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**A PROCESS MAPPING APPRAISAL OF MUNICIPAL WASTE
MANAGEMENT SYSTEM COMPLIANCE IN LIMPOPO PROVINCE,
SOUTH AFRICA**

Thesis submitted in fulfilment of the requirements for the degree of Doctor of
Philosophy in Environmental Science

By

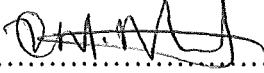
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FEBRUARY 2015

DECLARATION

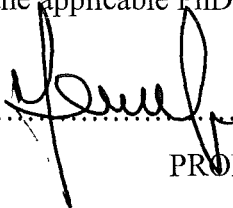
I, NTAVHELENI VIRGINIA MUDAU (student number: 23131160), hereby declare that this research is my original work. I further declare that I have acknowledged all my sources of information. The thesis is an accurate and honest record of work that has been done by me and the work has not been previously accepted for any higher degree or professional qualification at any other educational institution.

Signed.....

NTAVHELENI VIRGINIA MUDAU

Date 07/04/2018

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

Signed.....
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DEDICATION

This work is dedicated to my mother Mavhungu Mudau, my late brother Ntungufhadzeni Gharet Mudau and my children Rofhiwa, Murunwa and Sifhime, and all those who seek knowledge to enhance human resources and good livelihood through development of sustainable waste management and care for the environment.

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ABSTRACT

The study investigated the state of municipal waste management compliance in selected local municipalities in Limpopo Province, South Africa. The aim of the study was to apply process mapping and systems analysis in measuring the extent of compliance with minimum national standards in municipal waste management systems and to use the findings in designing an alternative intervention framework. A descriptive research design was employed involving questionnaire administration covering municipal waste managers, supervisors and general workers, as well as households. The data from the field observations and questionnaires was coded and analysed using Excel to yield descriptive statistics. Thereafter, Fisher's Exact test was applied in hypothesis testing. The key results indicated low levels of compliance with waste legislation, inherent problems of design within the municipal waste management system, problems of translating national minimum standards for waste management into quantitative measures, the lack of data on waste management, inappropriate prioritization of waste management, and low levels of environmental awareness in the general public. These findings were then used as inputs in the design of a waste compliance framework for potential application in waste management. The significance of the study lies in its contribution to the state of knowledge with respect to the measurement of municipal waste management compliance, the characterisation of waste streams, methods for improving efficiency and the translation of guidelines into quantitative measures.

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LIST OF ACRONYMS

APPA	Atmospheric Pollution Prevention Act
CBA	Cost benefit analysis
DEA	Department of Environmental Affairs (name change in 2010 from DEAT)
DEAT	Department of Environmental Affairs and Tourism
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EIP	Environmental Implementation Plans
EMI	Environmental Management Inspectorate
EMP	Environmental Management Plan
EMS	Environmental management system
EPA	Environmental Protection Agency
EPR	extended producer responsibility
EU	European Union
FAO	Food and Agriculture Organisation
FBRR	Free Basic Refuse Removal
GHG	Greenhouse gas
HPM	Hierarchical process mapping
IDP	Integrated development plan
IWARM	Individual waste reduction model
IWMP	Integrated waste management plan
LCA	Life cycle assessment
MCDM	Multi-criteria decision making
MIF	Municipal infrastructure investment framework
MSE	Minimum standards expected
MSWM	Municipal solid waste management
MTCE	Metric tons carbon equivalent
MTCO ₂ E	Metric ton of carbon dioxide equivalent
MWMCS	Municipal waste management compliance system
NEM:WA	National environmental management: waste act
NWMS	National waste management strategy

RSA	Republic of South Africa
SADC	Southern African Development Community
SAWIS	South African waste information system
SWM	Solid waste management
UNESCO	United Nations Educational Scientific and Cultural Organisation
WAPIS	Waste process interface response
WIS	Waste Information System
WM	Waste management
WMH	Waste management hierarchy
WMS	Waste management system
WMSC	Waste management system compliance

CHAPTER 1

INTRODUCTION

1.1 Background

Globally, there has been growing awareness of environmental issues such as global warming, acid rain, threats to biodiversity, and waste. These issues have been discussed at a number of international conferences such as the United Nations Framework Convention on Climate Change (UNFCCC). The convention was adopted at the 1992 Rio Earth Summit which was followed by the Kyoto Protocol. The Kyoto Protocol provided more specific obligations than the UNFCCC. Chapter 21 of UNFCCC Agenda 21 recognised the management of waste in an environmentally sound manner in order to maintain the quality of the earth environment (RSA 2009). From these discussions evolved the concept of 'sustainable development' which forms the core of environmental management (UNESCO 2009). The World Summit on Sustainable Development (WSSD) of 2002 reaffirmed the importance of waste management by calling for priority attention to be given to waste prevention and minimisation, reuse, recycling, and the use of environmentally friendly alternative materials (UN 2002). The WSSD also called for the development of environmentally sound disposal facilities, including technology to convert waste into energy. The Commission on Sustainable Development (CSD) addresses environmental issues and some of the aims include intergovernmental agreements, measures, policy options and concrete actions towards a zero waste economy. Special attention is given to particular types of waste and awareness campaigns (Matete & Trois 2008).

Waste management practitioners and administrators around the world are responding to the international concern about pollution caused by waste and are working towards zero waste strategies. Sustainable municipal waste management in the 21st century is supposed to recognize the significance and impact of waste at all phases of operation from planning to design, to operation, and to decommissioning (UNEP 2010). As a consequence, a range of new and existing waste treatment technologies and managerial strategies have emerged, with capabilities spanning from maintaining environmental quality at present to meeting sustainability goals in the future. Such an orderly evolution allows both waste management industries and government agencies to meet common needs of waste management with greatest green potential, to recycle materials out of waste streams, to enlarge the renewable

energy supply, to seek for more socially acceptable options, and to preserve biodiversity and natural ecosystems simultaneously. To achieve such goals, all technical and non-technical aspects of solid waste management systems should be analysed as a whole, since they are inter-related. Systems analysis techniques have been applied to handle municipal solid waste streams through a range of integrative methodologies in the last few decades. Pires et al. (2011) report that system assessment tools and systems engineering models are the two domains for waste management technologies. The principles of integrated waste management seem to be dominating the domain of waste management in both developing and developed countries. In the city of London, adequate legislation in place for the handling, treatment and disposal of all waste generated in the city has contributed positively to the development of the current integrated waste management system (Asase et al. 2009). Planning for sustainable solid waste management has to address several interconnected components. Therefore, it becomes increasingly necessary to understand the dynamic nature of their interactions. Real world phenomena are being increasingly conceptualized as systems that act and respond to the state of the components that they are made of, working interactively to form and act as a whole (Ngoc & Schnitzer 2009; Hrebicek & Soukopova 2010; Seadon 2010).

Waste management strategies differ from country to country. However, the waste hierarchy (Figure 1) globally remains the cornerstone of waste minimization strategies and it should be seen as a system. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste. Avoid and reduce is the foundation of the waste hierarchy and it is the ultimate zero waste challenge. But the concept of 'zero waste' remains essentially a dream. Over the past decade, the waste hierarchy (Figure 1) has taken many forms, but the basic concepts have remained the cornerstone of most waste minimisation strategies (Menon 2010).

