe and assess the waste management system

Source: Bilitewski et al (2009)

A. Definition of System boundary

In this first step of the MFA the spatial and temporary boundaries of the case study will be defined. The boundary of the study area is deduced by the scope of the analysis. For instance the boundary of this study is the municipal area of the CCT. Waste minimisation and disposal facilities that are managed by the SWMD of the CCT will be assessed in this study. This means that the study did not trace the flows of solid waste materials that are collected and managed by the private sector in their various private waste treatment and minimisation facilities within the CCT. The local conditions, socio-economic framework and regulations that govern waste management system in the CCT will be briefly summarised.

B. Characterisation of waste

The material flow of waste is characterised by the different types of waste that contain a different composition and different fractions (Bilitewski, 2009:15). In this study the researcher used the standard solid waste characterisation data as reported by SWMD officials at the point of data capturing. Waste was characterised as; general waste (comprises of household waste together with non-hazardous trade and commercial waste), builder's rubble and garden waste.

C. Modelling of the system

Brunner and Rechner (2004) define this stage as the process analysis step. This step traces the waste flow from source to the treatment processes and sinks. For example, in the solid waste management system, the inputs enter the process, they are then transformed and into outputs (which could be waste material and emissions, see Figure 11). The flows (normally shown by arrows) illustrate the relations and connections between the processes. Flows define the ratio of mass per time that flows through a given pathway. For an anthropogenic system, such as a solid waste system, system data is investigated over a period of one year as the available data records cover information collected in a one-year period. This strategy has been instrumental for the tracking the flow of waste in the system, Brunner and Rechner (2004).

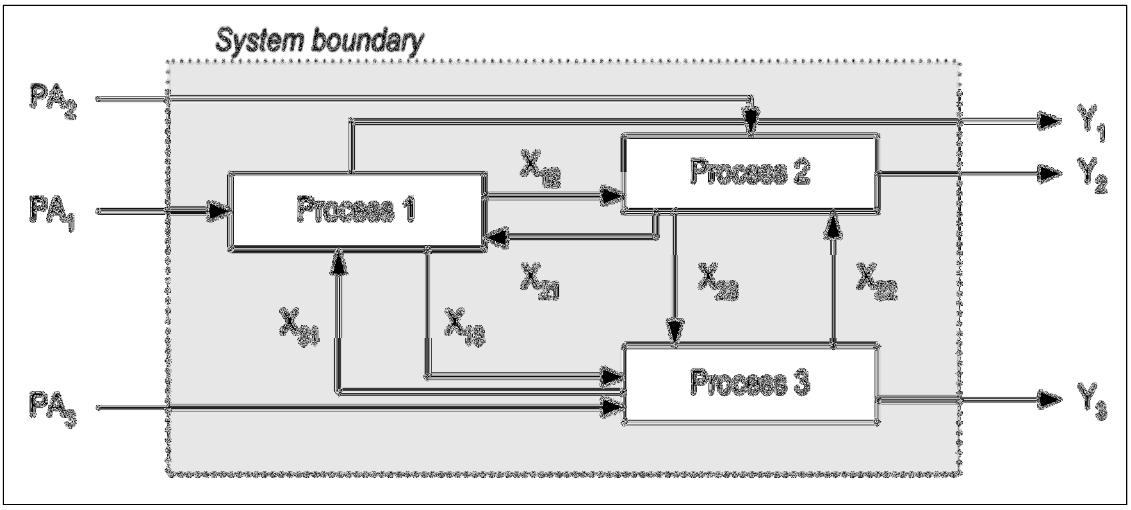


Figure 11 : Illustration of MFA Model

Source: Bilitewski et.al (2009)

The MFA model shown in Figure 11 also consists of ingoing material flow(s) (Inputs) and outgoing material flow(s) (outputs). Within the system the process converts the ingoing material. The output of one process might represent the input of the next process.

D. Inventory

According to Binder and Mosler (2006); Brunner and Rechberger (2004) and Eurostat (2001), the MFA process is based "*on the law of conservation of matter*", which implies that the results of an MFA can be controlled by a material balance whereby all inputs and outputs of a process can be accounted for. This step mainly uses the mass balance principle where the inputs and outputs of the different processes are defined and mass balance is performed. This means that quantifiable data is inserted into the MFA model in order to define the inputs and outputs of the system. The logarithmic presentation (Equation 1) of the balance principle states that all m_{Input} (mass of inputs) of a process equals the m_{output} (mass of all outputs) of the process, adding to it a stock term that considers accumulation. Equation 1 states that the mass of input should be equivalent to the mass of the output plus the mass of stock. For instance, in the case of the CCT waste minimisation facilities such as MRFs; the mass of waste entering the process must be equal to the mass of material that leaves the process after sorting. The stock mass balances the output side to account for stock.

Equation 1

$$m_{Input} = \sum m_{output} + stock$$

Source: Brunner and Rechner (2004)

The data analysis in this stage enables the user to comprehend a variety of information about the waste flow which then feeds into the next step of the data interpretation.

E. Assessment or efficiency analysis

According to Bilitewski et al (2009) the efficiency analysis step addresses three key questions of the waste management system namely:

(i) Where the waste flows to after leaving the minimisation facilities.
(ii) What the transfer coefficients of the waste through the waste facilities is.
(iii) Determining the paths of different waste types.

These three questions aim to fulfil the research objectives in determining the flow of waste through the CCT waste minimisation facilities. According to Bilitewski et al (2009:8), "*the transfer function describes the distribution of the process inputs and the process outputs".* Essentially, this stage enables the user to determine the efficiency of the system through the use of a transfer function of the input and output data. The transfer function (TF) is merely a ratio of the mass input (m_{input}) and mass output (m_{output}) of the waste material. The ratio equation is as follows:

Equation 2: Transfer function

$$\boldsymbol{TF = m_{output}/m_{input}}$$

Source: Bilitewski (2009)

The transfer coefficient ratio will be used to determine the waste flow rate in the CCT waste minimisation facilities that are assessed in this study.

3.3.2.1 Limitations of MFA

Even though the MFA has been appraised as a good approach for analysing the flow of waste materials and substances in the environment (and economy), challenges have been encountered with its application (Brunner, 2002). Bainbridge (2002) points out that in the first stage, namely defining the system where the boundaries are set and the whole life cycle of the material is studied, the most common problems are associated with the uncertainties in the material flow information and the data. As a result, a confidence factor normally needs to be used in order to validate figures. If data obtained in the initial stage is unreliable the second stage, namely the balancing stage, suffers inherent uncertainties in the quality of information which introduces further errors. These problems are amplified if there is a lack of data that is easily available and sufficient to conduct the study.

Another challenge observed by Allen et al (2009) and Brunner (2002) on the use of MFA is that it does not include all the necessary information to assess potential social impacts such as human health. Brunner (2002) emphasises that the most difficult stage in the use of MFA starts beyond the stage of calculating the flows of material. He highlights that there are certain applications after the MFA, such as standards evaluation of the system and projecting long term effects of the use of landfills in solid waste management, which it fails to answer because they cannot be expressed as tangible cost evaluating reports. Such problems are subsequently resolved by merging the MFA with alternative tools in order to turn it into a more comprehensive evaluation tool. Sholtz and Tietje (2002) pointed out that another method of manipulating the MFA is to employ a narrative approach.

3.4 Software used

Software applications were used for graphical visualisation of the MFA model. The database used for this study did not allow detailed analysis, therefore the researcher did not use energy flow rates calculations. This study represents a simple analysis of the MFA of waste minimisation facilities. The researcher used STAN (short for subSTance flow Analysis) software developed by the Vienna University of Technology (Institute of Water Quality Resources and Waste Management) to draw the models. This is free software that is specifically developed for application of MFA in waste management. The software consists of pre-designed components that help to visualise processes and present the results in the form of diagrams. If sufficient data is provided the software is able to reconcile and compute uncertain data (Cencic and Rechberger, 2008). However, the researcher only used STAN for diagrams and used Microsoft Excel based applications for making calculations as there was lack of technical expertise on the use of the software.

MFA requires detailed data as a function of time in order to depict all flows and the distribution within the different processes that have been explained. Primary quantitative data for this study was collected from SWMD namely raw data from the Disposal department[4], raw waste data from a private waste collecting company servicing the "Think Twice project" and interviews from staff members in the SWMD. The secondary data was collected from the monthly reports of the SWMD's waste minimisation initiative which reflects the result of primary data analysis and interpretation conducted in the department.

3.5 Limitations and Assumptions

One of the limitations of this study was that no data was available in the SWMD for private waste minimisation programs that take place in the CCT except for those that are contracted by the CCT. As a result the available data does not provide a clear picture of all the waste minimisation initiatives that are available in the CCT. Most of the private waste collecting companies that are contracted by the CCT were also not willing to discuss their waste minimisation operations and data due to strict privacy policies. The time frame for the data collection and site tours was also very limited and not all waste minimisation facilities were visited to observe operations. Kraaifontein MRF/RTS was not fully operational during the period of data collection, therefore it was not included in this analysis.

MFA requires detailed data because unknown data introduces errors and further uncertainties (Bainbridge, 2009). The data accessed by the researcher was taken

[4] Raw data is data that was collected directly from the waste disposal sites in the form of monthly weighbridge reports. This data is collected by officers from Disposal department who collect it once a month.

from SWMD. Data from some of the facilities was incomplete therefore the researcher used both absolute (flow amounts) and relative (flow rate) types of data. Data assumptions were made to cover for missing data based on the previous monthly data that was available. The Bellville compost plant for example failed to record the weight of waste every month due to technical problems. Relative data was used based on the general plant performance data that was recorded in earlier months.

In addition, the researcher observed that the weighbridge waste classification process was inaccurate. At the municipal landfill sites, the classification of waste is done by the weighbridge officer who may incorrectly classify a truck loaded with green waste that was mixed with sand as general waste. This data capturing process was observed during the month of April 2011. The disadvantage of this current setting is that this information is compiled by officers from the municipal disposal offices and generalised for reporting across the SWMD.

Estimations for publicly transported waste are sometimes based on the load capacity of private vehicles (usually 1.3 tons vehicles are used for the transportation of waste to the sites). The inaccuracies of the waste characterisation at the weighbridge has contributed to inconsistent and flawed waste information being collected in the SWMD. No waste characterisation was done in this research to specifically address these problems due to financial constraints in rolling out that exercise. This study used the available waste data that was captured by the SWMD to determine the flow of material. The data represents the financial year July 2010 to June 2011.

3.6 Ethical considerations

Qualitative and quantitative data collected for this project was considered to be confidential and was treated as such. All interviewees who provided information were assured that their personal names will not be quoted in context. No private waste collection company representatives that provided the researcher with data will be directly referenced neither will the names of the companies.

3.7 Conclusion

In this chapter the purposes of selecting the tools, design and methodology of the research were explained. The purpose of selecting the methodology used in this research was to aim to fulfil the research objectives in order to produce reliable research outcomes while at the same time providing a learning space. The CCT was used as a case study because a reliable source of information and data collection was made available to determine the performance of the ISWM system. There are studies that have been done in the past on the subject of waste management but there are few studies done in the CCT using MFA as a method to model the waste management system with particular focus on the collective performance of waste minimisation initiatives. The important aspect to note in this study is that it is a MFA study that aims at analysing the flow of waste in the minimisation initiatives of the CCT. This research opens room for further testing of the sustainability of the current system by assessing its impact on the economy, society and environment.

Chapter 4 applies the MFA framework discussed in this chapter. It starts off with details of the case study and provides background to the waste minimisation initiatives run by the CCT. Chapter 5 will proceed with the final conclusion to the research.

Chapter 4 – Results

4.1 Introduction

This chapter is divided into subsections where the quantitative and qualitative results will be presented. The qualitative data collected was guided by the MFA framework shown in figure 10 discussed in section 3.3.2 in chapter 3. According to the MFA framework the first step is to define the system in terms of the local conditions, legal framework and socio-economic issues. This step will be followed by the characterisation of the waste according to the standard characterisation reporting format used in the SWMD of CCT. The quantitative data will then be presented at the stage where the waste minimisation initiatives are modelled using the MFA. At this stage the waste flows, treatment processes and waste fractions will be shown and discussed. The modelling stage overlaps with the inventory stage where waste tonnages are discussed. This implies that the process chain analysis combines waste flows between processes, waste fractions and amounts of waste diverted per minimisation initiative analysed in the study.

4.2 Definition of system boundary

4.2.1 Local conditions and socio-economic issues of CCT SWM

According to the last census of 2001, Cape Town has a population of approximately 3.25 million over a municipal geographical area of approximately 2500 square kilometres (km^2) of the Western Cape Province of South Africa (Mtyi, 2008). After the first democratic elections in 1994 the restructuring of the local government began. The six local municipalities namely; Blaauwberg, the City of Tygerberg, Helderberg, Oostenberg, South Peninsula, and Cape Town (see Figure 12) were amalgamated to form the unicity in December 2000. This amalgamation was done in order to form a more manageable structure for municipal responsibilities including waste management (Engledow, 2007).

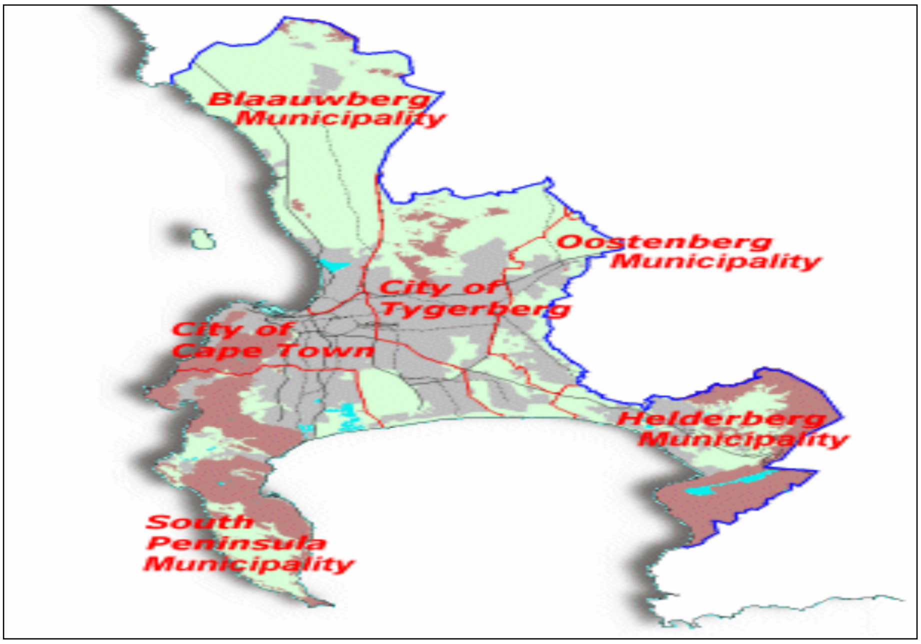


Figure 12: Map of Cape Metropolitan Area (CMA) showing the six municipalities

Source: State of the Environment Report: Cape Metropolitan Area (1999)

Municipal solid waste is generally sourced from residential areas, commerce and trade, agriculture, and (manufacturing) industries. According to Crane et al (2010) recycling rates in Cape Town are low by international standards as European cities with similar demographics and population recycle up to 40% of residential and commercial waste streams. A greater percentage of waste ends up at the three operating public landfills, namely; Bellville South, Coastal Park and Vissershok. For example in 2008/9, 3.03 million tonnes of waste was managed by the SWMD. At least 27% of this waste was diverted from landfill resulting in an estimated 2.2 million tons of waste being disposed to landfill
(including private landfill) (Akhile Consortium, 2011).

Solid waste has become one of the fastest growing sectors in terms of demand for management and removal services. In 2009 the net population growth average was between 1.6% and 2% while the projected waste generation was approximately 7% per annum (CCT Waste Management Sector Plan, 2009). This means that the rate of municipal solid waste generation is faster than that of the urban population growth. The fast waste growth rate calls for more options and multiple waste management capacities to be simultaneously activated as land use constraints limit the expansion capacities of landfills. Any progress in waste prevention can assist in the effectiveness of waste management by slowing down the waste generation impacts into the waste management system (Mazzanti and Zoboli, 2006).

Waste management services in Cape Town are required by 1,103,182 households, approximately one third of the population resides in 230 informal settlements consisting of 190 006 households (Akhile Consortium, 2011). Households that are deemed 'indigent' get 'free basic services' which are funded from government grants and cross-subsidised by a portion of the collected rates. The Indigent Policy of Cape Town identifies indigence based on household's income threshold, that is, households that receive less than R3000 per month and by value of the property receive free basic services (DA, 2011). The indigent rebate for financial year 2010/2011 is as follows:

- Households valued at under R100 000 (100% rebate)
- Households valued at under R150 000 (75% rebate)
- Households valued at under R250 000 (50% rebate)
- Households valued at under 300 000 (25% rebate) (City of Cape Town budget, 2011)

It is estimated that 99% of all households in Cape Town receive a weekly refuse collection. The 1% of households that do not have waste collection service are said to be a result of unplanned development of informal settlements (Akhile Consortium, 2011). According to a study done by Swilling and De Wit (2008), the household structure of Cape Town classified that 16% of households are richest, while 50% are the poorest households. Meaning that, the percentage of households getting free basic service is high. According to Akhile Consortium (2011) 58% of the revenue of SWMD originates from tariffs and the rest from rates. The responsibility to fund and perform solid waste management functions is the responsibility of the local municipalities in South Africa. Waste management activities such as area cleaning, drop-offs, waste collections, disposal and indigent grants are all funded by tariff revenue. The source of funding for future waste minimisation and diversion from landfill programmes is not clear.

4.2.1.1 SWMD of CCT and relevant stakeholders

The organisational framework of the CCT SWMD as shown in Figure 13, shows that it is divided into varying departments namely; Collections, Area cleaning, Disposal, Finance, Strategic Planning, Human Resources and Fleet Management. All these essential services fall under the category of Services and Infrastructure (Engledow, 2007). The functions of each of the department are as follows:

- The Collections department manages the residential and commercial collections services and public drop offs. Waste is currently collected from 669 500 domestic and commercial service points throughout the city (Akhile Consortium, 2011).