Waste management is a system made up of a set of interacting units or elements that forms an integrated whole intended to perform some function (Seadon 2010). Al Ansari (2012) advocates the use of a new hierarchy in integrated municipal waste schemes, with the purpose of eco-friendly management plans. According to Al Ansari (2012), waste management requires commitment to waste minimisation by reducing waste creation. In this regard the scope of this study covers waste management streams which are under the control of local municipalities in Limpopo Province, South Africa. These are household waste, commercial waste and industrial general waste.

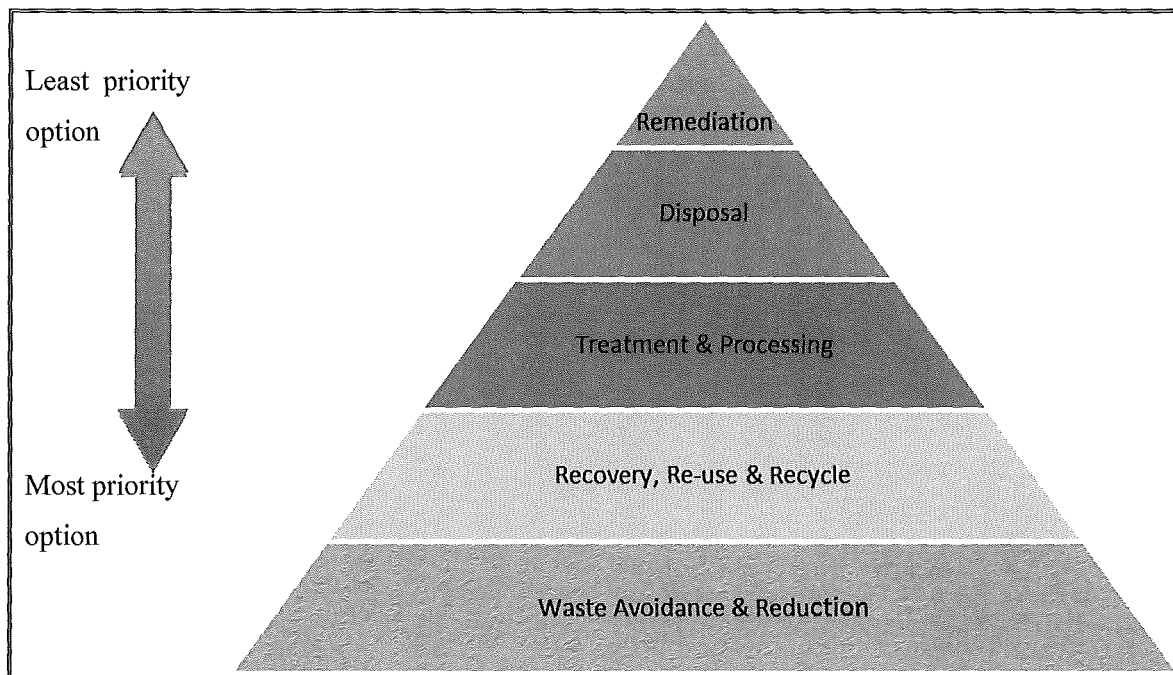


Figure 1: The waste hierarchy. Source: DEA 2011.

The ‘polluter pays’ principle is enacted to make the party responsible for producing pollution responsible for paying for the damage done to the natural environment (RSA 2009, Hiclike 2014). In international environmental law, the same principle is mentioned in the Rio Declaration on Environment and Development. Also known as the extended polluter responsibility (EPR), the producers will have to improve the waste profile of their products. This strategy is designed to promote the integration of environmental costs associated with goods throughout their life cycles into the market price of the products (Godfrey et al. 2012a, b; Nnorom & Osibanjo 2008). South Africa is also responding to the growing problem of excessive waste by adopting the *liability scheme* in which the manufacturers must take responsibility of their products. The aim of this scheme is to slow down the filling of landfills and the release of toxic materials from discarded products. Take-back laws state that manufactures, sellers and importers should take back their products at the end of the product’s useful stage (RSA 2009). But in reality the lack of enforcement makes such laws ineffective.

Environmental protection is the practice of protecting the environment, at individual, household, organizational or governmental level, for the benefit of the natural environment

and (or) humans (Cox et al. 2013). Due to the pressures of population and improvements in technology, the biophysical environment already shows signs of degradation. This has been recognized and governments began placing restraints on activities that cause such negative impact. Since the 1960s, activism by the environmental movement has created awareness of the various environmental issues but there is no full agreement on the extent of impact of human activity on the environment.

Often governments acknowledge the fundamental right to environmental protection and many international treaties acknowledge the right to live in a healthy environment (Marshall & Farahbakhsh 2013). However, complete environmental protection seems impossible as it often conflicts with the need for the survival of humans. There are international environmental protection organizations, such as the United Nations Environment Programme. Environmental protection has become an important task for the institutions of the European Community after the Maastricht Treaty for the European Union ratification by all Member States. The EU is already very active in the field of environmental policy with important directives like those on environmental impact assessment and on the access to environmental information for all citizens in member states (EPA 2013). Marshall and Farahbakhsh (2013) report that in high income countries, solid waste management (SWM) is primarily driven by five factors, namely: public health, the environment movement in the public and political agenda, resource scarcity and value of waste, climate change and public awareness and participation

Section 15(2) of the National Environmental Management Waste Act, No. 59 of 2008 (RSA 2009) stipulates that no person may recycle, recover, treat or dispose of a priority waste unless it is in accordance with this Act. The Act imposes several legal obligations on the generator of industrial waste; it repealed and replaced the waste-related provisions of the Environment Conservation Act of 1989 (RSA 1989). Several new obligations have been added including the obligation to avoid, minimize, reuse and recycle waste as far as is reasonably possible. At local municipalities, there are challenges in enforcement giving rise to a situation where environmental and sustainability principles are not effectively incorporated into local planning processes (RSA 2009; Hristovski et al. 2010; Skinner et al. 2003). Whereas since 1995 (following the watershed political change in 1994), a series of environmental legislations have been enacted by the state, little appears in local research

literature or government funded studies about issues of compliance with respect to waste management.

Achieving compliance and identifying situations where actions fail to agree with established standards remains a crucial aspect of environmental protection. Therefore, developing an effective waste management system compliance programme is an essential component for any successful public or private sector entity whose activities involve environmental protection. Process mapping of municipal waste management systems considers each individual step or unit of operation with input and output accounting for optimum process improvement that helps in identifying the data needed to quantify efficiency at each stage of waste hierarchy. The use of hierarchical process mapping (HPM) as a tool that determines how organizations seek data for useful conclusions might make it easier for decision makers to identify system operational procedures or protocols and compliance indicators. The HPM approach is essential in establishing parameters within which municipalities can correct their own environmental infringement. Compliance measurement through HPM can offer an alternative potential vehicle towards the efficiency of municipal waste management compliance system and good environmental practice.

1.2 Problem Statement

Local municipalities in Limpopo Province face challenges of effective implementation and achievement of WMS compliance against national minimum standards for municipal waste management. The effective implementation of the waste management hierarchy, and monitoring and evaluation in order to deliver an effective operational system, remain problematic. The application of systems analysis to the physical, managerial, technical and compliance components requires specific institutional prerequisites.

In addition, the national guidelines on municipal waste management (DEA 2010a) stipulate a series of compliance standards specific to the components of the waste chain to be implemented by local municipalities across the country. Existing national waste management guidelines do not provide adequate guidance for facilitating the measurement of performance along the waste chain nor the performance of waste management as a whole. Therefore, these guidelines do not specify measurable deliverables against which individual waste directorates can gauge compliance. Secondly, these national guidelines are silent about the need for benchmarking operations to allow for comparisons across municipalities in the country.

In contemporary literature, concerns about waste management centre on issues of legislation, administration and conservation such that little work appears in the literature in terms of compliance assessment of waste management systems against national guidelines. What appears in contemporary research on waste management is a pre-occupation with the legislative framework for environmental issues and the extent to which such legislation has diffused into local and district municipal planning instruments. Issues of compliance, therefore, elicit responses that centre on law enforcement with hardly any mention being made about the extent of compliance in the physical, technical and managerial components of waste management.

It is important to subject the waste management system to scrutiny in order to identify weaknesses, if any, in system design as a platform for assessing the efficiency in service delivery. Is the system in place designed to efficiently perform the tasks it is meant to do? If not, is the existence of internal system weaknesses a contributing factor in implementation? Can the challenges faced by municipalities in waste management be traced back to the systems in place or are there other external forces at play? Then, should it be established that the system itself has no internal design weaknesses, and then compliance has to be measured in terms of system expectations and the actual performance of municipalities. The main question will then be how to measure such deviations between actual and expected performance levels against the standards. And, how eventually to design an intervention model that exploits insights offered by process mapping and systems analysis to eventually minimize non-compliance and improve on compliance level.

Compliance is a measure of the extent to which operations of the municipal waste directorate compare to established national standards and requirements. These include the National Waste Management Act No. 59 of 2008 (RSA 2009), National Waste Management Strategy of 2010, Provincial Waste Management Strategy and the local Integrated Waste Management Plan (IWMP). It can be represented through a description of protocols and procedures or guidelines. It can also be approached from a measurement side by identifying key measurable/quantifiable elements of the system. Compliance, however, is a multi-dimensional quantity at two basic levels: (i) the institutional, and (ii) service delivery. There are minimum standards as stipulated by the Waste Management Act (2008) that every municipality, in theory, is expected to meet. These standards are broken down into five

process components: (i) waste collection, (ii) temporary storage, (iii) transportation, (iv) waste processing and (v) final disposal. At each level, measurable sub-elements are identified and listed, and compliance assessments made using numerical scores that render themselves to ratio and interval scale measurement. But for this to be possible, national environmental guidelines and minimum standards will have been converted into a similar measurement system to allow for the computation of meaningful deviations between actual operations (*AO*) and expected operations (*EO*), such that $EO - AO = C$ (compliance). The values of *C* are plotted for each level and process component across different sites (local municipalities) in the study area. This means that *EO* in essence represents a steady state irrespective of the municipality and/or province. How far a particular municipality registers a negative or positive deviation from the *EO* is a measure of the level of *C*. The sum of deviations across all levels of a particular site represents its overall standing in the measurement of compliance. Clearly, the larger the sum of deviations, the greater the lack of compliance, and vice-versa.

1.3 Conceptual Framework

Municipal waste management is studied within a systems approach because it entails, in essence, a clearly organized set of tasks and processes through which a diverse range of waste is eventually transferred to disposal sites. In its simplest form, a system is a structure that receives inputs, processes these into products and by-products and in the process it may release waste into the environment. Every system, therefore, has three basic components: inputs, processes and outputs. Municipal waste is characterized as a waste chain because waste has to be moved through a set of stages, from generation to temporary storage, then processing facility, and final disposal. Each of the stages of the waste stream represents certain technical elements that need to be understood in the measurement of technical efficiency (TE). The waste stream is a physical system, but without other non-physical components it would not move; hence, the human dimension in the form of support services, infrastructure, personnel, finance, equipment, management, monitoring and auditing. The waste management system is, therefore, part of other overlapping sub-systems that ultimately constitute the institutional and organizational structure of a municipality. This overlap, as will be seen in later sections of the thesis, has wider implications in the measurement of performance.

Process mapping captures the part of any system that deals with the specific stages and the interfaces that separate them. The term is appropriate for this study because of two critical characteristics. First, the waste chain is made up of stages which can be described in terms of

constituent processes. The need to understand the working of these processes and how they impact on downstream changes hardly appears in local contemporary literature. Second, process mapping deals with a chain-reaction type of relationship-which in essence is linear. Any loadings at any stage along the chain trigger a reaction in subsequent developments downstream of that stage. It follows, therefore, that every intervention at any point can be mapped or graphically captured in a manner that differentiates changing waste volumes along the chain.

Placed in the wider environment, there is need for a method for capturing and representing the behaviour of the waste chain in time and through space, hence a process mapping is part of this thesis. If the understanding of the systems approach as advanced here agrees with what governments at large understand, then the design of state organs should, ideally be sensitive to the need not to disrupt internal synergies that all overlapping systems share. Directorates, departments, sections and programmes typical of most state organizational designs may in fact fly in the face of creating the space for systems to operate efficiently. The discord between the requirements of a system and the location of its critical sub-components in separate departments and/or institutions often make it impossible for the smooth operation of modern systems. In the context of municipal waste management systems, these ideas provide the rationale for a careful assessment of performance.

The practical application of the human-environment system thinking in Figure 2 is explored in this thesis to understand waste management and to create insight and understanding of the relationship between and among variables. The system in Figure 2 changes, adapts and responds to the social activities imposed by human interaction with the environment. Feedback at all levels will be visible when technical efficiency measurements have been captured and this informs the degree of the environmental awareness (goals, strategies and actions) at each stage. The combination of several goals at different hierarchical levels leads to the understanding of the observed environmental transition process at the interface.