- Area cleaning is responsible for street cleaning, animal carcass removal, and illegally dumped waste. They also look after community based contracts for keeping the city clean.

- The Disposal department operates the three landfill sites and refuse transfer stations. It is also responsible for capping and rehabilitating landfill cells as they reach their point of closure and preventing contamination of groundwater and other environmental effects caused by leachate generation.

- The Technical service department is responsible for occupational health and safety regarding technical operations of the department as a whole. It also manages and maintains the municipal assets.

- Waste minimisation, under the National Environmental Management: Waste Act, 59 of 2008, serves a statutory function for all the other SWMD functions and manages all MSW minimisation activities. This division is under the Planning department.

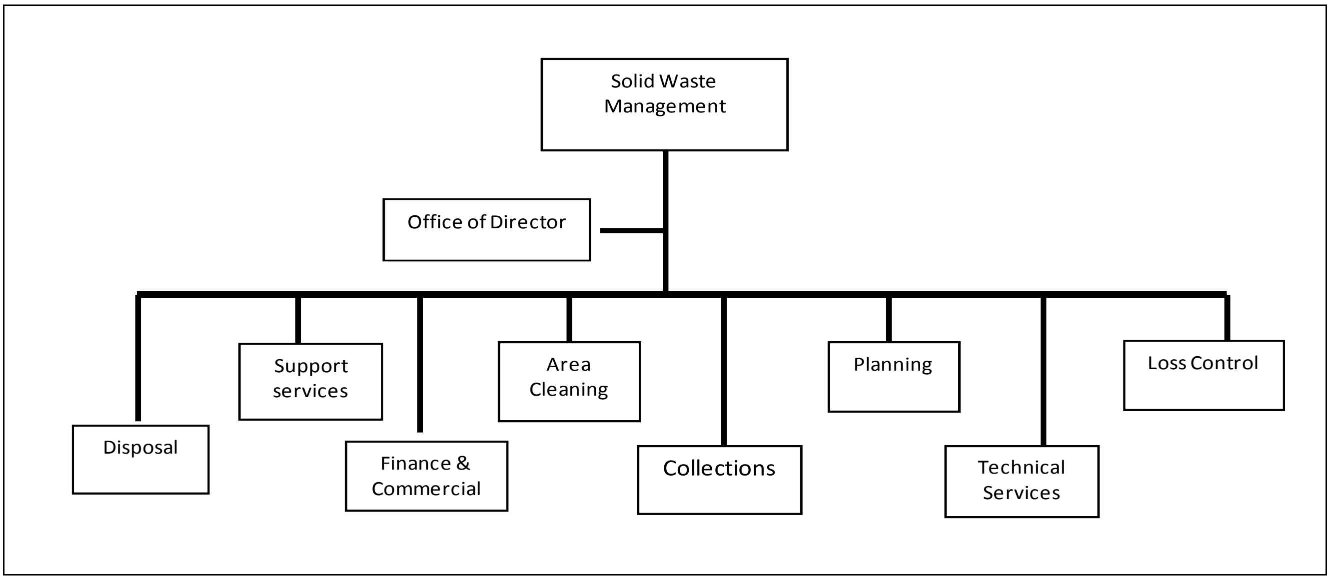


Figure 13: Solid Waste Management Department management structure

Source: Adapted from Engledow (2007)

There are a number of stakeholders that play critical roles to the successful implementation of waste management services plans. These are:

- Industry
- Non-governmental organisations and Residents monitoring communities
- National government departments
- Provincial government
- Professional organisations
- Community salvagers organisations
- Members of the public
- Businesses (Retailers and Corporate businesses)

4.2.1.2 Waste minimisation initiatives

The CCT subscribes to the conceptual approach to waste management as underpinned by the waste hierarchy shown in Figure 4 in chapter 2. This section discusses each of the waste minimisation programs that are currently run by the CCT as part of the objectives of this research; see Figure 14 for the geographic distribution of the existing waste minimisation infrastructure including the landfills in Cape Town. Waste material targeted for waste minimisation are; all types of packaging recyclables and tyres, organic waste (garden waste and all biodegradable waste), hazardous waste, e-waste, health care risk waste and pharmaceutical wastes. Each of the programmes will be briefly discussed including the current challenges that are encountered. There is a number of private waste minimisation initiatives that are currently operating in Cape Town apart from those that are run by the CCT SWMD. These initiatives will not be covered in this study. The CCT operates the following waste minimisation initiatives:

- Drop-off facilities
- Material recovery facilities (MRFs) and Refuse transfer stations (RTS)
- Builder's rubble crushing and garden waste chipping at landfill and selected drop off sites
- Compost Plant in Bellville.
- The Think Twice project.
- WasteWise Public Education, Awareness and Communication Project
- Waste paper separation project in municipal offices.
- Integrated Waste Exchange (IWEX) Website
- Schools environmental education and development (SEED) which aims at demonstrating sustainability and multifunctional learning to schools and the broader community.
- Waste Minimisation Clubs (WMC) – a voluntary partnership which promotes the exchange of experience and information between groups of companies or organisations.
- Retailer Partnerships.

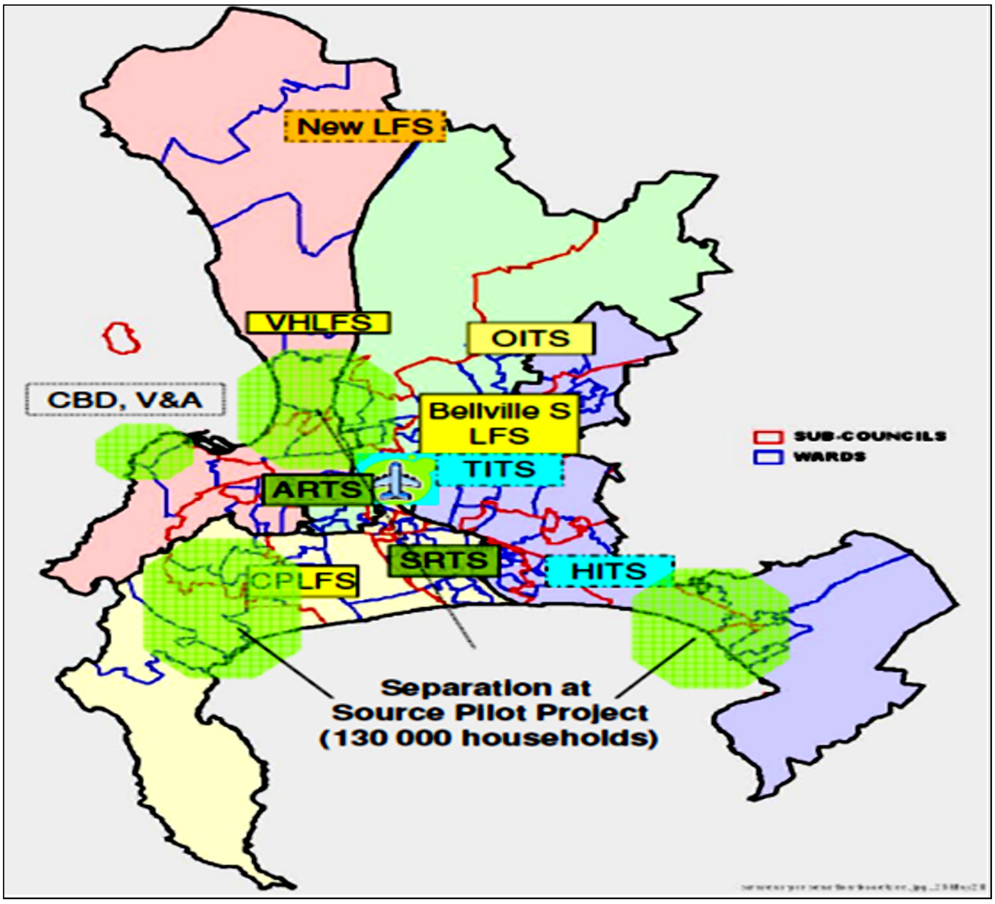


Figure 14: Map of the CCT, showing landfill locations, material recovery facilities and the separation at source pilot projects.

Source: Coetzee (2010)

The waste minimisation facilities whose waste flow were further analysed will be described in detail in the sub-section.

A. Source separation program - Think twice campaign

The Think Twice campaign was launched on 5 June 2007 and implemented on 13 August 2007, after the approval of the 2006 ISWM policy (Mcadi, 2008). This initiative was part of the IWM policy and a participatory planning approach was used in the inception phase of the project as various stakeholders were involved in all the selected areas (Davidson, 2011). These stakeholders included:

- Mayoral committee and executive management team
- Various City Departments, headed by Solid Waste
- Ward and Sub council structures
- Think Twice Contractors and Subcontractors

- Recycling Processors
- Residents and businesses

Due to budget constraints, the CCT Council decided to roll out the programme in phases in approximately 69 957 service points which is 8.67% of the City`s service points (Davidson, 2011). See Box A for the list of areas where the project is currently run. Private contractors commissioned by the CCT, market the pilot project to the public and provide clear plastic bags to participating households in order to separate dry recyclable waste from wet organic waste. Dry recyclable waste is then sorted at private material recovery facilities and sold to different recycling companies. The CCT tender requirements for all the Think Twice contracted waste haulers was to inform the public of meetings and project roll-out, facilitate meetings to promote separation at source, provide quarterly feedback to SWMD, do monthly adverts in the form of handouts and pamphlets or posters in order to encourage the public to separate their waste (Magubane, 2011). Figure 15 is an example of a poster that was used to advertise the pilot project by a private waste collecting company contracted to collect waste in the source separating project areas.

Box A **Think Twice Campaign areas:**

- **Helderberg area**: Gordon's bay, Somerset west, Strand, part of Macassar and surrounds.
- **Deep South/ South Peninsula**: Fish Hoek, Simonstown, Kommetjie, Ocean View, Noordhoek, Scarborough.
- **Atlantic Suburb**: Pinelands, Parklands, Melkbosstrand, Bloubergstrand
- **Houtbay**: Camps Bay, Clifton, Bantry Bay, Bakoven.
- Sectional titles and business areas such as Seapoint, Green Point, Mouille Point and Three Anchor Bay were also included in the program in 2008 (Davidson, 2011).

According to Strategic Development Information and GIS (2001), the socioeconomic levels of the sited areas indicate that the affluence level of the areas is middle to upper level income groups (personal income is between R10,101 and R14,500 a month or between R20,202 and R29,000 and over month). A private waste contractor (2011) confirmed that, a high percentage of people in affluent areas are willing to participate and also appreciate the recycling project than the less affluent residents. Davidson (2011) from Waste Minimisation attests that source separation projects in lower socioeconomic areas have failed. Reasons that led to failure include poor communication and misunderstandings between the contractor and community members, and less effective marketing strategies used by contractor in the community. For instance in Philippi Browns farm the project failed because community members felt that they were being exploited by the contractor and demanded cash in exchange for the recyclables. After negotiations with community leaders a few members of the community were employed to work with contractor, but this also led to riots and claims of nepotism. Waste collecting equipment such as shipping containers were stolen as an expression of declining to participate in the project (Magubane, 2011). Furthermore in Delft, Mfuleni and Ocean View residents demanded incentives in exchange for the waste thus the low participation rate. Informal recyclable waste collectors were also reported to derail the project. It was reported that in selected areas, they collected recyclable waste bags from participating households before the contractors arrived for collection. Contractors needed to bring them into the contract structure in order to sustain their business but in some areas this remains a challenge (Magubane, 2011)

Solid waste management (2011) argue that even though incentive based encouragement of source separation programmes could improve participation rates in less affluent areas; it is not feasible for the CCT to fund such a programme yet. Poswa (2011) also highlighted that programs such as the Think Twice campaign are expensive to run and this is the major reason why incentives cannot be provided as all funds are used to operate the project.

The researcher visited one[5] of the private MRF that recovers dry waste collected from Think Twice campaign areas. A significant amount of packaging waste such as; multi-coloured polystyrene food packs, tetrapak, multi-laminated plastic foils (for food packaging such pet food and bacon), punched confetti, laminated or waxy paper and carbon paper were set aside because these waste types do not have a recycling

[5] Private MRF management requested anonymity

market in the country. Dirty packaging waste that cannot be sent to recycling companies is also sent to landfills because recycling companies strictly require clean material. A plastics recycling company the researcher also visited, confirmed that they do not accept dirty plastic as the cleaning process raises their operational costs.

The contracted waste haulers have a target to divert a minimum of 3.5kg of recyclable waste per participating household (Magubane, 2011). The average cost to the CCT for delivering this service is R2.55/kg of recyclables collected and sold (Magubane, 2011). The total cost to the council for the private waste collector`s contract depends on the mass of the recyclables sold. A costing study completed by De Wit in 2009, indicated that the programme rollout is not financially sustainable in terms of the tonnages of waste diverted from landfill (Davidson, 2011). However, the CCT is still running the project and percentage increase of waste recovered in all the pilot areas has increased over the years, see table 1 for an example. According to Crane and Swilling (2008), at the beginning of the project, 84 tonnes of recyclable waste was collected in a single month. Table 1 shows the amount of recyclables obtained from the different areas comparing financial years 2009/2010 and 2010/2011. The highest recovery rate increase was observed at Sea point while the lowest was at Helderberg. Recent data and information on tonnages of waste diverted from landfill for this financial year (2010/2011) is discussed in chapter 5.

Table 1: Recyclables recovered from the Think Twice campaign areas.
Source: CCT SWMD waste minimisation, (2011)

Area	**July 2009 to June 2010 (Tonnes/yr)**	**July 2010 to June 2011 (Tonnes/yr)**	**Percentage increase**
Sea Point	2352	3416	45%
Atlantic	1974	2651	34%
Helderberg	3578	3698	3%
Deep south	1523	1925	26%
Hout Bay	1545	2199	42%

Figure 15: Example of a Poster used by contracted private waste collectors, advertising the separation at source project.

Figure 16 provides a sequence of the collection and sorting of the Think Twice campaign recyclables at the Deep South. A private company contracted by the CCT serviced this area during the period of data collection.


1


2


3


4


5


6

Figure 16: Think Twice recyclables collection and sorting process. (Pictures 1-10: 1&2- truck collects household sorted in clear bags from residential areas; 3-5 - Bags of recyclables sorted into categories; 6 - Sorted and packaged recyclables 7 - Sorting bins filled with dirty recyclables and packaging material that cannot be sold. The waste bins in the picture are filled and sent to landfill for disposal; 8-10 Sorted recyclables are separated into specific skips. Pictures were taken on site visit at the Deep South on 10/08/2011).

B. Composting

There were three composting facilities in the CCT namely Swartklip, Radnor and Bellville South Compost plant which were established in the late 1960s and early 1970s. These facilities were making compost out of mixed municipal waste. Over the years many private companies also joined the composting industry thus giving competition to the municipal composting facilities. Radnor and Swartklip compost plants were closed, however the Bellville compost plant is still operational. The facility treats municipal solid waste and converts the organic component into compost. Due to the 'poor' compost quality produced, the plant is currently operating at a high cost and is unsustainable (Akhile Consortium, 2011). The CCT has approved a public-private partnership (PPP) where interested members of the public were invited through media on 5th August 2011 to take part in the evaluation of Radnor and Bellville composting facilities as an initiative of involving private sector businesses. This was a rollout of the SWMD's decision to establish partnerships with private institutions that are competent to operate waste processing activities such as composting to increase the plant performance.

C. Material Recovery facilities (MRF) and Refuse Transfer Stations (RTS)

There are three MRFs and RTS in the CCT namely; Athlone (ARTS MRF/RTS), Swartklip (RTS only) and Kraaifontein (MRF/RTS). MRFs provide a service to process co-mingled recyclable waste or dirty waste for the purpose to recover recyclable waste. A MRF is used to sort recyclable waste received from households, commercial and industrial sectors. The RTS acts as a temporary storage point prior to transporting and disposal of waste to landfills. ARTS is owned by the CCT and the RTS section is operated by the CCT. The MRF section is operated by a private contractor called Unicell. The facility also contains a drop-off facility where garden waste chipping and builder's rubble are collected.

ARTS is a 'dirty MRF' and the material recovery process is a combination of mechanical and manual sorting. ARTs RTS/MRF receives an average of 1500 tonnes of waste per day on average, of waste per day (1000 tonnes is the maximum design capacity of the facility per day) and a portion of waste is diverted to the dirty feed MRF (Nontangana, 2008). Waste material recovery tonnages have dropped since the beginning of source separation project around the CCT. The project is believed to be the reason for the drop in recovery waste tonnages (Nontangana, 2011). In addition, there is a poor demand for recyclable material recovered from the dirty MRF as incoming recyclable waste is highly contaminated. The plant supervisors highlighted that the dirty waste contributes to machinery (such conveyor belts) mechanical problems. Recyclable waste material recovered from the MRFs is sold to recycling companies while the remainder is compacted into steel containers that are approximately 20 tonnes each and sent via rail transport to Vissershok landfill site. Given the low prices and poor demand for dirty recyclables and low recovery rate experienced in the plant, Akhile Consortium (2011) recommended that this plant is converted to a “clean MRF”. There are also plans of a northwards extension of the de-commissioned Athlone power station site in order increase the MRF site. The extension will allow for increasing the design capacity of the plant from 1000 tonnes per day to 1500 tonnes per day with a separate standby line. The extension will further provide room for considering other waste minimisation technologies such as waste-to-energy and composting (Akhile Consortium, 2011).

The Kraaifontein MRF/RTS was established in February 2011 to serve the northern suburbs of Cape Town that were previously serviced by the closed Brackenfell landfill. The station together with the fixed machinery belongs to the CCT, but it is operated by a contracted private company that was commissioned to run the facility in August 2011. The contractor is called Waste Plan. The facility has a public drop-off, a MRF, a RTS and a garden waste chipping area. The researcher did not do a MFA on this site because during the period of data compilation in June 2011 the facility had not been commissioned to officially operate. Waste material was sent to the site during the period of data collection, but all waste was transferred to the landfill.

The Swartklip RTS was designed to serve as a transfer station for Mitchell’s plain area. In the 1980s the facility was converted into a compost plant and operated in that fashion until 2003. It was then converted back into a transfer station to replace the closed Swartklip landfill site (Mohamed, 2011). A drop off is planned to be constructed on the site in 2012. The department is also planning to open two more RTS at Tygerberg and Helderberg. At Swartklip there is no material recovery. All incoming waste is thus transferred to the landfill.