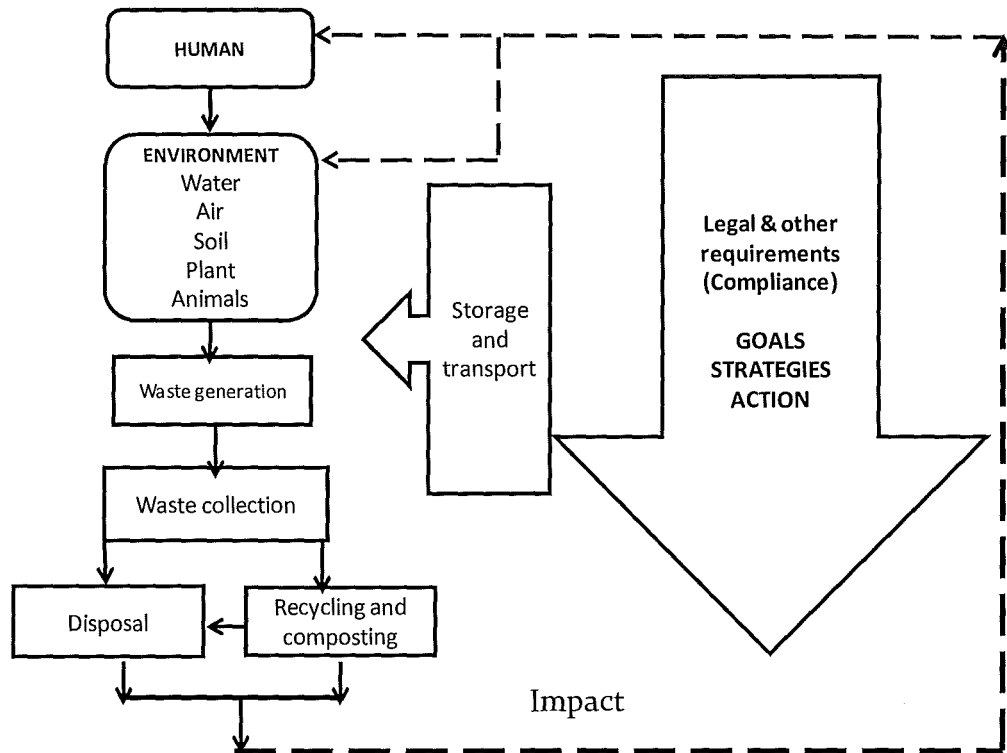


Figure 2: Municipal waste management process mapping conceptual framework

1.4 Research Aim

The purpose of this study was to apply process mapping and systems analysis in measuring the extent of compliance with minimum national standards in municipal waste management systems and to use the findings in designing an alternative intervention framework

1.5 Research Objectives

The following were the objectives of the study:

- 1 To analyse the municipal waste management system and levels of compliance to national standards
- 2 To examine the flow of waste from generation source to final destination.
- 3 To evaluate factors that influence municipality waste management system performance.
- 4 To design a municipal waste management compliance framework.

1.6 Hypotheses

The hypothesis was that the nature of the waste management system is the main determinant of differences in levels of compliance with waste management legislation between municipalities.

Five sub-hypotheses were formulated in order to test this hypothesis. In each case, the null hypothesis (H_0) advances the position that such a relationship does not in fact apply.

H_1 : Municipalities with an integrated waste management plan (IWMP) are more likely to comply with the National Waste Management Policy of 2008 than those without an IWMP. The null hypothesis stated that municipalities with IWMP's are equally likely to comply as municipalities without IWMP's.

H_2 : The existence of an operational waste management plan enhances the effectiveness of waste management in the municipality. The null hypothesis was that there is no relationship between waste management efficiency and the availability of an operational waste management plan.

H_3 : Municipalities with recycling facilities have higher compliance with waste management legislation than those without recycling facilities. The null hypothesis stated that there is no relationship between recycling facility availability and compliance with waste management legislation.

H_4 : Municipalities with an operational weighbridge system at municipal landfill sites are more likely to comply with licensing requirements than those municipalities' without such a system. The null hypothesis stated that there is no difference in municipality compliance with licensing requirements between municipalities with a weighbridge and those without it.

H_5 : Internal managerial attributes are the most important in explaining the efficiency of the waste management system than external factors. The null hypothesis stated that internal managerial attributes have no significant influence on the efficiency of the municipal waste management system compared to external factors.

1.7 Theoretical Framework

Waste management is a strategy of dealing with anthropogenic waste. The strategy has developed within the paradigm of industrial ecology (IE), with waste minimization and resource use optimisation as an important objective (Pongracz et al. 2004). Industrial ecology combines minimization and resource use optimization measures and ensures that resources are effectively circulated within the ecosystem, as indicated in Figure 3. Figure 3 shows the waste management design theory with goals and values linking to the social theory. According to the theory of waste management, a number of tools can be employed in trying to achieve effectiveness. These include product life cycle assessment, dematerialisation, appropriate environment, eco efficiency and green engineering or economy (Figure 3). For example life cycle assessment (LCA) may be regarded as a powerful tool for identifying the environmental impacts of an activity or a product (ISO 14042 2000; ISO 14044 2006). Furthermore it can successfully be used to facilitate decision making processes and in the evaluation of options at various stages of producing a product. Goals, values and restrictions in waste management deal with the priority order and principles by which specific materials from raw materials should be managed for investigating the environmental impact at each stage that the material goes through. There are regulations to be followed for managing waste. Therefore, holistic planning is required in order to incorporate integrated waste management considerations into the development of municipal waste policies, strategies and programmes.

Waste minimization encourages strict avoidance of waste creation by preventing waste at the source point while one of the principles of industrial ecology is that every unit that enters a specific manufacturing process should leave that process as part of a saleable product. Waste management leads to better control of waste related activities in society through sustainable development. A waste management strategy is established in terms of the building blocks of language, conceptual scheme, models and sentence systems. The language domain of waste management revolves around management purpose, structure, state and performance (Nurminen & Pongracz 2004). These constitute a system that is composed of physical and human activities and connection loops between and within, in order to provide consistent explanation of all waste related concepts and to offer a formal methodology of waste management.