D. Drop – offs

There are 20 stand-alone drop–off facilities in Cape Town that collect general household, garden waste and builder’s rubble. Drop offs only allow disposal of up to 1.3 tonnes of non-hazardous waste at any of the sites. Most of these sites provide facilities to recycle waste such as garden waste, builder's rubble, electronic waste (e-waste), motor oil, paper, cardboard, glass, plastic and can. Waste that cannot be recycled is periodically collected and sent to the landfill sites for disposal. Drop-offs further promote waste minimisation by providing the public with free and convenient sites to dispose and further reduce transportation costs (Mohamed, 2011).Even though the CCT has successfully distributed these sites within Cape Town; the challenge is that people with no personal vehicles find it difficult to make use of these facilities. The strategy to curb this challenge is providing low income areas with less formal disposal units such as skips.

E. Landfill sites

There are currently three landfill sites in the CCT namely; Bellville South, Coastal Park and Vissershok South landfill. The landfills in Coastal Park and Bellville South are classified as general waste disposal sites (GLB+). It is estimated that Bellville South landfill will close in June 2013, while Coastal Park is envisaged to close between 2019 and 2022. Vissershok South is a low hazardous waste disposal site (H:h) and is the only landfill site in Cape Town with a rail infrastructure for receiving waste. It is envisaged to close between 2014 and 2016 assuming that Vissershok North landfill and the proposed landfill site will be operational. There is a privately owned landfill in Vissershok close to the state owned site that handles industrial hazardous waste (H:H). It is estimated to close in the next 9 to 13 years (Wright-Pierce, 1999). The lifespan of the remaining municipal landfill sites is between 8 and 11 years excluding the private landfill. There are drop off facilities in all three landfill sites that minimise waste, albeit the amount of recyclable waste diversion in the drop offs is very minimal. There are also contracted services for garden waste chipping and builders` rubble crushing on site.

SWMD disposal data indicates that over the past five years; when waste minimisation initiatives started, there has been a steady 2% decrease in tonnages of waste sent to the landfill. Figure 17 shows the trend of waste recieved at the CCT landfills over the past 5 years.

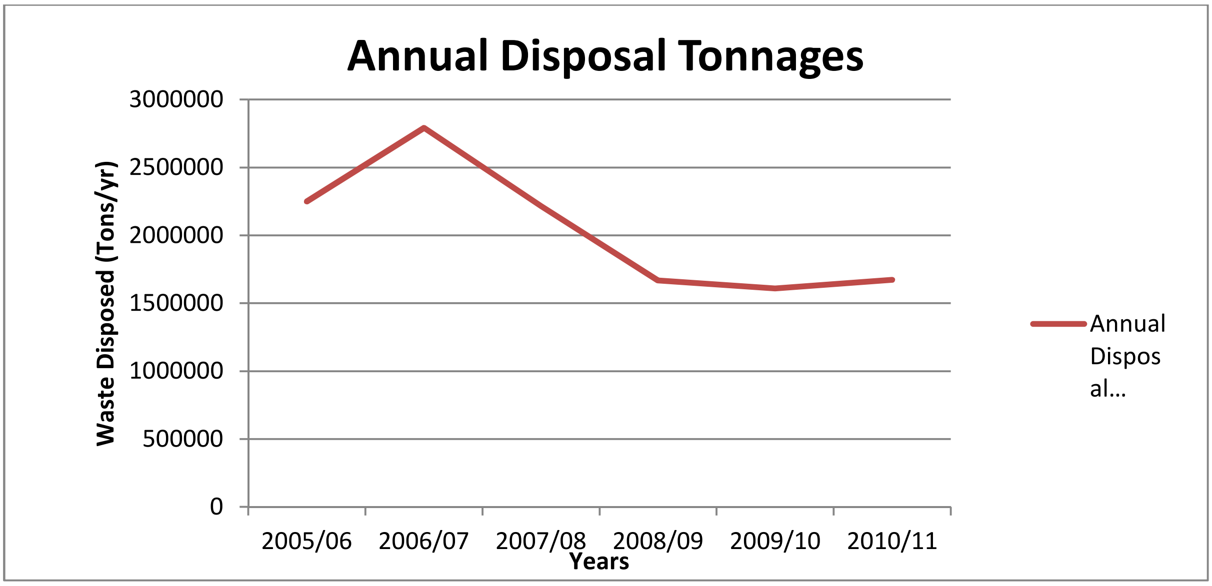


Figure 17: Trend in solid waste received at the City of Cape Town landfills over the past 5 years.

In 2000 the CCT appointed consultants to identify and assess potential sites for a regional landfill to serve CCT for the next 30 years. After a comprehensive site selection was made two sites were allocated, namely: at the South of Atlantis and at Kalbaskraal near Philadelphia (Coetzee, 2007). The application for the new regional waste disposal facility for the CCT was lodged under the Environmental Impact Assessment (EIA) EIA Regulations promulgated under the Environmental Conservation Act, 1989 (Act No. 73 of 1989) (ECA) (CCT Environmental, 2011). However, after site investigations were done, feedback from environmentalists and planners highlighted the following critical factors that hindered the development of the landfill:

- At the site there is the future R304 road crossing the Southern part of the site.
- The proposed airport
- The west part of the site falls within the designated southern core of the Cape west Biosphere Reserve where the West Coast Conservation Area (WCCA) intended to be formally protected as a nature reserve.
- At the Northern part of the area, there is groundwater used as a source of water supply for smallholdings and a chicken farm.

Despite the above named factors, the Department of Environmental Affairs and Development Planning- issued a Record of Decision (RoD) for the project in terms of the ECA EIA Regulations on 16 July 2007 (CCA Environmental, 2011). The RoD granted authorisation with conditions to the CCT to undertake the execution of the activities as applied for on the landfill site situated south of Atlantis**.** The landfill site development was fervently opposed at public meetings where there was legal representation to contest the development of the landfill. In addition, a substantial number of appeals were presented on the decision and the main opposition came from smallholdings situated to the east and southwest areas of Atlantis. The Member of Executive Council (MEC) at that time, Mr Pierre Uys, overturned the decision and authorised the establishment of the regional landfill site on the farm Bottelfontein, referred to as Kalbaskraal on 7 April 2009 (CCA Environmental, 2011). Interested and affected parties in the area also applied to the High court to set aside the MEC`s decision. On 5 January 2010 the new MEC, Mr Anton Bredell was ordered by the High Court to set this decision aside. Currently, the application of the landfill sites is still at appeals stages. The MEC requested that the CCT appoint an independent environmental assessment practitioner to compile a Supplementary Environmental Impact Report (SEIR) before a new decision is issued. At present the proposed regional landfill project is still on appeal in terms of section 35 (3) of the ECA.

4.2.2 Legislative Framework

In South Africa, the national governments and provincial governments provide monitoring, support services and also establish relevant norms and standards relevant for solid waste management (Spamer, 2009). The CCT has numerous guiding policies and principles that provide an integrated policy framework in order for the city to achieve waste minimization (see Table 2). Examples of the policies and principles are namely: White Paper on Integrated Pollution and Waste Management for South Africa-Government Gazette 20978, 17 March 2000, the National Waste Management Strategy (2010), National Environmental Management: Waste Act 2008 (Act 59 of 2008) and the Polokwane declaration (2001) on waste management. The "*Council supports the goal of the Polokwane Declaration to reduce waste generation and disposal by 10% by 2012 and develop a plan for Zero Waste by 2022. In this respect, the target set by the Council is to reduce waste* *generated by 20%, and to reduce waste to landfill by a further 10% by 2012*" (CCT Integrated Waste Management Policy, 2006).

These governmental documents highlight that awareness of waste management is receiving government's attention. The sustainable development principles of waste minimisation are the golden thread in all the stated mandates on waste management. These principles have also been viewed as possible job creation initiatives as well as economic empowerment opportunities which many unskilled South Africans have already started benefitting from even though there is still room for improvement.

The legislative environment in terms of waste management in South Africa has evolved since the first democratic elections in 1994. The changes in legislation have changed the way that waste related issues are viewed in South Africa thus aligning with international advances of solving waste issues. In this thesis the relevant waste management legislations are only listed and summarised in Table 2. See Engledow (2007) for a detailed summary of each.

Table 2: Summary of legislation/policies of waste management

Source: Adapted from Akhile Consortium (2011) and Engledow (2007).

Year	Legislation/Policy/Regulation/Plan	Main Emphasis
1996	Constitution 108 of 1996 – Bill of Rights	Refuse removal, disposal sites. Local Government function– governed by Provincial Government
1998	DEAT – National Environmental Management Act, 107 of 1998	Environmental Impact Assessment Regulations and Framework for the overall protection of environment
1998	DWAF – Waste Management series 1998	Handling, classification and disposal of waste
1998	DWAF – National Waste Minimisation Strategy	Pollution of water resources
1999	DEAT – National Waste Minimisation Strategy	Not in use – new draft out for comment
2000	DEAT –White Paper on Integrated Pollution and Waste Management for South Africa	Prevention of pollution, waste minimisation impact management and remediation
2000	Local Government – Municipal Systems Act, 32 of 2000	Section 74(1) of the Local Government Municipal Systems Act 32 of 2000, as amended by the Local Government: Municipal Systems Act 44 of 2003 ("MSA"), provides that a municipal council must adopt and implement a tariff policy on the levying of fees for municipal services provided by the municipality itself or by way of service delivery agreement.
2003	Local Government – Municipal Finance Management Act, 56 of 2003	The object of the MFMA is to secure sound and sustainable management of the fiscal and financial affairs of municipalities and municipal entities by establishing norms and standards and other requirements for interalia: ensuring transparency; the management of revenues, expenditures, assets and liabilities: budgetary and financial planning processes and the coordination of those processes with the organs of state in other spheres of Government; borrowing; the handling of financial problems in municipalities; supply chain management and other financial matters.

Year	Legislation/Policy/Regulation/Plan	Main Emphasis
2006	City of Cape Town – Integrated Waste Management Policy	Defines the problem of increasing waste generation, identifies guiding principles set by legislation and other Council policies, and defines the scope, intent, purpose and objectives of the IWM policy.
2008	DEAT – Environment Conservation Act, 73 of 1989: Waste Tyre Regulations, 2008	Purpose is to regulate waste tyres in South Africa
2008	Consumer Protection Act (Act 63 of 2008)	In terms of Waste this Act deals with extended producer responsibility insofar as any supplier who in the ordinary course of business supplies goods that national legislation prohibits the disposal thereof, must accept the return of any such goods, components, remnants, containers or packaging without charge to the consumer. If any regulation or industry waste management plan approved by any other legislation or the management of a specific waste type applies, the consumer may dispose or deposit the good to a collection facility provided for in the regulation or industry waste management plan.
2009	City of Cape Town – Integrated Waste Management By-Law	Overarching integrated waste management by-law in the City of Cape Town repealing all previously fragmented litter/dumping by-laws from previous administration. Focus as per the NEMWA is on waste minimisation.
2010	DEA – Draft National Management Strategy	Revised focus from Cradle to grave to cradle to cradle approach. A revised Integrated Waste Management Hierarchy has been proposed including remediation. The strategy includes sections on health care risk waste, priority waste, e-waste etc.
2010	DEA – Draft Waste Classification and Management Regulations	Regulate the classification and management of waste meeting the provisions within NEMWA, including licensing, transport, handling, storage, treatment and disposal of waste.
2010	National Domestic Waste Collection Standards	Government Gazette, 21 January 2011. This regulation is in response to the Waste Act 2008 and is applicable to all domestic waste collection services in South Africa. The Standard provides a directive on how such a collection system should be structured to support the principles of the Waste Act, and focuses on affordability sustainability, equitable service delivery whilst also addressing certain waste streams, such as recyclable stream, household hazardous waste stream, whilst recognising the benefits of drop-off facilities, collection points, bulk transfer facilities, and community involvement as alternatives. The regulation mentions Waste-to-energy as an alternative when no recycling industry is present.

The legislative environment of waste management continues to undergo continuous changes as an effort to improve waste management and enforce compliance to all relevant stakeholders. These additional changes are:

- The Waste Act, 59 of 2008 Section 12 requires industries and municipalities to prepare integrated waste management plans. Waste information is to be reported to the central waste management department as landfills are no longer the preferred option for disposal. According to Solid waste management (2011) a number of companies across the CCT have already submitted their plans to the council and are currently being reviewed. This initiative is part of the Extended Producer Responsibility (EPR) mechanism aimed at reducing waste generation in South Africa at large.
- There are new regulations and standards, namely; the Waste Act Classification Regulations, the Standards for Assessment of Waste for Landfill Disposal and the Standard for Disposal of Waste to Landfill, which have already been published for public comments. The standards provide the technical methodology for assessing the level of risk posed by waste, waste classification, time frames for acceptance of certain waste for landfill disposal and containment barrier design (Seggie, 2011).
- There is also a new National Waste Minimisation Strategy after the one released in 1999 which is still in draft format at the time of this report and has been sent to cabinet for comments. The approval for the strategy is expected by the end of October 2011. It provides legal basis for existing waste policies by setting priorities, goals and objectives for the implementation of the Waste Act. It also highlights the importance of establishing the recycling economy and job creation in the waste sector. This strategy is expected to be a prominent action towards a more integrated approach in waste management in South Africa.

The changes on the Waste Act no.59 of (2008) seem to have been influenced by the international waste policy standards such as the European Landfill Directives of 1999. In 1991 the government of Helmut Kohl in Germany passed the packaging ordinance law that shifted the burden of recycling and disposing of packaging wastes from tax payers onto manufacturers (Rogers, 2005). In 1993, Sweden also introduced the same ordinance law as a waste minimisation strategy. This law is basically premised on extended producer responsibility (EPR) mechanism that many countries, including South Africa are enforcing. A preliminary report of the on-going research conducted by the Council for scientific and industrial research (CSIR) on the success or feasibility of waste policy instruments such as command-and-control instruments[6], market-based instruments and information instruments suggests that, these first world policies face a number of challenges in developing countries. This is because the trends of population growth, economic growth and social perceptions are different between the two continents (Godfrey and Nahman, 2007). For instance in South Africa the Department of Environmental affairs is working on instituting EPR mechanism for manufacturing industries in the country who will be required to comply with waste reduction programs and carry out life cycle assessments of their products regulatory tools and rules such stringent policies in the South African context, could lead to economic disasters as many producers may not have the capacity to fully comply.

4.3 Characterisation of waste

Table 3 shows a summary of the annual tonnages of general waste, builder's rubble, garden waste, hazardous waste and minimised waste. According to waste data for July 2010 to June 2011 financial year, 1 851 759 million tonnes of solid waste were generated. According to the data, only 8.67% (165 533 tonnes) of generated solid waste was minimised (Waste minimisation Unit, 2011). Waste classified under the heading 'general waste' is household waste together with non-hazardous trade and commercial waste. According to the latest municipal waste data, this waste category makes up 69% of the total waste generated and this waste was disposed in landfills (see Table 3). These figures further indicate that even though there are waste minimisation initiatives in the CCT, a larger percentage of waste generated is sent to landfills. According to the Akhile Consortium (2011) an estimate of 46% of general waste landfilled is sourced from households while the remainder is from commercial and trade sources.

[6] Also referred to as standards or regulations.

WASTE	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Total	Percentage
GENERAL WASTE	99488	104644	113250	101273	119032	128962	96325	99742	104251	97694	106818	110366	1281844	69%
BUILDERS RUBBLE	16940	19706	22323	15959	31997	23190	16427	29832	25856	31880	26103	26155	286366	15%
GARDEN WASTE	15714	15442	3634	2225	3804	3805	4936	1668	1118	4057	3814	5283	65498	4%
HAZARDOUS WASTE	4221	4858	3998	3975	5135	6455	4825	3559	4659	3446	3671	3419	52219	3%
WASTE MINIMISED	15626	12049	15814	13588	12268	13098	14406	14285	13611	12616	13187	15285	165833	9%
TOTAL	151989	156698	159018	137018	172236	175509	136918	149086	149495	149692	153592	160507	1851759	100%

Table 3: Waste tonnages for financial year July 2010 to June 2011

Source: SWMD Waste minimisation unit, 2011

The objective of the study is to analyse the waste minimisation initiatives of solid waste in CCT. The researcher used the summary of total waste minimised data to determine the mass flow of waste in each of the waste minimisation facilities. Table 4 is a summary of waste minimised in the financial year July 2010 to June 2011. Data from all the facilities was consolidated by Waste minimisation section and a total of 165833 tonnes was reported to be minimised. The researcher then accessed primary data for each of the waste minimising facilities in order to determine the mass flows and the total waste diverted by each facility.

ACTIVITY	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Total
Bellville South	442	722	809	778	755	100	750	491	733	546	839	650	7615
Drop off sites	368	355	401	421	527	631	478	427	422	378	413	372	5194
ARTS (unicell)	264	542	462	321	458	325	393	259	366	306	329	326	4351
Crushing of Builder's Rubble at	0	0	0	0	0	405	1607	0	0	0	0	0	2012
Chipping Of Garden waste at landfills	648	480	436	360	814	240	139	230	2698	896	3862	5076	15879
Chipping Of Garden Waste at Drop offs	12006	8028	11942	9715	7668	9431	9863	11802	8362	8710	6727	7781	112035
Crushing Of Builders rubble at Drop offs	810	850	710	860	840	910	0	0	0	790	0	0	5770
Sea Point	252	244	232	268	287	270	265	252	280	263	279	279	3171
Atlantic	186	184	202	197	198	201	216	231	197	214	209	229	2464
Helderberg	296	326	342	338	397	274	240	223	241	186	254	247	3364
Hout Bay	186	166	151	168	161	182	202	203	162	150	152	145	2027
Deep South	138	132	115	149	154	117	242	156	137	173	114	168	1795
City Paper project	31	20	11	12	10	12	11	12	14	4	9	12	155
TOTAL	15626	12049	15814	13588	12268	13098	14406	14285	13611	12616	13187	15285	165833

Table 4: Waste minimised data for financial year June 2010 to July 2011

Sources: SWMD Waste minimisation, 2011

Waste minimisation facilities that had data at the time of data collection were Bellville compost plant, ARTS MRF/RTS, Think twice campaign, Drop off sites and the city paper project pilot project. Swartklip is not regarded as a minimisation facility at this stage as no material recovery is done at the site yet. Figure 18 shows waste recovery trends for the year 2010/2011. The Drop-off facilities are diverting the highest tonnage of waste. Garden waste chipping projects at the drop-off contributes to the high diversion. Waste minimisation data only records builders rubble crashing and garden waste chipping data. There is no data on the diversion of recyclables at the landfill drop-offs. Figure 19 shows a pie chart that clearly demonstrates the percentage diverted by each of the waste minimisation initiatives run by the CCT.