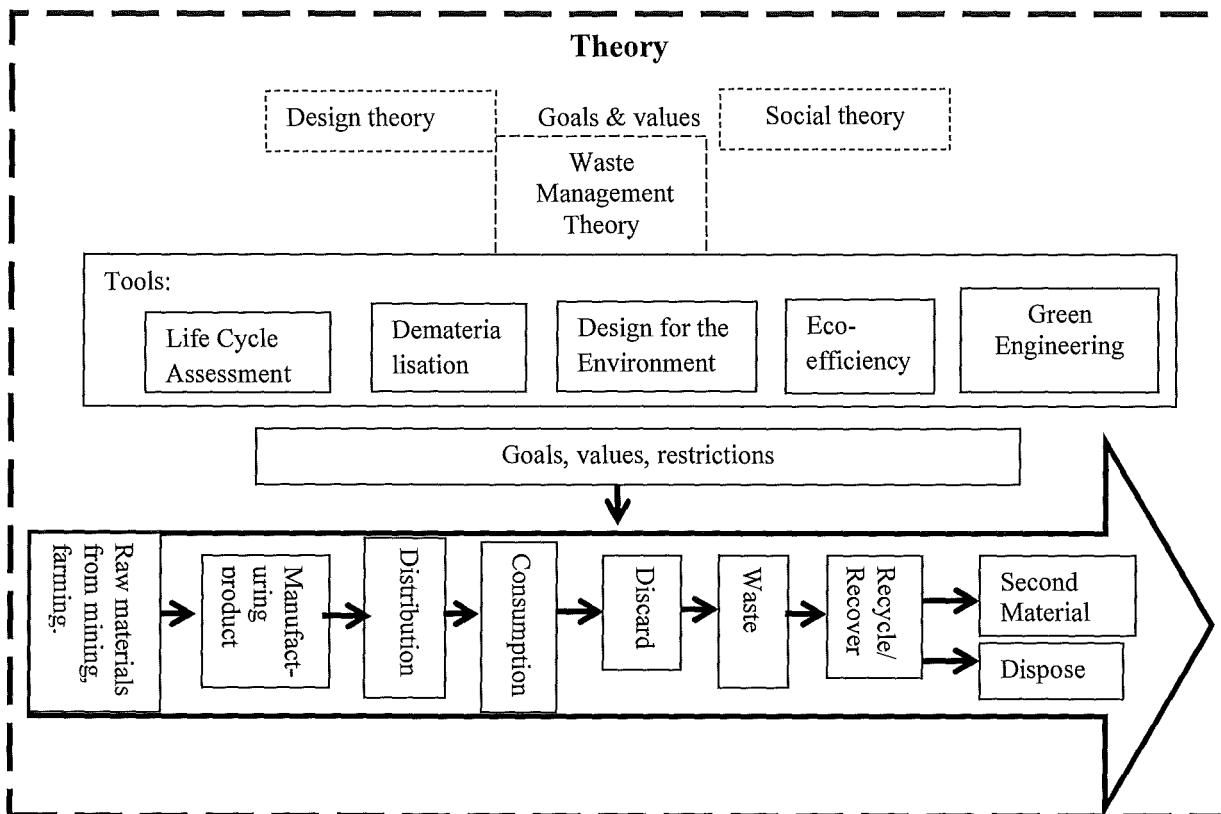


Figure 3: Waste management and the Industrial Ecology domain.
 Source: Adapted from Progracz & Pohjola 2004 and Meadows 2009.

With regard to purpose, the limiting factors and criteria for structure, state and performance of the modelled objects should be specified (Ab et al. 2013). Based on work by Nurminen and Progracz (2004), one can conclude that it is possible to look at the modelled objects as a measure of compliance of the waste management system. Furthermore, the purpose statement of waste management system compliance (WMSC) is like a mission statement, which is to prevent waste from causing harm to human health and the environment (Pohjola & Progracz 2002; Nurminen & Progracz 2004). The purpose statement drives the decisions that are made, the priorities that are set, and the risks that are taken. The way in which municipal WMSC is developed, implemented and managed should be based upon the defining purpose. A clear purpose statement sets expectations and opportunities and helps to establish the scope of compliance. Compliance audits and monitoring activities constitute the most common purpose statements for a WMSC. Consequently, auditing and monitoring are crucial to accomplish one of the essential purposes of compliance.

The drivers of solid waste management, according to Marshall and Farahbakhsh (2013), include purpose, state, structure and performance (PSSP). These are the main themes that are

applicable in each of the stages of the waste hierarchy in Figure 1. The PSSP drives decisions that are made, the priorities that are set, and the risks that are faced by the municipal waste management system and compliance directorate. The way in which a WMSC is developed, implemented and managed should be based upon its defining purpose. A clear waste management purpose statement sets expectations and opportunities and helps to establish the scope of compliance. The waste hierarchy is a structural building block with the spatial, temporal and causal relationships between the specified stages. The structure should be appropriate to the municipality's size and compliance requirements (Nurminen & Pongracz 2004).

According to Agamuthu et al. (2007), most developing country local government structures do not have policies and procedures that support the compliance purpose. However, the authors did not specify the alternatives that can remedy this gap between policy and compliance that they identified. The purpose of WMSC is, in general, to improve environmental compliance with legal and ethical standards, and identify and prevent activities that deviate from waste management standards, policies and laws. The WMSC ensures that the waste directorate meets its regulatory obligations, creates and maintains a culture of integrity, ensures objectivity, and supports stated values of the municipal WMSC goals. It is also important to show commitment by the waste management directorate to do the right thing, uphold and improve quality of human health and the environment and to display genuine, on-going efforts to comply with all applicable laws and other requirements (Hickle 2014).

Drack and Schwarz (2010) state that system structure indicates the divisions of management line in a system. From the outlook, system structure cannot be used to draw conclusions about the division of waste management directorate. Divisions vary because some municipalities might have a compliance section that solely focuses on compliance activities, while in others the compliance function may be more dispersed, with responsibilities handled by a legal department. Internal auditors ensure that they understand the distribution of compliance responsibilities throughout the municipality before undertaking periodic audits. But this may only be true for well financed and established urban local government structures. A WMSC function that is disjointed, with numerous internal control and compliance groups, can be a drain on the municipality's resources. Therefore, it is important

that internal auditors should look for any duplication of effort with other control functions and monitoring groups and verify that management has set clear goals and responsibilities.

The state of the waste system deals with the spatial and temporal distributions of the variables that evolve from the aggregate of the causal link given under a specified structure. This suggests that when assessing the effectiveness of the structure in place, auditors need to consider whether it meets the municipality's particular waste management compliance needs. Little has been recorded in literature on South Africa about the requirements of dumping sites that are not landfills to accommodate waste from municipalities. A municipality that has experienced compliance problems in the past or that has more complex compliance requirements will need a more sophisticated and dedicated waste system structure. On the other hand, the municipality with minimal compliance requirements and fewer issues to address may be able to utilize the legal departmental staff to fulfil its needs.

The nature of WMSC activities requires that those involved in compliance-related activities, possess the skills and knowledge to perform their duties adequately. The understanding assumed for each municipality is that a WMSC line staff, in particular, needs to have an adequate knowledge of applicable compliance requirements to effectively handle new situations, interpret activities, and prevent problems from occurring. Inappropriate and inefficient state of capacity is reported as one of the dominating factors by UNESCO (2009) in developing countries in general and by Godfrey (2008) in South Africa. Based on this it can be deduced that developing countries are slow in the development of human capacity for operation of waste management systems. However, the reports by UNESCO (2009) and Godfrey (2008) generalise the concept of capacity without specifying whether it is finance, technical or knowledge and skills in management. New development activities within the municipality's area of jurisdiction, for example, should be considered in light of waste management regulation compliance requirements prior to initiation. A view that education is the strongest factor affecting compliance and waste minimisation is echoed in Botelho (2012). This appears to be an unnoticed factor that is not specified in waste regulations but which can influence compliance.

If it is accepted that waste minimization and resource use optimization are the most important objectives of waste management, then it is also essential that resource use optimization reach beyond the traditional scope of waste management (Zeng et al. 2005). This is especially so

because during the 20th century products and technologies were developed without consideration of recovery of the most valuable components at the end of the products' useful life cycles to re-circulate their material resources. Building a theory of waste management is an effort towards accuracy in order to create a theoretical base for application in real life situations (Corley & Gioia 2011). It is argued that there are common characteristics between the goals of Industrial Ecology and sustainable waste management that need to grow into optimizing resource use.

1.8 Justification the Study

The assessment of compliance with waste management regulations in South Africa is important if waste management is to improve. Little research about it has been carried out. What appears to be prominent under the umbrella term 'environmental management' are issues concerning the administrative mandates that go with regulations and permits, as well as enforcement of compliance. However, little attention is paid to the underlying factors that influence compliance levels. This study contributes to addressing this gap. Existing national waste management guidelines do not provide adequate scope for facilitating the measurement of performance. Additionally, waste management guidelines fail to specify measurable deliverables against which individual waste directorates can measure compliance. The guidelines are silent about the need for benchmarking operations to allow for comparisons across the municipalities in the country. These weaknesses create a basis for this study. The information from the study can contribute to enhancing waste management at municipal level in South Africa. There is currently a lack of information on waste management at the local government level. Such information can inform decision-makers as to the best alternatives in delivering an integrated waste management system at the municipal level.