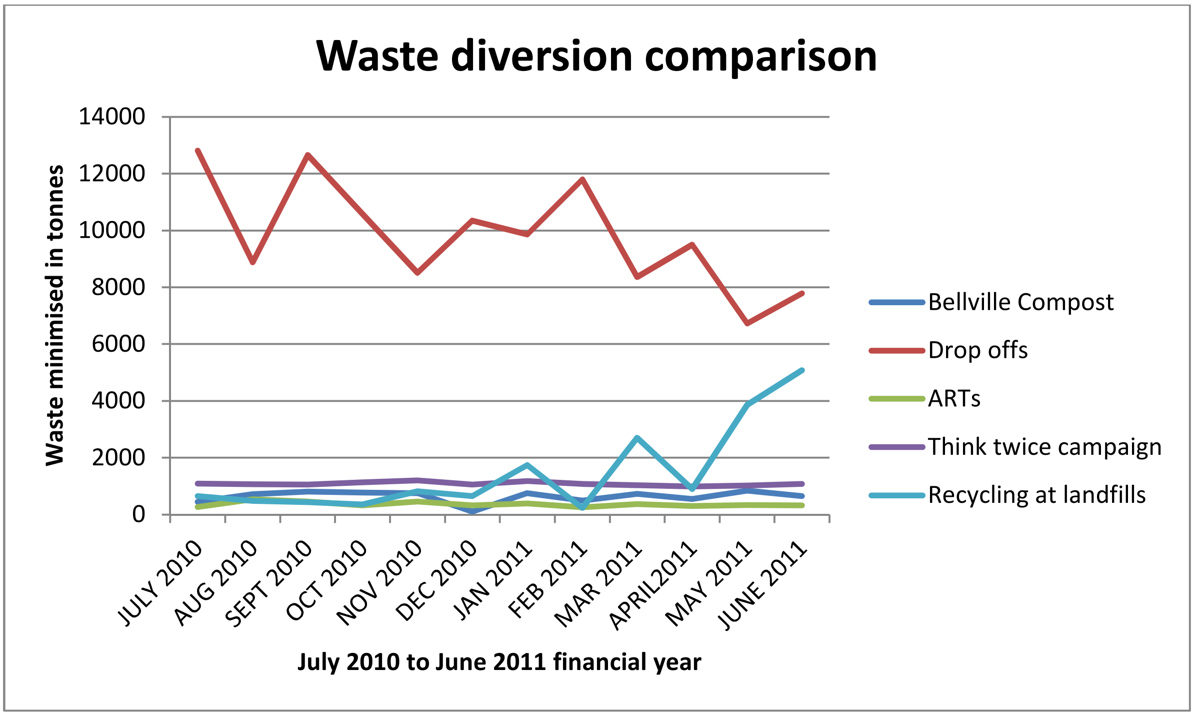


Figure 18: Recovery rates of waste minimisation initiatives in financial year July 2010 to June 2011

Figure 19 graphically describes the percentage waste diverted by the different waste minimisation initiative.

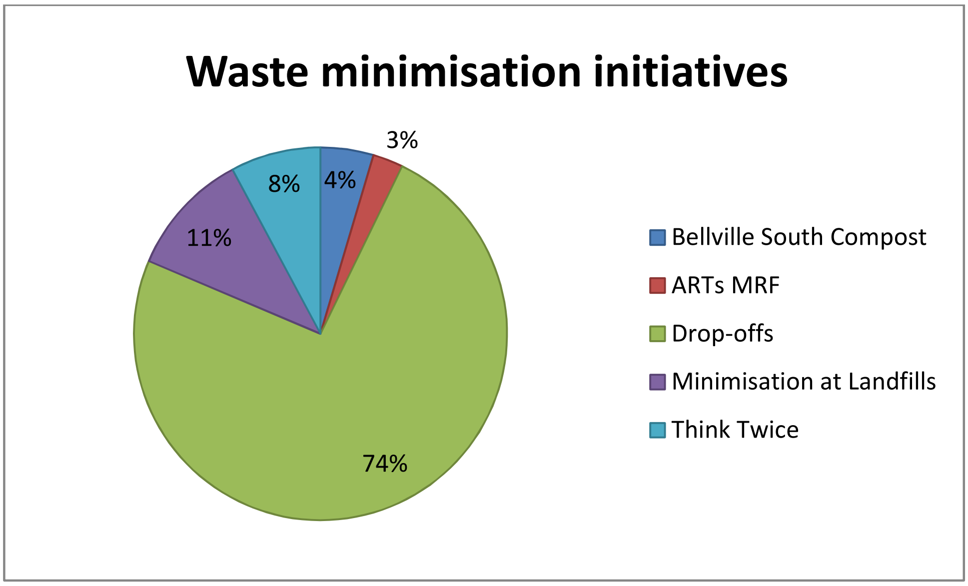


Figure 19: Graphic illustration of the contribution of the waste minimisation initiatives implemented by the CCT SWMD.

Source: SWMD Waste minimisation data of 2010/2011

4.4 Modelling of Waste System

A summary of the flow of solid waste material in the CCT is shown in Figure 20. This model illustrates the complexity of the solid waste minimisation system and also provides a clear picture of the flows of solid waste material through the different waste minimisation facilities. Figure 20 basically shows the flow of general waste material from commercial industry, households, industrial sites and parks cleaning that is managed by SWMD of CCT. According to Nontangana (2011), the sources of MSW entering waste management facilities are not known as the current characterisation method only demarcates wastes by type; that is, general waste, garden waste, builder's rubble and hazardous waste. This means that that, the actual percentage split between residential areas, industrial and commercial areas can only be estimated as there are currently no accurate waste source quantifying devices that can determine the exact waste sources.

The summary of waste flows shown in Figure 20 simply illustrates that:

(a) There is waste that comes from sources and is sent straight to landfills. Within the landfills there are waste minimisation programmes which are currently running; builder's rubble crushing, green waste chipping and drop offs where recyclables are stored. Crushed builder's rubble and chipped garden waste are sold to their respective markets.

(b) There is recyclable waste and garden waste from sources that is sent to drop off sites. There is garden waste sent to drop offs where it is chipped on site and sold to garden waste markets. Recyclable waste is also sold to different recycling industries.

(c) There is recyclable waste that is collected from sources which form part of the Think Twice Campaign. These wastes are sorted in private material recovery facilities where part of it is sold to the recycling industry. However, during the sorting, recyclables that do not meet recycling company's specification are sent to landfills for disposal.

(d) There is general waste that is sent to ARTS MRF/RTS. Recovered material is sold to recycling industry and some waste is transferred to landfills.

(e) Waste sent to Swartklip is transferred to landfill as no waste material recovery or drop off was available at the time of data collection.

(f) General waste from sources that goes to Bellville compost plant is filtered. Part of the waste is converted to compost and part of is rejected and sent back to landfills for disposal.

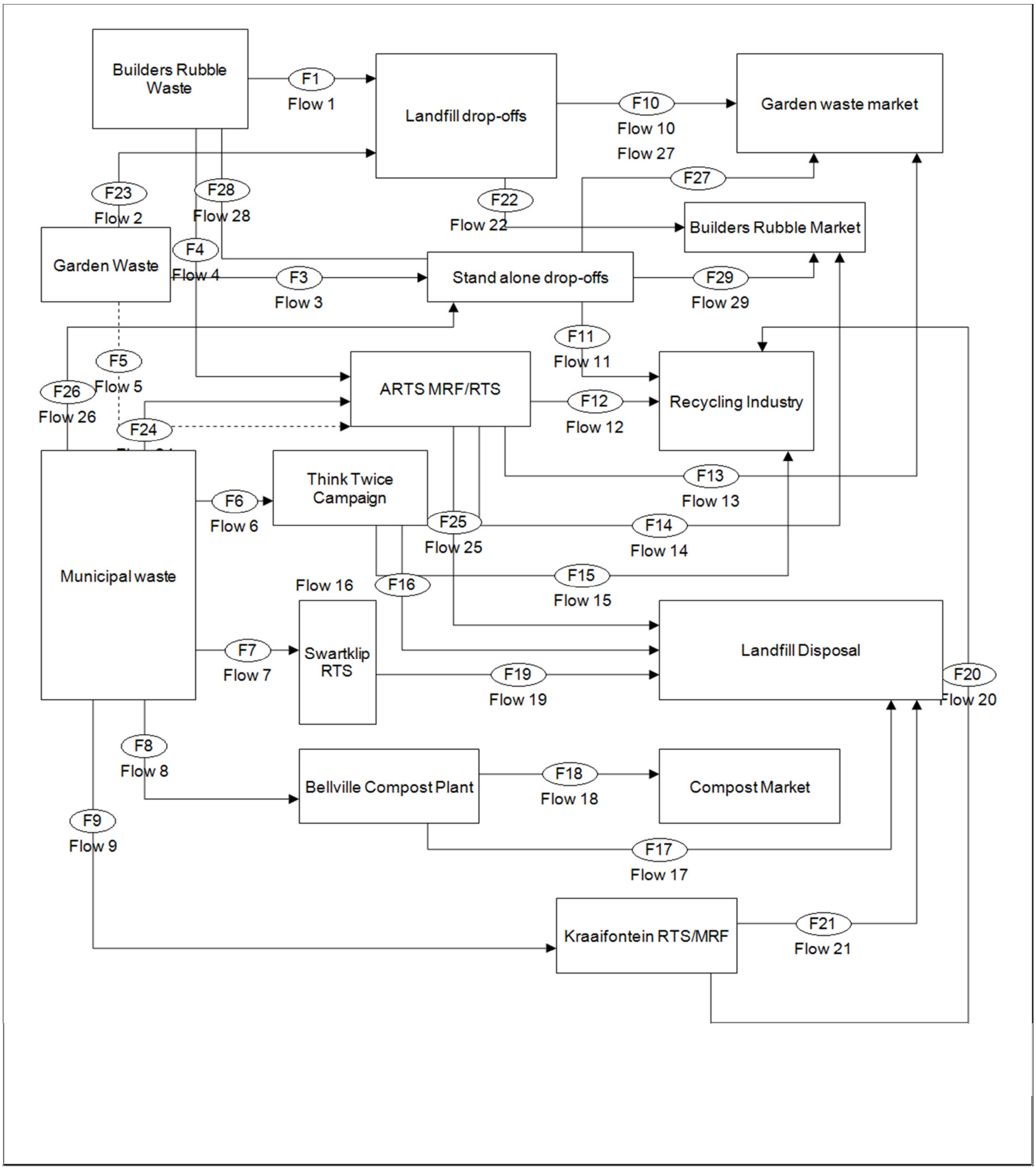


Figure 20: Flow analysis of waste in CCT.

Table 5 shows the flow of municipal waste as illustrated in the model in Figure 20. The formulas of the cumulative flows are also shown where the mass balance equation 1 is applied.

Table 5: Solid waste flow of the MFA model in Figure 20, including their mass balance formulas

Flow	Input	Flow	Output	Calculation Formulas (based on equation 1 principle)
F23	Landfill Drop-offs	F22	Builders rubble market	F23 = F22
F1		F10	Garden waste Market	*F1 = 10*
F26	Stand-alone drop-offs	F11	Recycling industry	F26 = F11
F3	Stand-alone drop-offs	F27	Garden waste Market	F3 = F27
F28	Stand-alone drop-offs	F29	Builders rubble market	F28 = F29
F6	Think Twice Campaign	F15	Recycling industry	F6 = F15 + F16
		F16	Landfill disposal	F6 = F15 + F16
F5	ARTS MRF/RTS	F13	Garden waste Market	F13 = F14
F24	ARTS MRF/RTS	F12	Recycling industry	F24 = F12+F25
		F25	Landfill disposal	F24 = F12+F25
F4	ARTS MRF/RTS	F14	Builders rubble market	F4 = F14
F7	Swartklip RTS	F19	Landfill disposal	F7 = F19
F8	Bellville Compost Plant	F17	Landfill disposal	F8 = F17 + F18
		F18	Compost market	F8 = F17 + F18
F9	Kraaifontein MRF/RTS	F21	Landfill disposal	F9 = F21 +F20
		F20	Recycling industry	F9 = F21 +F20

In order to clearly articulate the flow of waste, each of the waste minimization facilities were separately analysed in order to illustrate the waste flow. The formulas shown in table 5 were used to balance the masses of inputs and outputs.

4.5 Inventory Audit

This subsection describes the flow of waste per waste minimisation initiative. It is depicted from the overall MFA shown in Figure 20.

4.5.1 Mass flows of Think Twice campaign in the year 2010/2011

Figure 21 shows the process flow of waste collected from the Think Twice campaign. Recyclable materials are collected from households and business centres by private companies that are commissioned by the CCT SWMD. Areas that were allocated for the project are; Helderberg, Atlantic, Hout bay, Deep South, Sea point and the City paper project, see Box A. According to waste minimisation data for 2010/2011 financial year, an overall of 8% (15, 285 tonnes) of minimised waste was diverted by this pilot programme. The contracted waste haulers sort the waste at private material recovery facilities. During the sorting, recyclable waste is grouped in different categories, for example cardboards, PET plastics, clear glasses are separated. After sorting not all recovered waste material is sent to recycling companies. Staff members of a private MRF the researcher visited indicated that, not all packaging materials have a recycling market in the CCT. Packaging materials such as multi-coloured polystyrene food packs, clothing, dirty and contaminated packaging waste, tetrapak, multi-laminated plastic foils and toothpaste tubes are set aside and not sold due to lack of market.

According to waste minimisation data, each of the pilot project areas managed to divert the following figures this financial year before the recyclables were sorted at the private MRFs:

Helderberg = 3364 tonnes
Atlantic = 2464 tonnes
Hout bay = 2027 tonnes
Deep South= 1795 tonnes
Sea point = 3171 tonnes
City paper project = 155 tonnes

As shown in Figure 21, 5.2% (794.73 tonnes) of the total recyclable waste collected in this initiative is “unsold” recyclables. 10% (1513 tonnes) of the total waste collected is normally ‘spoils’, meaning that, it is recyclable waste that is either dirty or that does not meet the quality specified by recycling companies. Spoils and unsold recyclables are eventually sent to the landfills for disposal. Of the waste that was sent to recycling companies, 18% (2316 tonnes) was plastics, 42% (5356 tonnes) was cardboard and paper, 38% (4813.32 tonnes) glass and 3% (492 tonnes) metal. In total 12,977 tonnes of recyclables collected from all the programme areas were sent to recycling companies.

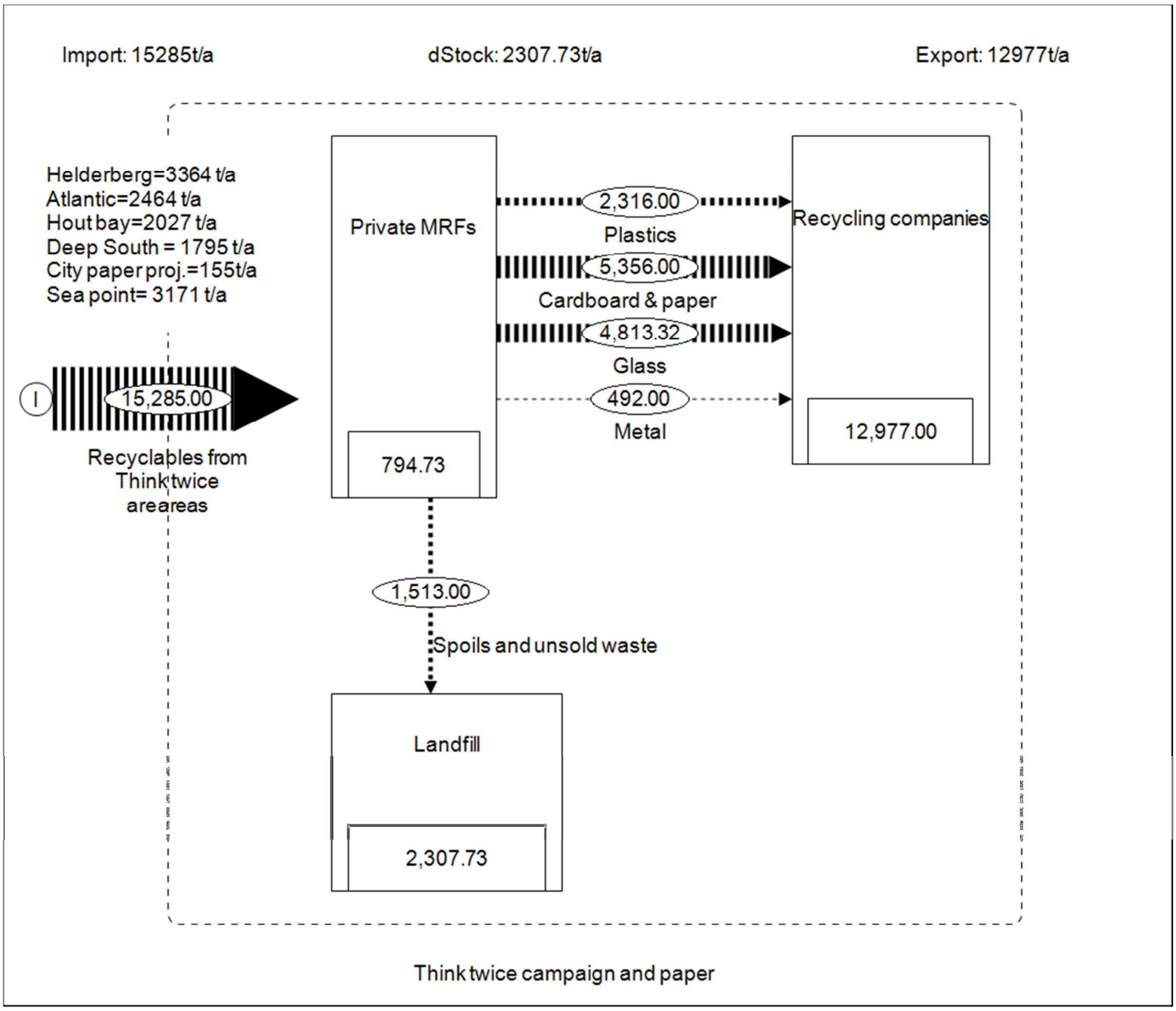


Figure 21: Mass flows for Think Twice recyclable waste including the mini office paper recycling project.

The overall percentage waste that was diverted by Think Twice campaign is 1% of the overall general waste generated in the financial year 2010/2011.The data shows that the participation rates for the Think Twice campaign varied for the different areas in the financial year July 2010 to June 2011. More waste is yielded from Helderberg while Deep South waste data indicates low waste recovery. The MFA indicates that the transfer function of waste to landfill is 0.15 whereas transfer function of waste to recycling companies is 0.85 in this initiative. This indicates that there is high recovery rate of recyclables in this initiative.

Figure 22 shows a graphical presentation of waste diversion trend of the overall Think Twice Campaign over the financial year July 2010 to June 2011. Waste diversion over the financial year was variable thus the troughs and peaks in places such as Helderberg and Deep South. However the waste diversion tonnages seemed to stabilise towards the end of the financial year in areas such as Sea point and Hout bay. The paper project is a small scale initiative for separation of paper waste in the CCT office buildings.

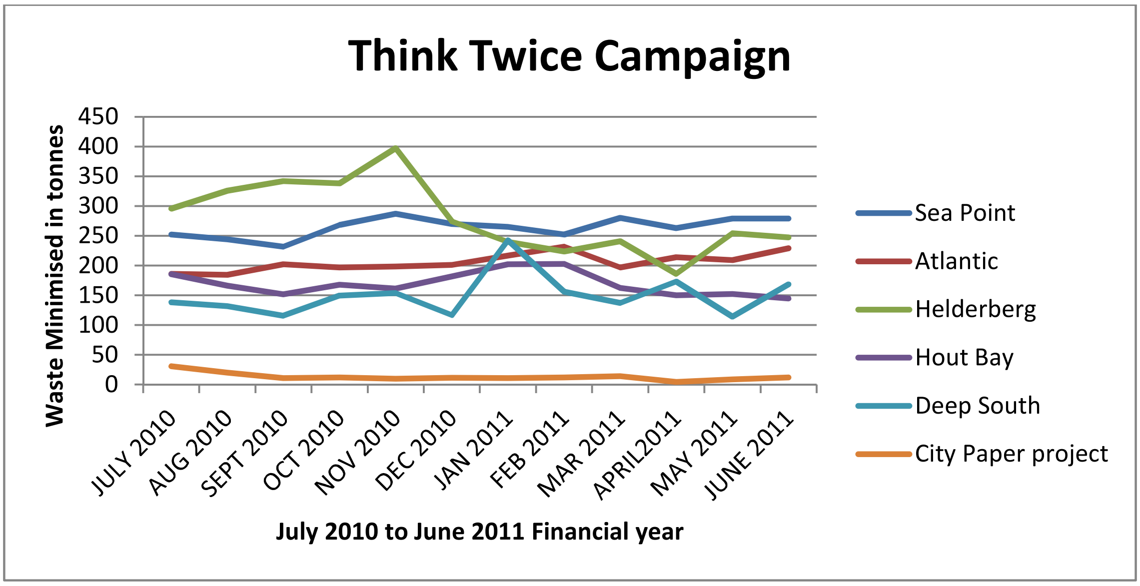


Figure 22: Graph showing tonnes of recyclable waste collected by the Think Twice campaign in financial year July 2010/June 2011.

4.5.2 Mass flows of Bellville Compost Plant for the July 2010 to June 2011

Figure 23 shows the mass flows of waste at the Bellville compost plant. The compost plant uses mixed waste to make compost. According to the current SWMD waste minimisation data 13,806 tonnes of total was recorded as total incoming waste at the facility. After this waste was sorted within the site, 44.8% (6,191 tonnes) was rejected waste meaning that it was composed of waste components such as bottles, plastics and metal that could not be used to make compost. The process chain analysis indicates that 55.2% (7,615 tonnes) of incoming waste was turned into compost.

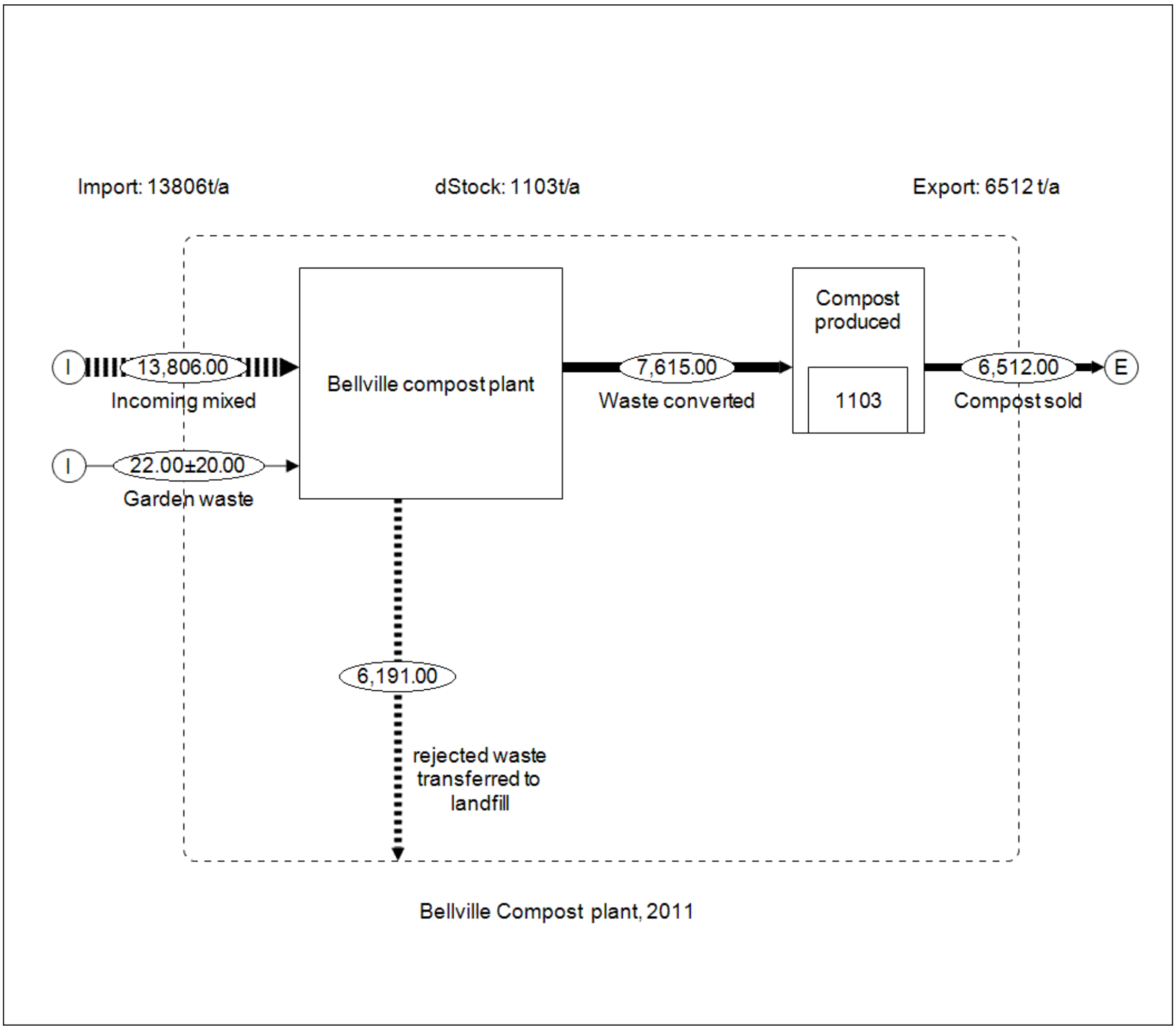


Figure 23: Bellville South compost plant process flow and mass balance.

The MFA indicates that the use of mixed municipal solid waste as input material at the Bellville compost plant is not highly effective. The transfer ratio of waste to landfill is 0.45 (6191 tonnes) whereas transfer ratio of waste converted to compost is 0.55 (7615 tonnes) of incoming waste was rejected and sent to landfill for disposal.

Figure 24 shows the trend of waste that was minimised by this initiative throughout the financial year. In December 2010 there was a low tonnage of waste minimised by the plant as there were plant maintenance procedures that were carried out.

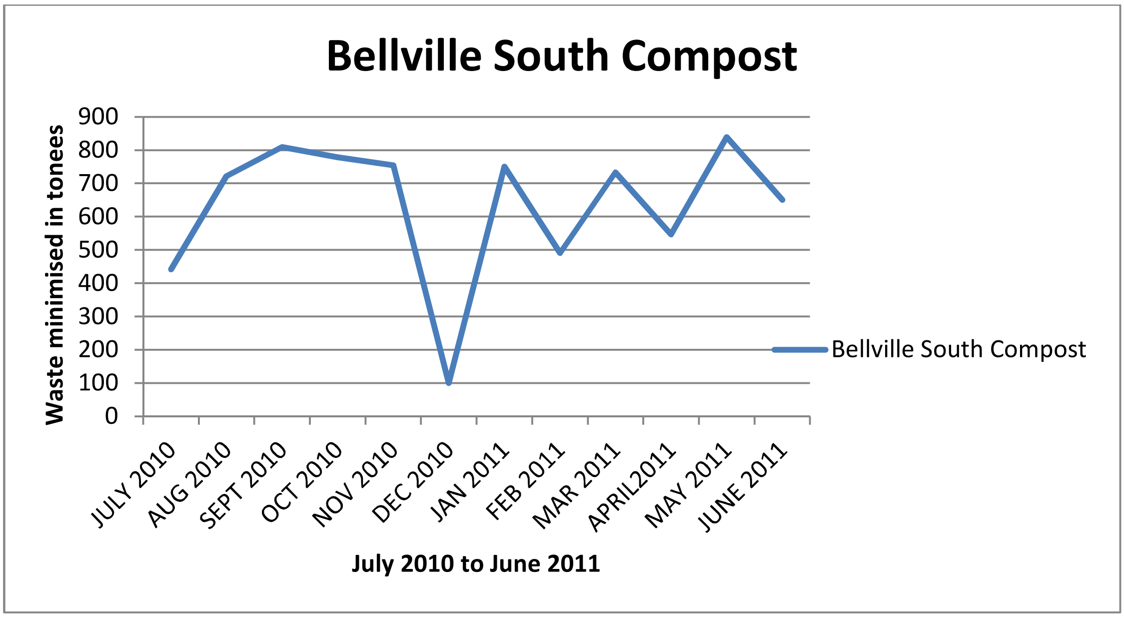


Figure 24: Graphical illustration of trend of waste minimised by Bellville South Compost Plant in financial year July 2010 to June 2011

4.5.3 Mass flows of ARTS MRF/RTS

According to waste minimisation data ARTS MRF diverted 2.7% of total waste minimised. The facility's monthly reports indicate that monthly incoming waste ranges between 19,000 and 23,000 tonnes. The flow analysis diagram in Figure 25 shows that the transfer ratio of recyclable waste was 0.017 (4,351 tonnes). This mainly comprised of 11% (478.60 tons) of glass, 55% (2393.10 tonnes) paper, 5% (217.60 tonnes) of metal and 29% (1,261.80 tonnes) plastics. The transfer rate to landfill was 0.98 (244405 tonnes). The transfer ratios indicate that a high proportion of waste incoming waste in the facility is sent to landfill for disposal.

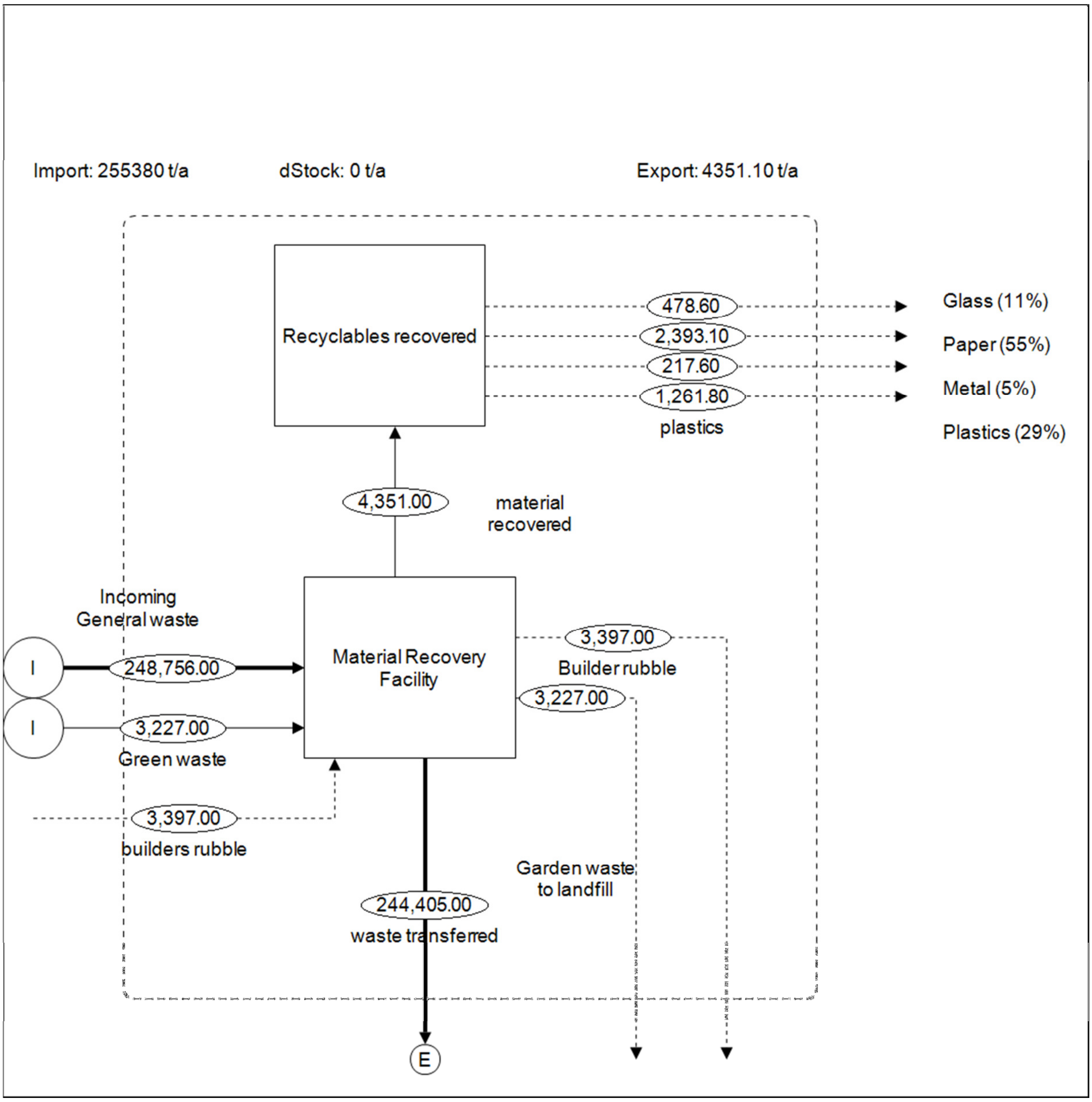


Figure 25: Athlone MRF/RTS mass flow.

Figure 26 shows the distribution of 255380 tonnes incoming waste diverted to ARTS in the July 2010 to June 2011 financial year.

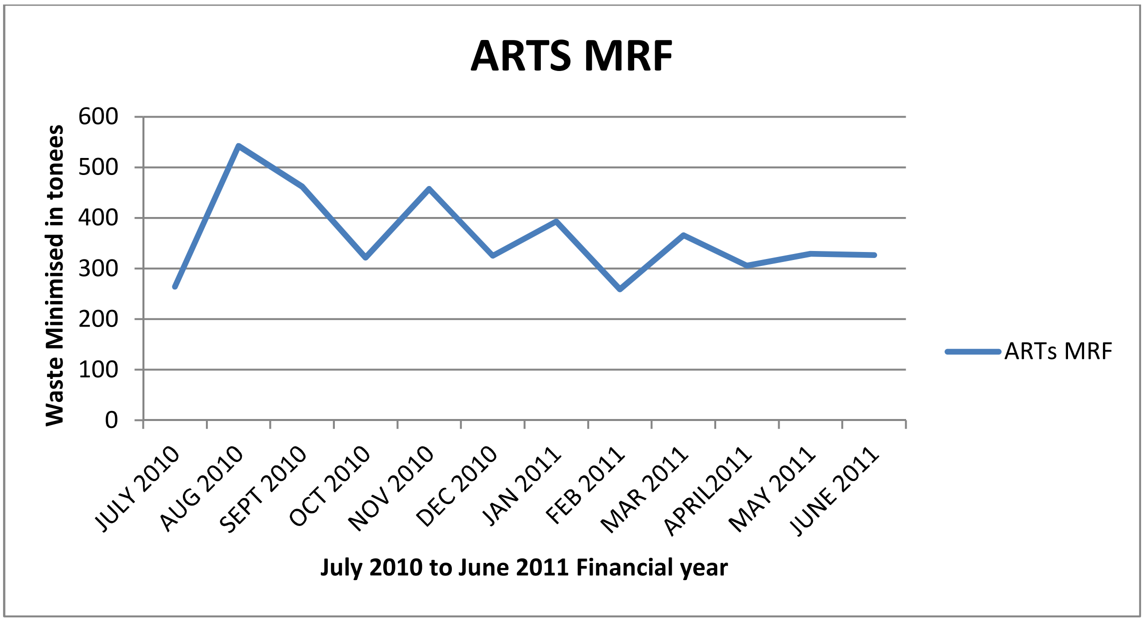


Figure 26: Waste minimised by ARTS MRF/RTS in July 2010/June2011

4.5.4 Mass flow 4 – MSW drop off facilities

The mass balance in Figure 27 shows collective mass flows of recyclable material from 20 drop off facilities including the ones at the landfills (Coastal Park, Bellville South and Vissershok). 5,194 tonnes (3% of total waste minimised) of recyclable waste was sent to drop-offs and 112,035 tonnes (70% of total waste minimised) of garden waste was also sent to the facility where it was chipped. Recyclable waste that was sorted comprised of 15% (779 tonnes) of paper, 15% (779 tonnes) of glass, 29% (1,506 tonnes) cardboard, 20% (1,039 tonnes) of metal, 11% (517 tonnes) mixed recyclables and 10% (519 tonnes) of plastic. The mass flows indicate that drop-offs divert a significantly high percentage of garden waste. A total of 5,770 tonnes of builder's rubble sent to drop-offs was transferred to landfills for crushing.