Municipalities have been the main waste removal service providers in all the provinces of South Africa, which is why assessing waste management compliance at the municipal level is important. South Africa is composed of three spheres of government: National, Provincial and the Local Government which is the sphere that is very closest to the people. In December 2000, South Africa held the first local government elections and new municipal boundaries were drawn to replace the old Apartheid ones. The White Paper on Local Government (RSA 1998) spells out the work of the local government. Since 1994, South Africa has been divided into nine provinces: Eastern Cape (EC), the Free State (FS), Gauteng Province (GP), KwaZulu-Natal (KZN), Limpopo Province (LP), Mpumalanga (MP), North West (NW), the

Northern Cape (NC) and the Western Cape (WC). Table 1 shows that at national (RSA) level, the percentage of households whose refuse was removed by the municipality increased from 57.8% to 62.2% between 2002 and 2006 before falling back to 55.1% in 2009 and then increasing to 59.0% in 2010. The percentage of households whose refuse was removed by the municipality in Limpopo Province increased from 12.8% to 20.5% between 2002 and 2007.

Table 1: Households with Municipal Refuse Removal per Province, 2002–2010

	WC	EC	NC	FS	KZN	NW	GP	MP	LP	RSA
	%	%	%	%	%	%	%	%	%	%
2002	84,0	33,4	69,5	63,1	54,2	42,3	88,1	38,9	12,8	57,8
2003	85,0	34,0	65,7	67,5	55,2	43,5	88,3	46,3	13,6	59,1
2004	87,2	35,0	62,6	66,6	55,0	44,2	86,9	43,0	14,3	59,0
2005	91,6	43,3	68,7	73,4	56,9	51,8	84,9	39,4	17,8	61,7
2006	91,7	43,6	66,5	78,6	56,9	49,7	85,1	40,2	19,6	62,2
2007	90,8	44,2	67,7	76,0	53,9	50,2	86,3	42,3	20,5	62,1
2008	88,3	40,0	64,0	75,7	50,2	47,9	88,1	38,7	15,6	60,1
2009	73,3	38,6	56,0	63,9	47,0	38,5	84,7	33,2	13,2	55,1
2010	85,5	41,3	59,8	72,9	46,2	44,1	89,7	36,3	11,8	59,0

Source: StatsSA (2010). Limpopo Province (LP) is highlighted in blue.

1.9 The Study Area

1.9.1 Location and Profile

The study was conducted in Limpopo Province of South Africa (Figure 4a, inset). The province has wide climatic variations due to its sub-tropical location. Daily temperatures range from between 17°C and 27°C in the summer and 4°C to 20°C in the winter. The temperatures range from a high average of 21°C in the upper catchments, to a very high average of 25°C in the Limpopo Province section of the Kruger National Park (KNP). Frost rarely occurs and certain areas can be extremely hot with maximum daily temperatures at times reaching as high as 45°C. Most of the rain falls in the summer months between October and March. During these summer months (October-March), the heat is often interrupted by a short duration thunderstorms which is usually a welcome respite from the sometimes extreme heat of the day. The average annual rainfall in the area ranges between 300-600 mm.

However, the mountain areas have annual rainfall of about 2 000 mm while the dry low-veld in the Limpopo section of the Kruger National Park receives about 400 mm. About 90% of the rain falls during the summer months.

The population of the province is 5 439 600 and it constitutes 10.9% of the country's population (StatsSA 2010). Socio-economic and demographic indicators such as urbanization, unemployment and population growth have impact on future waste trends and service provision. South Africa has a growing population characterized by both urbanization and the rapid development of the African middle class. Increasing affluence not only leads to an increase in the quantities of waste generated, but also leads to more complex waste streams (DEAT 2007). This trend is reinforced by the continued industrialisation of the South African economy. In South Africa, rapid urban growth throughout the country is seriously outstripping the capacity of most cities to provide adequate waste services. Over the next 50 years, South Africa's population growth will be almost entirely concentrated in urban areas (StatSA 2012). If adequate waste management policies and practices are not implemented, cities will be overwhelmed by their own waste, seriously affecting the quality of life of all citizens (DEA 2006). Household waste generation varies considerably by settlement type and income, with wealthier consumers in urban areas generating much higher volumes of waste.

Municipalities in South Africa are in three categories (A, B, C) depending on population, percentage of the urban population and size of municipal budgets. Category A is composed of metropolitan municipalities, category B is local municipalities and C is district municipalities. These characteristics are relatively fixed over time, and assist in understanding of municipal profiles. However, they are not a rational indicator of performance and capacity in waste management, or of the key economic drivers within a municipality. The Municipal Infrastructure Investment Framework (MIIF), a system for funding municipalities, has arranged the local municipalities in South Africa in somewhat different categories (Development Bank of Southern Africa 2011). The study area is composed of five district municipalities (Capricorn, Greater Sekhukhune, Mopani, Vhembe, and Waterberg,) as shown in Figure 4a and b. Table 2 summarizes the characteristics of the local municipalities that were used in the study (Figure 4b), and shows that they fall under categories B1, B3 and B4. At the time of the study Polokwane Local Municipality was the only local municipality in Limpopo Province that had the characteristics of a metropolitan

municipality. The municipalities in the B4 category were dominated by rural areas which were governed by the local municipality and the traditional authorities.

Table 2: Categories of the Local Municipalities in the Study Area

Category	Characteristics	Municipality/ study area	Households without access to refuse removal	Households without access to refuse removal in %
B1	Local Municipalities with large budgets and containing secondary cities	Polokwane	11531	62.9%
B3	Local Municipalities with small towns, with relatively small populations and significant proportion of urban population but with no large towns as cores.	Ba-Phalaborwa	33791	58.78%
		Musina	14201	33.6%
B4	Local Municipalities which are mainly rural with communal tenure and with, at most, one or two small towns in their areas.	Blouberg	35597	90.5%
		Lepele-Nkumpi	58484	86.6%
		Greater Giyani	57537	86.8%
		Greater Tzaneen	89831	84.8%
		Makhado	114060	91%
		Thulamela	137852	85.5%

Source: Development Bank of Southern Africa (2011).