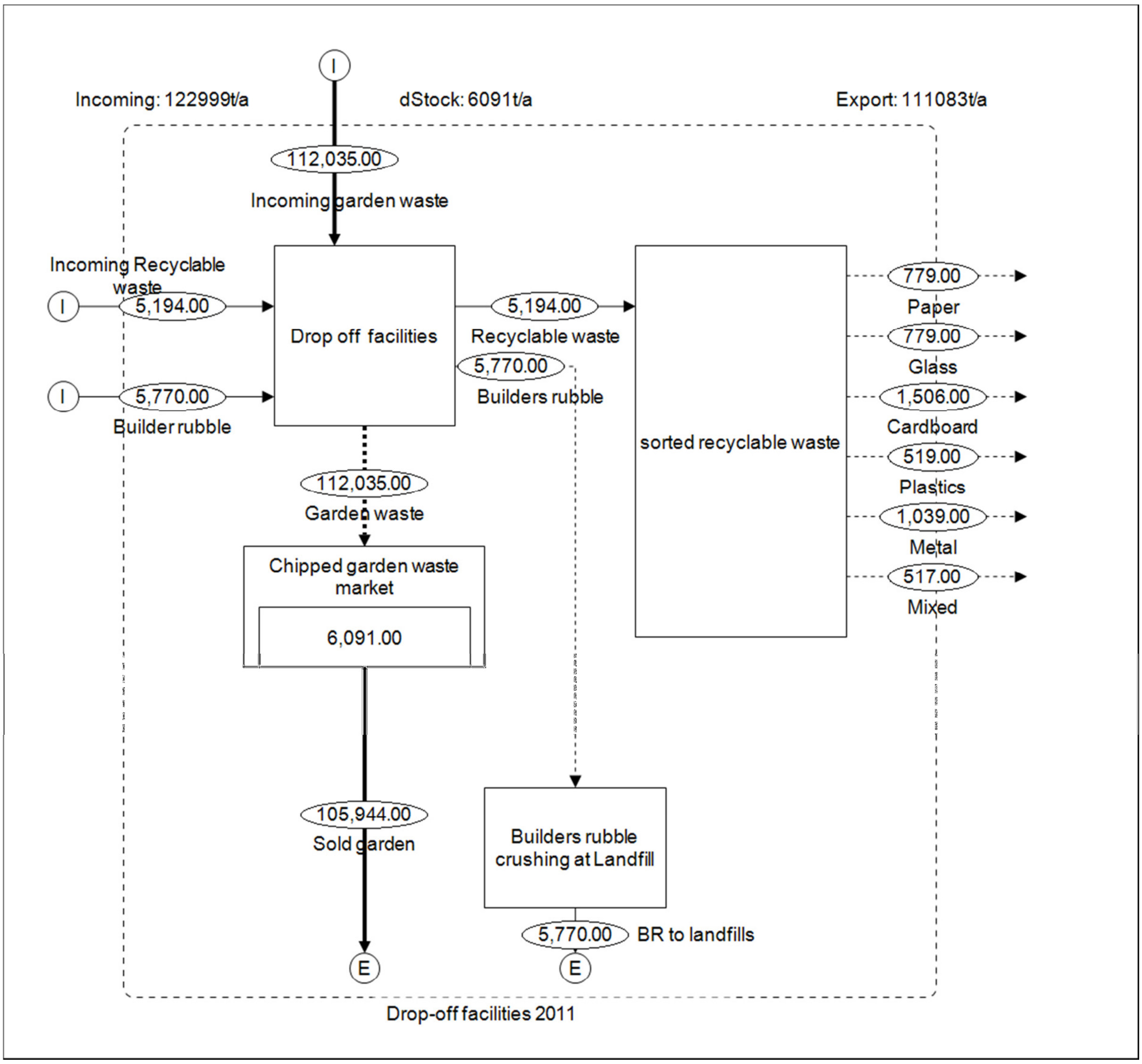


Figure 27: Flow of waste at drop-offs

The MFA indicates that the transfer rate of builder's rubble was 0.047; for garden waste it was 0.91; for recyclable waste it was 0.04. The data indicates in the financial year of 2010/2011, drop-off facilities diverted a high amount of garden waste.

Figure 28 is a graphical presentation of the waste flow trend throughout the financial year. Builder's rubble project performance was not operating in some months as naught tonnes were reported in January, February, March, May and June (see table 3). This affected the overall performance of the drop-off facilities. The overall waste diversion at drop-offs was the highest compared to the other minimisation initiatives.

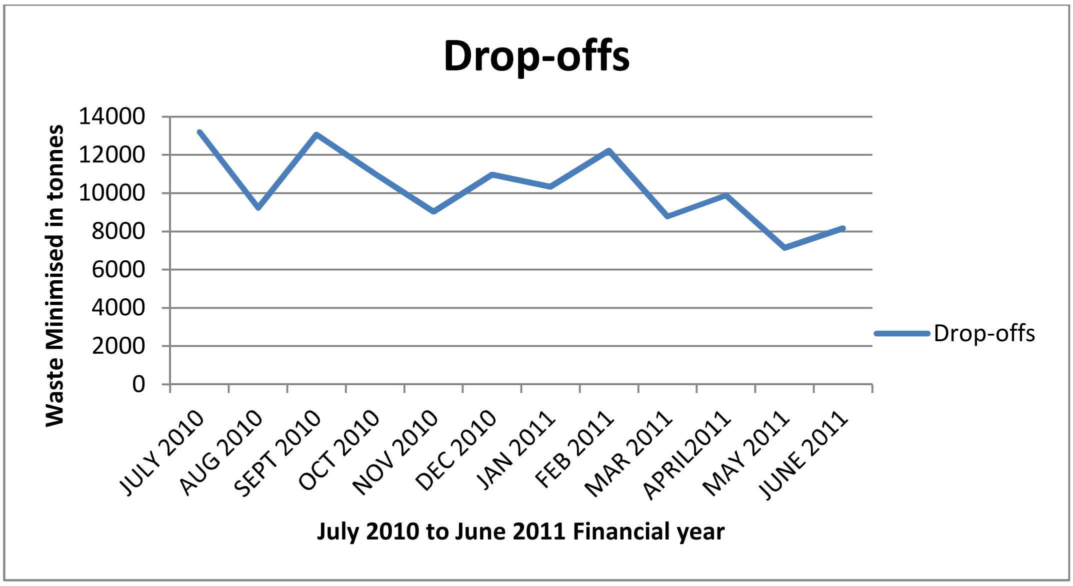


Figure 28: Graphical presentation of waste minimisation at Drop-off sites.

4.6 Discussion of results

The MFA determined the flows of waste in the waste minimisation facilities in SWMD of CCT. It further unveiled that there is still a large amount of MSW that ends up in landfills regardless of the waste minimisation facilities that are available. Table 6 presents the percentage of waste that was minimised by each of the initiatives that were analysed in this chapter in comparison to total general waste that was sent to the landfill. Table 3 indicates that the total municipal solid waste that was generated is 1851759 tonnes.

Table 6: Percentage waste minimised in relation to total general waste sent to landfills for disposal.

Waste minimisation initiative	Total waste diverted (tonnes)	Percentage waste minimised Vs Total waste generated
Think Twice Project	12977	1%
ARTS MRF/RTS	10975	0.59%
Drop Offs	122999	6.36%
Bellville Compost Plant	7651	0.41%

Table 6 percentages indicate that the waste recovery rate is still low in the CCT waste minimisation initiatives. A higher percentage of waste still ends up in the landfills. The comparison shows that Bellville South compost plant is the least performing initiative while the drop-off diverted the highest waste.

The quantitative and qualitative analysis of the SWMD waste minimisation system revealed the following about the initiatives based on the total waste generated rating:

- **Think Twice Campaign** – the 1% percentage diverted indicated that this initiative can improve its output over the years as it expands to other areas in Cape Town. Public awareness and education are pertinent in increasing the recyclable waste recovery. Binder and Mosler (2007) studied society's response to waste minimisations initiatives in Santiago Cuba. Their findings were that, the use of social mobilisation and social pressure on communities improve community member`s environmental awareness and behaviour toward waste minimisation initiatives. The lack of success of the Think twice campaign in less affluent areas indicated that variable marketing strategies and social mobilisation strategies need to be devised for different communities in order to increase the recyclable waste recovery.

  Manufacturers of packaging waste still continue to manufacture unrecyclable packaging material. The MFA indicated that between 10%-15% of MRF incoming waste is sent to landfill for disposal because it is unrecyclable. The packaging industry still continues to manufacture unrecyclable material which cannot be re-instated back into the 'circular economy'. It is still immature at this stage to conclude the success of the Think Twice campaign, since this is a fairly new initiative that relies on response of the public. It seems to be a progressive initiative to the MRF problems to separate waste at source but challenges associated with societies, attitudes and education still need to be addressed.

- **ARTS MRF/RTS -** initiatives to separate and recover recyclables from general mixed "dirty" waste stream has shown to be inefficient as the MFA shows that

0.59% of the facility's incoming waste was diverted from landfill disposal. This initiative is generally unsuccessful owing to the high operating costs as well as the poor demand of dirty and contaminated recyclable waste. The high percentage of wet biodegradable waste fractions that is transferred to landfills could be further diverted to other waste minimisation initiatives such as waste to energy initiatives.

- **Drop off facilities -** seem to be a successfully diverting a large amount of garden waste and builders rubble waste. The input waste tonnage can be improved though if similar facilities are conveniently situated for members of the public who do not have private transport.

- **Bellville South Compost Plant** – the MFA indicates that 45% of incoming waste at the compost plant is sent for landfill disposal. The high competition of more improved compost products available compromises the level of success of the compost plant.

Collectively the MFA findings highlight that the sole purpose of the waste minimisation facilities is not adequately met. Waste minimisation initiatives such as waste to energy, may come in handy especially with the waste fractions that do not have a recycling market. According to Lasaridi (2009) leading waste minimising countries such as Germany and Switzerland use combinations of waste minimisation initiatives such as waste-to-energy, separation at source, incineration and composting in order to archive high waste diversion rates. Further interventions are required for the CCT to begin to realise high waste diversion rates.

Chapter 5 – Conclusions and Recommendations

5.1 Conclusions

The main objectives of the study as listed in Chapter 1 were, firstly to do a broad material flow analysis of waste, in order to trace the flow of solid waste material through the CCT municipal infrastructures. This was done in order to determine the amount of recyclable material-diverted to the recycling industry and the quantities which end up in landfills. The second objective was to break the broad MFA into parts in order to clearly determine the inflows and outflows of waste materials per minimisation facility. The use of a MFA model provided a conceptual understanding of the flow of waste materials in the CCT and showed that in the last financial year July 2010 to June 2011 SWMD minimisation managed to divert 8.67% of waste. It has fallen short by 1.33% to reach its integrated solid waste plan goal of reducing MSW by 10% by the year 2012. The research objectives were met and the overarching findings that came out of the study were that:

- There is lack of willingness in some communities to participate: This mostly refers to communities that realise the commercial of financial value of recyclable waste. The survey showed that, the marketing strategies and plans of rolling out the project in areas with different affluent levels needs to change. Most households, mainly in less affluent areas, believe they need compensation from the CCT as reward for participating. The Think Twice campaign marketing approach was generic yet the levels of environmental awareness and social needs of the target participants is not the same. This reaction illustrated that this strategy is driven by economic and social variables therefore the heterogeneity and varying needs of the neighbourhoods within the city need to be considered in order to find better approaches of incorporating all population groups.
- Judging from the rate of waste recovery it is clear that currently the waste minimisation initiatives are not sustainable considering the mass of waste that

ends up at landfills. Waste minimisation officials have voiced their concerns on the sustainability of the current Think Twice campaign as more capital-intensive improvements need to be made on the project. Therefore, rolling out such a project to the rest of the Cape Town may not be feasible as the municipality is currently not getting financial support from government to run such projects. The role of industry and private sector is further identified in this regard. For instance, the CCT is considering waste-to-energy projects where it will partner with private companies.

- The overall MFA of the waste minimisation facilities has identified the effects of the lack of integrated approach of partnering with informal recyclable collectors, industry, private sector, non-governmental organisations, community based organisation. Currently the ISWM system is centralised and undiversified, meaning that all waste minimising initiatives are run by the municipality and there seems to be little contribution by the private sector to partner in waste minimisation projects. Data for waste minimisation projects conducted by external organisations is not available. The sustainability of waste minimisation activities cannot be borne by the municipality alone to establishment of working relationships with all stakeholders. The current fragmented setting makes it difficult to clearly determine the true potential of waste minimisation initiatives in Cape Town as a whole.
- The MFA established that it seems as if the waste minimisation programmes in the CCT are mainly premised on ‘recycling’ programmes. For example the Athlone MRF recovers waste and targets to sell to recycling companies and the remaining municipal waste fractions (except for garden waste and builder’s rubble) are compacted and sent to landfills; the Think Twice campaign only focuses on diversion of recyclable waste; Drop offs also divert waste and aim at sending them for recycling.

Addressing these challenges could be key in improving the percentage of waste recovery. The low waste recovery rates indicate that the centralised model of waste minimisation needs to be modified.

5.2 Recommendations

The recommendations that are covered in this section are listed as further possible research opportunities that the Researcher identified as important elements that were not covered in this study. In summary, further research can be done in:

a) Studying the effect of social norms, behaviour and attitudes towards waste minimisation initiatives.

b) To assess the direct and indirect economic, social and environmental impacts caused by waste management in general.

It is recommended that more studies are done in the above mentioned points in order to determine the sustainability of waste management initiatives in terms of the three pillars of sustainability that contribute to the sustainability of similar systems. From a sustainability point of view a waste management system operates:

- Economically sustainably if it covers all its expenses.
- If it identifies and assesses its environmental impacts using a set of indicators such as health risks, land use disruption, greenhouse gas emissions and acid precipitation.
- If impacts on the standard of living of a society in terms of health effects and business opportunities are monitored.

5.3 Closing Remarks

The largest overall challenge that lies ahead that can further be researched, is devising a practical plan of 'closing the loop' in order to develop a circular economy. The concept of 'cradle-to-cradle' seems to be premised on administrative control mechanisms such as, extended producer responsibility, which currently is believed will yield negative consequences in the South African context. The study discovered that there seems to be a conflict arising from different values of the recycling concept. For instance packaging material producers are still producing materials that have no recycling market. Yet at the 'end of the pipe' SWMD is spending a large portion of its budgets in trying to sustain waste diversion initiatives. Based on these observations, this study has subsequently realised that there is still a lot of work that needs to be done in order to achieve a genuinely integrated solid waste management system, one that finds ways of harmonising the turbulence in social, economic and environmental issues affected by solid waste generation.

References

Ackermann F, 2005. Material Flows for a Sustainable City: Special feature on the Environmentally Sustainable City International Review for Environmental Strategies, 5 (2), 499-510.

Allen WA, Halloran PA, Leith AH, Lindsay MC, 2009. Using Material Flow Analysis for Sustainable Materials Management: Part of the Equation for Priority Setting. *Journal of Industrial Ecology,* 13 (5):662-665.

Akhile Consortium. 2011. MSA Section 78(3) to Assess Alternative service delivery options. Consolidated report to Solid waste management department.

Annecke, E. & Swilling. M.2008. *Sustainable Futures: A Southern Perspective*.

Ball J, Fiehn H. 2005. Integrated waste management: Background research paper produced for the South Africa Environment Outlook report on behalf of the Department of Environmental Affairs and Tourism

Bainbridge DA, 2009. *Rebuilding the American Economy with True Cost Accounting.* Chapter 5, San Diego: Rio Redondo Press

Barles S, 2009. Urban Metabolism of Paris and its Region. *Research and Analysis*. Yale University, 13 (6), 898-913.

Baud I, Post J, Furedy C, 2004. *Solid Waste Management and Recycling: Actors, Partnerships and Policies in Hyderabad, India and Nairobi, Kenya*. Netherlands: Kluwer

Bilitewski B, Khouangvichit S, Tia S, Trang TD, Visalsok T, Werner P, Wiesmeth H, Wittmaier M, Wooldridge CF, Quynh DN. 2009. *Invent Handbook*: Integrated Waste Management Modules for different courses of graduate studies. [Online]. Available: http://www.invent.hs-bremen.de/elearning_Dateien/Handbook_chapters/chapter_8.pdf [Accessed on 12 December 2011]

Binder CR, Mosler HJ, 2006. Waste-Resource Flows of Short-lived goods in Households in Santiago de Cuba. Resource Conservation and Recycling. *Science Direct*, 51:265-283.

Brunner PH, Rechberger H, 2004. *Practical Handbook of Material Flow Analysis: Advanced methods in resource and waste management*. Lewis Publishers. Washington DC

Brunner PH, Baccini P, Kytzia S, Muller D, Obernosterer R, Hendricks C, 2000. Material Flow Analysis: a tool to Support Environmental Policy Decision Making. Case-Studies on the city of Vienna and the Swiss lowlands. *Local Environment*. 5(3), 311-328.

Brunner PH, 2002. Beyond Material Flow Analysis. *Journal of Industrial Ecology*, 6 (1):8-10.

CCA Environment, 2011. *Solid Waste and Waste Water* [Online]. Available: http://www.ccaenvironmental.co.za [12 June 2011].

Cencic O, Rechberger H, 2008. Material Flow Analysis with Software STAN. Institute of Water Quality Resources and Waste Management Vienna University of Technology. *Journal of Environmental Engineering Management*. 18(1). [Online] Available: http://www.iwa.tuwien.ac.at

Cilliers, P. 1998. *Complexity & Postmodernism.* Routledge: New York, pp112-140

City of Cape Town Solid Waste Management Department, 2011. *MSA Section 78 (3) to assess alternative service delivery options.*

City of Cape Town, 2011. Original Budget, 2011-2012 [Online]. Annexure 5. Available: http://www.capetown.gov.za/en/Budget/Documents/2011-12%20Final%20Main/ANNEXURE%205%20-%20CONSUMPTIVE%20TARIFFS.pdf [01 March, 2012]

City of Cape Town, 2009. Integrated Waste Management By-Law. [Online]. Available: http://www.capetown.gov.za [5 May 2011].

City of Cape Town, 2006. Integrated Waste Management Policy. [Online] Available from: www.capetown.gov.za [Accessed on

City of Cape Town. 2008. Solid waste management department Integrated waste management and service delivery sector plan. Solid waste management sector: Available www.capetown.gov.za/en/idp/statutory [Accessed on 12 September 2011]

Cheng N, c2011. *Systems Analysis for Sustainable Engineering: Theory and Applications*. New York, McGraw-Hill.

Coetzee B, 2007. Proposed New Landfill Sites. [Online]. Available: http://www.capetown.gov.za/en/Pages/NewlandFill.aspx [5 April 2011]

Coetzee B, 2010. City of Cape Town's formal assessment of alternatives to enable large scale recycling [Online]. Technical Strategic Support (Utility Services). Available: http://www.cleanup-sa.co.za/Images/GRF_City_CPT.pdf [28 July 2010]

Cointreau S, 2006. Occupational and Environmental Health Issues of Solid Waste Management: Social Emphasis on Middle-and Lower Income Countries. *Urban Papers*. The World Bank, Washington DC.

Crane W, De Wit M, Swilling M, Thompson-Smeddle L, 2010. Towards Infrastructure Sustainability in Cape Town. (In Pieterse E (Ed.), *Counter Currents: Experiments in Sustainability in the City of Cape Town Region*). Pretoria: Jacana Media.

Crane W, and Swilling, M, 2008. Environment and Sustainable Resource Use and the Cape Town Functional Region- An Overview. *Urban Forum*. 19:263-287.

Creswell, JW. 2005. *Educational Research: Planning, Conducting and Evaluating Quantitative and Qualitative Research.* 2nd Edition. Pearson Education Inc, Upper Saddle River, New Jersey

Davidson A, 2011. Solid Waste Management Department: Waste minimisation. Email correspondences with information on waste minimisation programmes.

Democratic Alliance, 2011. Delivering to the People Poor in Cape Town, 2006- 2011. DA Daily Delivery Fact Number 19 [Online]. Available: http://thedadeliverydaily.com//?s=waste+services [Accessed on 10 September 2011]

DEAT, 2007. Planet-People-Prosperity: A National Framework for Sustainable Development in South Africa.

Doughty M, Hammond G, 2004. Sustainability and the Built Environment at and Beyond the City Scale. *Building and Environment*, 39:1223-1233

Eckelman MJ, Chertow MR, 2009. Using Material Flow Analysis to Illuminate Long-Term Waste Management Solutions in Oahu, Hawaii. Research and Analysis. *Journal of Industrial Ecology.* 13 (5):758-774.

El-Haggar, S. 2007. *Sustainable Industrial Design and Waste Management: Cradle to Cradle for Sustainable Development*. California, Elsevier Academic Press.

Engledow S, 2007. Integrated Analysis Solid Waste Baseline Report. Report compiled for the
UNDP. Stellenbosch: Sustainability Institute.

European Union, 2008*. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and Repealing Certain Directives*. [Online]. Available http://eur-lex.europa.eu/lexUriServ [Accessed on 23 October 2011]

Eurostat, 2001. *Economy-wide material flow accounts and derived indicators: A methodological guide*. Luxembourg: European Communities.

Fiehn H, Ball J, 2005. Integrated Waste Management: Background Research Paper, Waste. South African Environment Outlook. Department of Environmental Affairs and Tourism. Pretoria

Franchetti MJ, 2009. *Solid Waste Analysis and Minimisation: A Systems Approach.* New York, McGraw-Hill.

Gallopin G, 2003. A Systems Approach to Sustainability and Sustainable Development. Sustainable Development and Human Settlements Division. United Nations. Chile

Godfrey L, Nahman A, 2007. Are Developing Countries Ready for First World Waste Policy Instruments? Eleventh International Waste Management and Landfill Symposium. Sardinia. CSIR Natural Resources and the Environment.

Government of South Africa. 2011. National Waste Management Strategy. [Online]. Available: http://www.wastepolicy.co.za/sites/default/files/NWMS_November2011.pdf [Accessed on 10 December 2011]

Government of South Africa. 2007. National Environmental Management: Waste Bill

Government of South Africa. 1998. National Environmental Management Act No.107.[Online] Available: www.environment.gov.za/polleg/legislation/natenvmgmtact [Accessed 24 July 2011]

Gurauskiene I and Stasiskiene Z, 2011. Application of Material Flow Analysis to Estimate the Efficiency of E-waste Management Systems: The Case of Lithuania. *Waste Management and Research*, p. 1-15.

Hattingh J, 2001. Conceptualising Ecological Sustainability and Ecologically Sustainable Development in Ethical terms: Issues and Challenges. *Annale*, 2.

Institute of Waste Management Southern Africa. [Online]. Available: http://www.enviropaedia.com/topic/default.php?topic_id=239 [Accessed on 4 September 2011]

Jacobsen H, Kristofferson M, 2002. *Case Studies on Waste Minimisation Practices in Europe. European Topic Centre on Waste. European Environment Agency.* Copenhagen

Jakrawatana N, McGill I, Moore S, 2007. *A decision support tool for regional biomass waste management and its application in regional Australia*. ISWA/NVRD World Congress, Amsterdam, the Netherlands. Available: http://www.ceem.unsw.edu.au/content/userDocs/ISWAconfpaperfinal_NJakrawatanaIMacGillSMoore_1.pdf [3 July 2011]

Jarrod & Ball Associates, 2002. *Identification of a Regional Landfill to serve the Cape Metropolitan Area: Candidate landfill Site Identification, Short-listing and Ranking Report.* Vol 1. [Online]. Available: http://www.ccaenvironmental.co.za/Current%20Projects/Downloads/Regional%20Waste%20Site/185RR-%20Junel%20Ranking%20Report2%20FIN_11Aug03.pdf [5 September 2011]

Kerani P, Jewasikiewitz SM. 2006. Waste Management and Sustainable Development in South Africa. *Environment, Development and Sustainability*, 9:163-185.

Lasaridi K, 2009. Implementing the Landfill Directive in Greece: Problems, Perspectives and lessons to be learned. *The Geographical Journal*, 175(4), 261-273.

Ling OG, Yuen B, 2010. *World Cities: Achieving Liveability and Vibrancy*. World Scientific Publishing Company: Singapore.

Lehmann S, 2010. Resource Recovery and Materials Flow in the City: Zero Waste and Sustainable Consumption as Paradigms in Urban Development. *Sustainable Development and Policy,* 11(1): 13. Available: http://digitalcommons.wcl.american.edu/sdlp/vol11/iss1/13 [13 July 2011]

Lyons D, 2005. Integrating Waste, Manufacturing and Industrial Symbiosis: An Analysis of Recycling, Remanufacturing and Waste Treatment Firms in Texas. *Local Environment*, 10 (1):71-86. [Online]. Available: http://www.cas.unt.edu/~./dlyons/files/links/TEXAS%20RECYCLING%20FINAL%20PAPER.pdf [Accessed on 4 April 2011]

Lyons D, Rice M, Wachal R, 2009. Circuits of scrap: Closed Loop Industrial Ecosystems and the Geography of US International Recyclable Material Flows. *The Geographical Journal*, 174 (4):286-300.

Magubane T, 2011. City of Cape Town: Waste Minimisation Department. (Personal Communication). 1 July 2011

Markel E, Ferrara C, Gutierrez A, Slater Y, Haider MS, 2008. Opportunities in Waste: from Cape Town to Ruiru. *Proceedings of the 19th Waste Management Conference of IWMSA*, 6-10 October, p Durban: Institute of Waste Management of Southern Africa

Mcandi MD, 2008. Think Twice Project Waste Minimisation: Recycling Beneficial to us All. *Proceedings of the 19th Waste Management Conference of the IWMSA (WasteCon2008)*, p. 390-422, Durban: Institute of Waste Management of Southern Africa.

Mazzanti M and Zoboli R, 2006. *Examining the Factors Influencing Environmental Innovations*, Working Papers, Fondazione Eni Enrico Mattei

McCollough J, Roesch ME, 2008. The Learning Curve`s Role in Explaining Household Curbside Recycling Rates. *Journal of Environmental Systems*, 31(4):333-347.

McDonough W, Braungart M, 2002. *Cradle to Cradle: Remaking the way we make things*. North Point Press: New York.

Meadows D, Randers J, 2004. *The Limits to growth: The 30-Year Update.* White River Junction, Vermont: Chelsea Green Publishing.

Medina M, (unpublished article). *Globalisation, Development and Municipal Solid Waste Management in Third World Cities*. Available: www.gdnet.org/CMS/...5th_pl5.2_martin_medina_matinez_paper.pdf

Mtyi M, 2008. The disposal card system-control mechanism at the disposal sites. *Proceedings of the 19th Waste Management Conference of the IWMSA (WasteCon2008)*, 6-10 October, p. 948-953. Durban: Institute of Waste Management of Southern Africa.

Mohammed S, 2011. City of Cape Town Solid Waste Management Department, Disposal Unit. (Personal Communication). [5 July 2011]

Moriguchi Y, 2007. Material Flow Indicators to Measure Progress Toward a Sound Material-Cycle Society. *J Mater Cycles Waste Management*, 9:112-120.

Mouton, J. 2001. *How to succeed in your Master's & Doctoral Studies***.** South Africa: Van Schaik.

Mulidzi D, 2011. City of Cape Town Solid Waste Management Department: Waste Minimisation Department. (Personal Communication). [10 June 2011]

Muller J, 2011. City of Cape Town Solid Waste Management Department: Waste Minimisation Department. (Email Communication). [14 January 2012]

Nhamo G, 2008. Regulating Plastics Waste, Stakeholder Engagement and Sustainability Challenges in South Africa. *Urban Forum*, 19:83-101.

Nontangana M, 2008. Prospects of anaerobic digestion of municipal solid waste in the City of Cape Town. *Proceedings of the 19th Waste Management Conference of IWMSA (WasteCon2008)*, 6-10 October, p.727-735. Durban: Institute of Waste Management of Southern Africa.

Nontangana M, 2011. Solid Waste Management Department: Disposal Unit. (Personal Communication). [12 June 2011]

Oelofse SHH, Strydom WF, 2010. The Trigger of Recycling in a Developing Country – In Absence of Command- and- Control Instruments. CSIR, Natural Resources and the Environment

Oelofse SHH, Godfrey L, 2008. Defining Waste in South Africa: Moving Beyond the Age of 'waste'. *South African Journal of Science*, 104:242-246.

Pezzoli K, 1997. *Sustainable Development: A Transdisciplinary Overview of the Literature. Journal of Environmental Planning and Management*, 40 (5):549-574.

Pinderhughes, R. 2004. *Alternative Urban Futures: Planning for Sustainable Development in Cities through the World*. Rowman & Littlefield Publishers: Lanham.

Pires A, Martinho G, Chang N, 2011. Solid waste management in European countries: A review of systems analysis techniques. *Journal of Environmental Management*, 92:1033 - 1050

Poswa K, 2011. City of Cape Town: Waste Minimisation Department (Personal Communication). 10 June 2011

Seggie E, 2011. Waste offenders face stiff penalties, but enforcement capacity questioned. *Engineering News*: 22 July

Sholtz RW, Tietje O, 2002. *Embedded Case Study Methods: Integrating Quantitative and Qualitative Knowledge*. London: Sage Publishers

Sneddon C, Howarth R B, Noorgard R B, 2006. Sustainable Development in post-Bruntland world. *Ecological Economics*, 57:253-268.

Solid waste management. 2011. City of Cape Town: Waste Minimisation Department (Personal Communication). 12 August 2011

Spamer E, 2009. *An Investigation into Sustainable Solid Waste Management Alternatives for the Drakenstein Municipal Area*. Stellenbosch: University of Stellenbosch. (MA-Thesis)

State of the Environment Report, 1998. [Online] Cape Metropolitan Area, UNEP initiative. Available: www.environment.gov.za/enviro-info/sote/citysoe/cape/cma.htm [Accessed on 11 August 2011]

Strategic Development Information and GIS, 2001. City of Cape Town Census 2001 [Online]. Available: http://www.capetown.gov.za/en/stats/2001census/Documents/Cape%20Town.htm [Accessed on 12 September 2011]

Swilling M, de Wit M, 2008. Sustainability, Poverty and Municipal services: The Case of Cape Town, South Africa. Sustainable development, Forthcoming

Swilling M, 2004. Rethinking the sustainability of the South African city. *Development Update*, 5(1):76-89.

Tchobanoglous G, Theisen H, Vigil S, 1993. *Integrated solid waste management: Engineering Principles and Management Issues*. Irwin McGraw-Hill

Troschinetz AM, Mihelcic JR, 2009. Sustainable Recycling of Municipal Solid Waste in Developing Countries. *Journal of Waste Management,* 29:915-923

UNCED, 1992. *Agenda 21*. [Online]. URL: Available: http://habitat.igc.org/agenda21 [Accessed on 10 August 2011]

UNEP, 2010a. Engaging Governments and Industry in Demonstrating 3R Principles through Integrated Waste Management.

UNEP, 2010b. Waste and Climate Change: Global Trends and Strategy Framework.

United Nations Human Settlements Programme (UN-Habitat), 2010. Solid Waste Management In the World Cities: Water and Sanitation in the World Cities. *Earthscan.* Washington DC.

Valle OP, Reis E, Menezes J, Rebelo E, 2004. Behavioural Determinants of Household Recycling Participation: The Portuguese Case. *Environment and Behaviour*, 34(4):505-540

Waste Minimisation Management, 2011. City of Cape Town: Solid Waste Management Department; Meeting held in July discussing challenges of waste minimisation projects.

WCED, 1987. *Our Common Future.* Oxford University Press: Oxford

Wilson DC, 1996. Stick of Carrot? The Use of Policy measures to Move Waste Management Up the Waste Hierarchy. *Waste Management Research*, 14(4):385-398.

Wilson DC, 2007. Development Drivers of Waste Management. *Waste Management and Research,* 25:198-207.

Wright-Pierce, 1999. Cape Metropolitan Council Feasibility study Towards an Integrated Solid Waste Management Plan for the Cape Metropolitan Area. Cape Metropolitan Council. Cape Town, South Africa.

Yap NT, Zvauya R, 1999. Business Decision Criteria with Respect to Waste Management: Case Studies from Southern Africa. (In Yap NT (ed.) *Cleaner Production and Consumption: Challenges and Opportunities in East, Central and Southern Africa, Harare, Zimbabwe*: Weaver Press. p 134-170.)