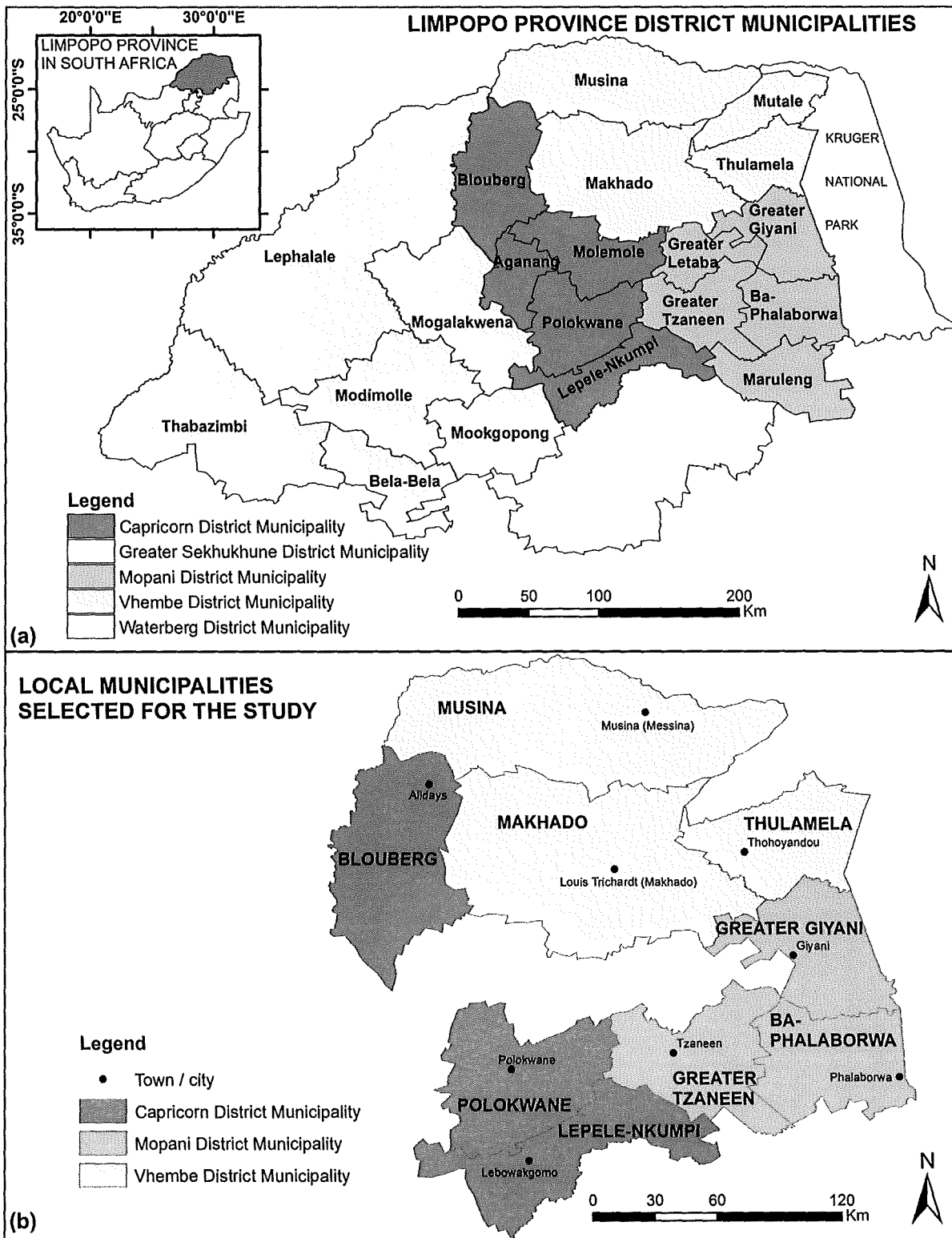


Figure 4: Map of the study area showing district and local municipalities

[Notes: Local municipalities are labelled]

Source: Municipalities Demarcations Board, Pretoria

1.9.2 Waste Management Services

The Statistics South Africa (2010) data in Table 1 shows that refuse removal services provided by municipalities throughout the country were notably higher in the largely urbanised provinces of Gauteng (89.7%) and Western Cape (85.5%) in 2010 compared to lower levels in the more rural Eastern Cape (41,3%), Mpumalanga (36,3%) and Limpopo Province (11,8%). At district municipality level in the study area, data on refuse removal for each district municipality indicated slight changes in access to the refuse removal service between 1996 and 2009. In Vhembe District, there was a slight increase in access to formal refuse removal service from, 8% in 1996 to 11% in 2009 (RSA 2011a). Personal refuse removal also went up slightly over the years reaching 70% in 2009. In Capricorn District, access to formal refuse removal service increased from 12% in 1996 to 19% in 2009. Personal refuse removal increased to 70% in 2009 (RSA 2011b). In Mopani District there was a slight increase in access to the formal refuse removal service from 1996 to 2009. Access increased from 11% in 1996 to 13% in 2009 (RSA 2011c). Personal refuse removal also went up slightly over the years, reaching 65% in 2009. All three districts are rural and the low levels of formal refuse removal must be taken into the context of low settlement densities, where on-site disposal or backyard burning of waste was sometimes appropriate (RSA 2011a, b, c).

According to RSA (2000a), each district municipality was expected to indicate turn-around strategies in their annual reports and refuse removal was one of the crucial aspects to be included in the strategic planning. The district municipalities that were selected for this study (Figure 4) had the waste removal characteristics in Table 3, which shows that Polokwane had the largest number of households with access to refuse removal. The reports on turn around strategies from Capricorn and Vhembe Districts on waste management did not indicate plans on waste minimisation at source, which is the highest priority of the national waste management policy. Vhembe District Municipality indicated challenges that included lack of regional refuse dumping sites with availability of waste transfer stations which were not licensed and which were not cost effective to operate. Out of 129 000 households, 9 856 had access to basic refuse removal and 119 809 were still outstanding. Furthermore the district municipality developed and ensure implementation of Integrated Waste Management Plans while finalising the closing of illegal transfer sites, and implementing awareness and cleaning campaigns (DEA 2012a).

Other support and interventions by the municipality that were required were to follow up with the Department of Local Government and Housing (DLGH) on the funding and establishment of waste transfer stations. Vhembe District needed to engage the provincial Department of Economics, Environment and Tourism on landfill closure and rehabilitation, and the opening of new landfill sites for the town of Louis Trichardt (in Makhado Local Municipality; Figure 4b) and neighbouring towns. Capricorn District Municipality needed Environmental Management Plans for landfill sites, and to construct two landfill sites, purchase waste management equipment and engage the Limpopo Economic Development, Environment and Tourism (LEDET) Department for fast-tracking the licensing process for landfill sites (RSA 2011a, b).

Table 3: Number of Households with a Waste Removal Service in the Study Area

Local municipalities	Removed by local authority/private company at least once a week	
LIM331: Greater Giyani	7412	Mopani District
LIM333: Greater Tzaneen	11522	
LIM334: Ba-Phalaborwa	13817	
	Subtotal 32751	
LIM341: Musina	9406	Vhembe District
LIM343: Thulamela	19302	
LIM344: Makhado	9998	
	Subtotal 38701	
LIM351: Blouberg	3346	Capricorn District
LIM354: Polokwane	47342	
LIM355: Lepele-Nkumpi	7389	
	Subtotal 58077	

Source: StatsSA (2007).

1.10 Scope of the Study

The study was limited to the analysis of municipal waste management systems presented in a process mapping and systems analysis scope. Therefore, related issues that are outside a municipality, such as national level waste management issues, were outside the scope of the study. Similarly, issues of national political priorities were outside the scope of the study.

Compliance in this study is a measure of the extent to which current operations conform to national environmental standards. The measurement of compliance requires a prior understanding of the municipality as an institution and how it responds to environmental policy in the form of the national minimum standards. These two provide the basis for analysing the dynamics of the waste chain in order to identify characteristics, limitations and constraints and were used in the study.