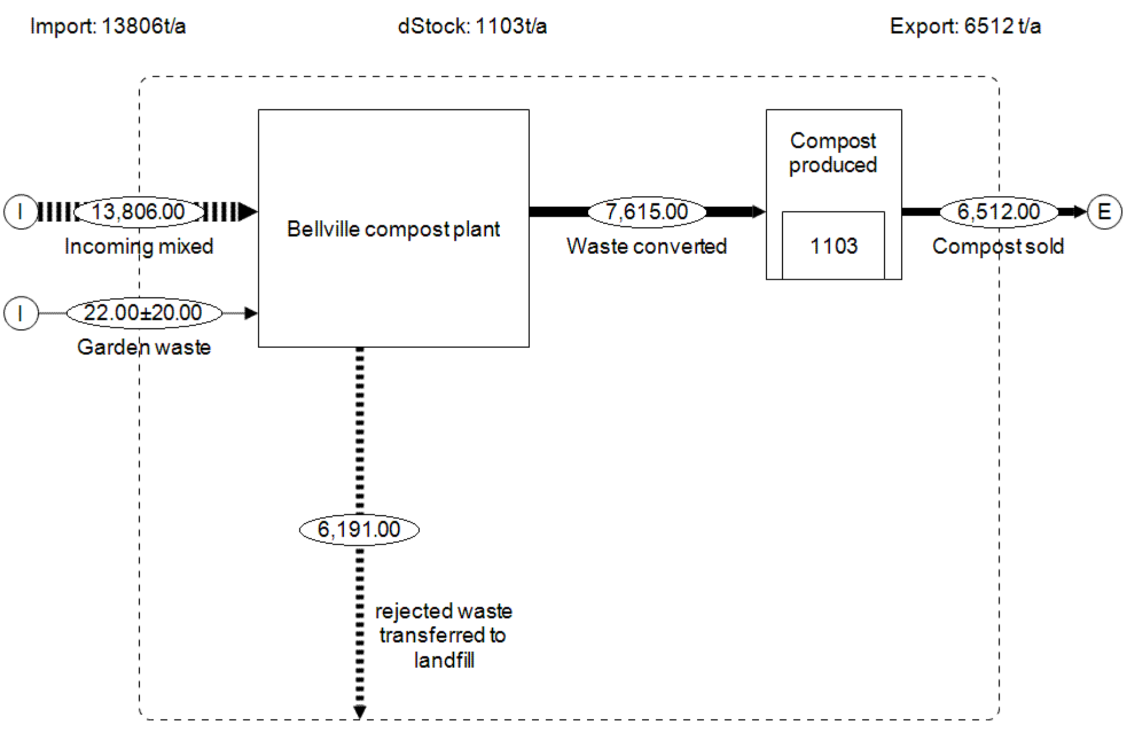
Yong R, 2007. The Circular Economy in China: 3R Initiatives and Circular Economy. *Cycles Waste Management*, 9:121-129

Zeng X, Sun Q, Huo B, Wan H, Jing C, 2010. Integrated Solid Waste Management Under Global Warming. *The Open Access Waste Management Journal*, 3:13-17. Available: www.benthamscience.com/open/towmj/articles/V003/13TOWMJ.pdf [23 July 2011]

Zumbuehl D, 2006. *Mass Flow Assessment and Assessment of Recycling Strategies for Cathode Ray Tubes for the Cape Metropolitan Area, South Africa*. Swiss Federal Institute of Technology Zurich. (Diploma Thesis)

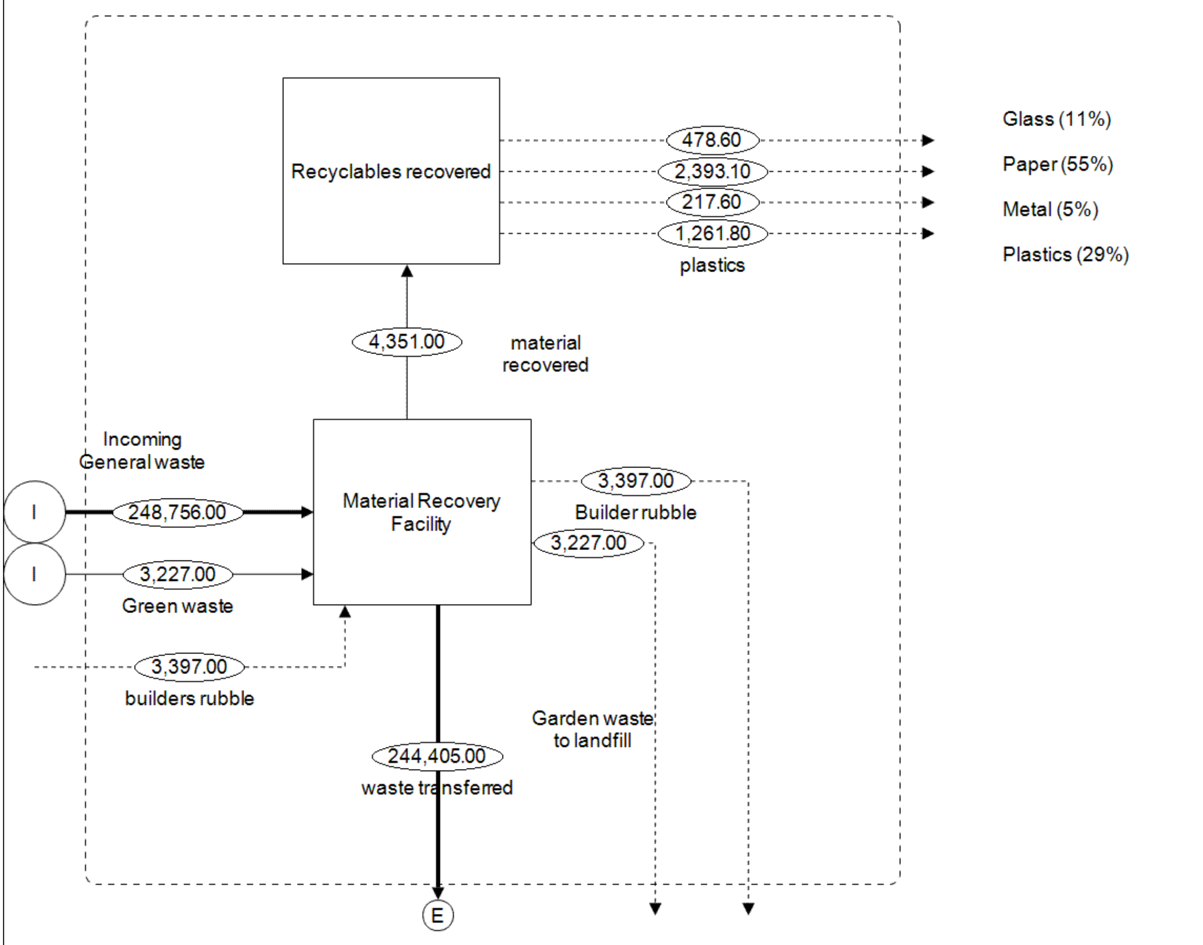
6. Appendices

6.1 Appendice A - Bellville compost plant



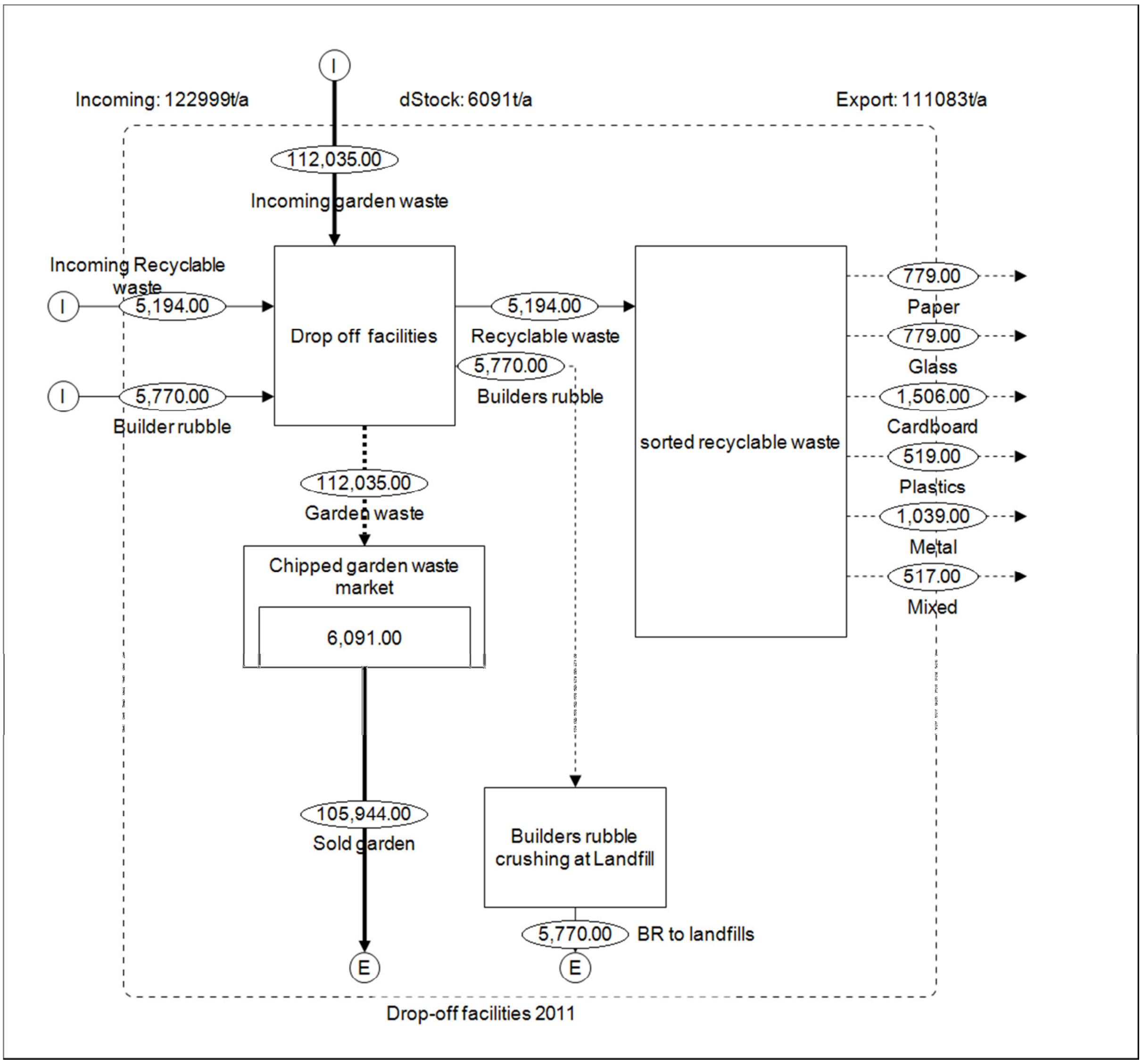
Bellville Compost plant, 2011

6.2 Appendice B - Athlone MRF/RTS

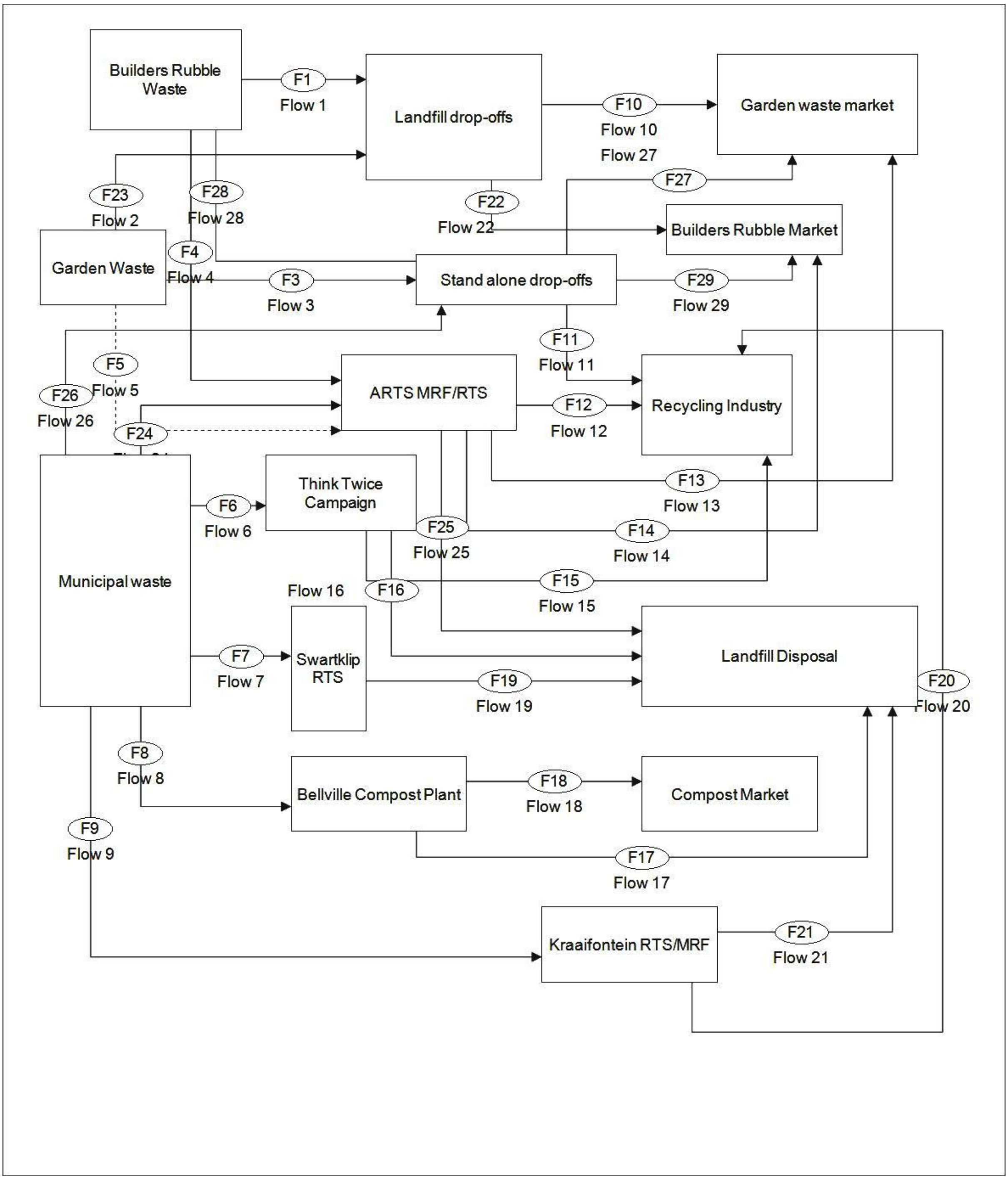


Athlone refuse transfer station, 2011

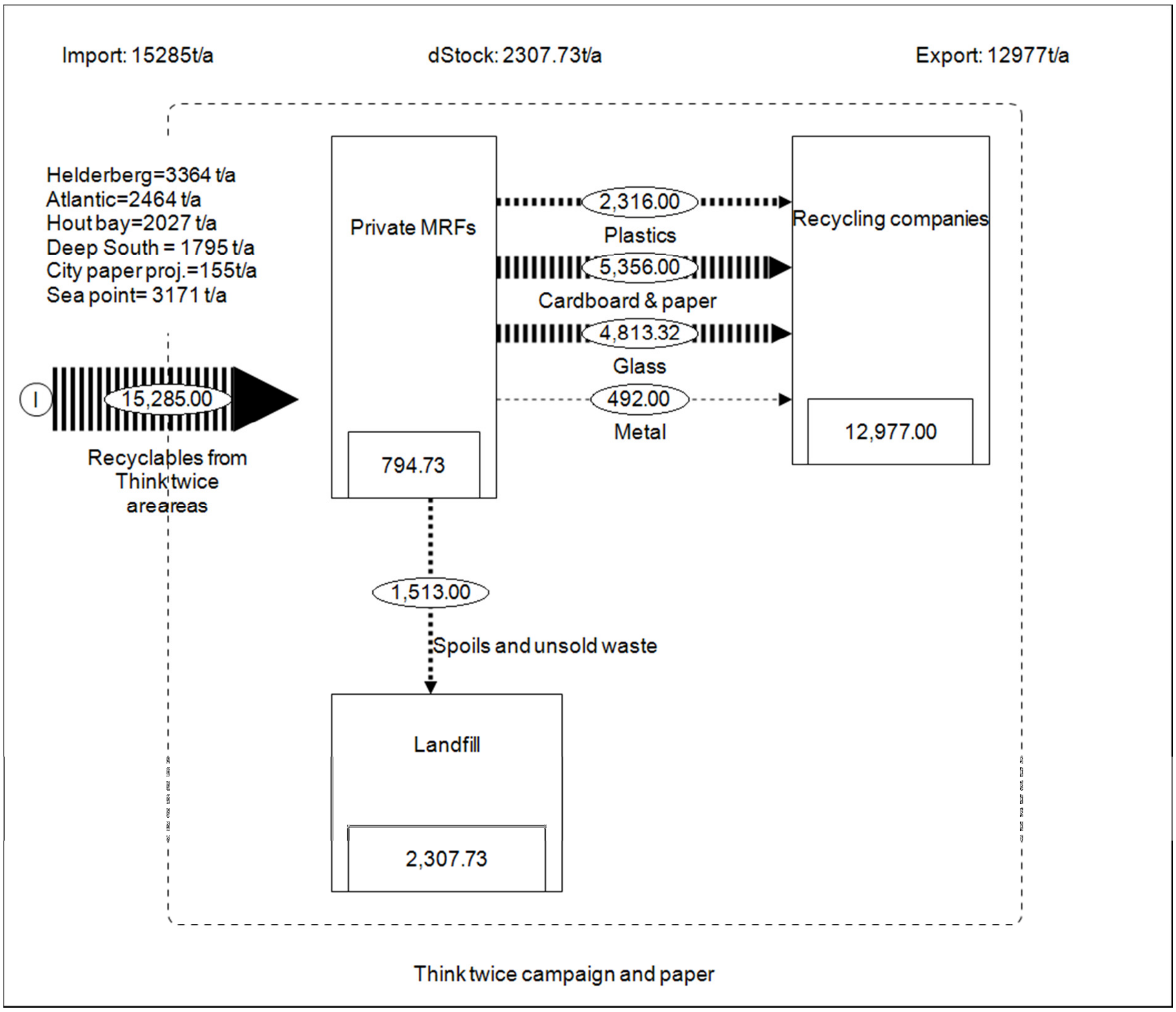
6.3 Appendice C - Drop facilities



6.4 Appendice D - Summary MFA



6.5 Appendice F - Think Twice campaign MFA



6.6 Appendice G - Reference Letter from Supervisor

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

25 July 2011

To whom it may concern

Research project – Zandile Nkala

This is to confirm that Mrs Zandile Nkala is a registers Masters student (no. 15942813) in the Sustainable Development programme at Stellenbosch University. Mrs Nkala is undertaking a research thesis, under my supervision, pertaining to the flow of waste material in the greater Cape Town Municipality. The study has been commissioned, and is supported, by the City of Cape Town.

I can be contacted directly, should further information be required.

Yours sincerely

Prof Alan Brent

6.7 Appendice - Approval letter from SWMD of CCT

CITY OF CAPE TOWN | ISIXEKO SASEKAPA | STAD KAAPSTAD

Civic Centre
12 Hertzog Boulevard
Cape Town 8001
P O Box 298 , Cape Town 8000
Ask for: Mr G Jonkers
Tel: (021) 400-5536
Fax: (021) 400-4302
E-mail: george.jonkersl@capetown.gov.za
Website:
Manager Support Services:
Mr George Jonkers

Civic Centre
12 Hertzog Boulevard
Cape Town 8001
P O Box 298 , Cape Town 8000
Cela: Mnu G Jonkers
Umnxeba: (021) 400-5536
Ifeksi: (021) 400-4302

Burgersentrum
Hertzog Boulevard 12
Kaapstad 8001
Posbus 298 , Kaapstad 8000
Vra vir: Mnr G Jonkers
Tel: (021) 400-5536
Faks: (021) 400-4302

UTILITY SERVICES — Solid Waste Management — Support Services

11 August 2011

To: Ms Zandile Nkala

RESEARCH PROJECT – SUSTAINABLE DEVELOPMENT PROGRAMME

I refer to a letter dated 25 July 2011 received from the School of Public Leadership and endorsed by Professor Alan Brent.

As much as we support the academic achievements of students and take pleasure in assisting where possible, it is important to note that we will assist by providing you with information on your request. However, this does not imply that we approve, support or endorse your study or your findings.

All the research work you conduct in this project and the conclusions you reach, is based entirely on your work and your interpretations and not that of the City of Cape Town.

The role of the City of Cape Town in your research project is ***to provide information on request only***.

MANAGER: SUPPORT SERVICES
GEORGE JONKERS