1.11 Significance of the Study

This study could make a contribution towards the effective management and operational dynamics of the waste management system in rural municipalities in South Africa. The results could enhance waste management compliance in such municipalities in the country. Appraising how waste management protocols shape the daily operations of municipal waste management systems and implications thereof remains virgin territory, at least in the case of South Africa and the rest of the Sub-Saharan Africa. Furthermore, the study identify specifications of what the system is able to accomplish under varying waste generation capacity scenarios through time. This, in turn, could further contribute towards a better understanding of parameters that should be included in measuring municipal performance. Effective waste management has a significant impact on public health, environment and economic development (Uyarra and Gee 2013).

1.12 The Target Audience

Solid waste management is a multidisciplinary field extending beyond Environmental Science to include water resources, water and sanitation, Industrial Engineering, Civil Engineering and Industrial Chemistry. Therefore, this study is principally targeted at environmental scientists, practitioners and researchers in these disciplines. Other role players that should find this work of interest include individuals, households, waste managers, planners and municipal administrators from the three spheres of government, non-governmental organisations, operators of disposal facilities, business enterprises and private institutions such as professional consultants and researchers.

1.13 Chapter Outline

The thesis consists of seven chapters. Chapter one presents background issues and a problem statement, the aim and objectives of the study, the research hypotheses, the scope of the study

and introduces key characteristics of the study area that are relevant to the study. The chapter also presents definitions of key concepts and terms that are used in the thesis. Chapter two summarises material from the literature with regard to the state of knowledge on municipal solid waste management and compliance, thereby identifying research gaps in the field. Chapter three details the methodology and procedures that were employed in addressing the aim and objectives of the study and in testing the research hypotheses.

Chapter four to seven present results from the study and discuss them in the context of the objectives of the study. Chapter four analyses the municipal waste management systems and compliance with legislation in the municipalities that were used for the study. Chapter five then examines the waste hierarchy issues with respect to the municipalities that were selected for the study. Chapter six and seven looks at the factors that influence the performance of municipal waste management system. a waste compliance framework designed based on the findings from the study. Chapter eight then presents conclusions and recommendations emerging from the study.

1.14 Definitions of Key Concepts

The following terms will be taken to have the following meanings in the thesis:

- **Buy-back Centre** – A designated point where people deliver and sell recyclable materials (DEA 2011).
- **Compliance** – Means conformity and adherence to environmental policies, plans, procedures, laws, regulations, contracts and other requirements by an organization (Okibo & Kamau 2012).
- **Disposal facility** – Is a municipal controlled disposal site that includes dumping sites and landfill sites (DWAF 1998).
- **Domestic waste** – Waste excluding hazardous waste that emanates from premises that are used wholly for residential, educational, health care, sport or recreational purposes (CSIR 2011).
- **Drop-off Centre** – Designated points where recyclable materials are dropped off by consumers without receiving payment for the materials (DEA 2010a).
- **Dumping site** – Is an illegal waste facility which lacks proper processing and control but it is regulated by the responsible authority (DWAF 1998).
- **Effectiveness** – Assesses the extent to which the actual outcomes of an activity align with the desired outcomes (Grimshaw et al. 2004).

- **Efficiency** – Assesses the relationship between the outputs and the inputs used to produce them (Grimshaw et al 2004).
- **Environmental risk** – Threat to the environment arising from the activities of human beings or business which could result in the degradation of the environment (DEAT 2007).
- **General waste** – Waste that does not pose an immediate hazard or threat to health or to the environment and it includes domestic waste, building and demolition waste (DEAT 2007).
- **Inputs** – The resources invested to produce outputs and outcomes (Meadows 2009).
- **Institutional arrangement** – Refers to the delegation, distribution, or sharing of power related to growth management decision-making and implementation authority (Tadesse et al. 2007).
- **Landfill** – Is a highly regulated waste disposal facility that adheres to waste treatment laws and processing regulations (DEA 2011).
- **Limiting factor** – A significant system input limiting the activities of the system at a particular moment (Hristoviski et al. 2010).
- **Materials Recovery Facility** – Specialised plant that receives, separates and prepares recyclable materials for marketing to end-user manufacturers and/or recycling companies (CSIR 2011).
- **Minimum standards** – These are specific national standards that govern all forms of waste management operations at the individual municipality level (DEA 2011).
- **Municipal waste** – Includes household waste, industrial waste, chemical waste, medical waste and toxic waste (Couth & Trois 2012).
- **Operational control** – Procedures to manage and control waste management hierarchy systems and for verifying the effectiveness of such controls (Chen et al. 2000).
- **Outcomes** – The effect or impacts of an activity or programme (Kurdve et al. 2014).
- **Outputs** – Tangible product (it can be a document) in order to fulfil expected outcomes (Kurdve et al. 2014).
- **Process Mapping** – Structural analysis of a process flow by distinguishing how work is actually done at each stage from how it should be done, and what functions a system should build into the definition using a flow-line diagram (Kurdve et al. 2014).
- **Responsiveness** – The ability of the system to complete an assigned task at a given time (Drack & Schwarz 2010)

- **Scalability** – The ability of a system to cope and continue working despite the difficulties and obstacles (Meadows 2009).
- **Solid waste** – Unwanted materials with a low moisture content, and they are usually disposed of on land (Bosman & Boyd 2008).
- **System** – A set of elements that is coherently organised and interconnected in a pattern or structure that produce a characteristic set of behaviours (Meadows 2009).
- **Systems Analysis** – A procedure to determine the desired outcome and the most efficient method of obtaining that outcome (Pires et al. 2011).
- **Transfer Station** – Facility where waste is temporarily stored, and ideally sorted, before it is transported more economically to either recycling centres or landfills (DEA 2011).
- **Waste Management** - Is the collection, transportation, processing, recycling or disposal and monitoring of waste material from different sources (DEA 2011).

1.15 Summary

This chapter has provided the background issues that form the basis for the thesis. It has shown that there is legislation in the waste management sector with which municipalities in South Africa must comply, hence the need to study compliance. The chapter then set out the aims, objectives and hypotheses of the study. The study area is shown in the chapter as consisting of predominantly rural municipalities that are somewhat lagging behind others in the country in terms of waste management. The next chapter summarises material from literature related to the work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of literature of pertaining to the study. The literature review begins with literature material on the regulatory framework in waste management, and then tackles the dynamics of waste management. Then a regional approach is used in reporting on the state of waste management in different parts of the world. The remaining parts of the literature review focus on performance, compliance and monitoring. Finally, gaps in knowledge identified in the literature are stated, thereby providing the basis for the methodology chapter (Chapter 3).

2.2 Regulatory Framework

Good environmental governance should reflect sound understanding of the structure, function, processes, and variability that typify natural systems (Nzeadibe & Anyadike 2012). Without this understanding, it is possible for inappropriate decisions to be made. Perhaps based on sound knowledge there has, in recent years, been a considerable development in environmental legislation from the European Parliament, resulting in changing the views of both the public and industry (Costa et al. 2010). UNESCO (2009) recommends that integrated waste management plans have to support pro-poor policies, and encourage their involvement as a source of income generation. The average consumer is more environmentally aware of key concerns through purchasing power and pressure groups. Greater numbers of people are willing to pay more for ‘correctly’ and ‘genuine’ green products and consumer guides are influencing ever greater numbers of consumers (Pires et al. 2011).

In South Africa the key pieces of environmental legislation pertaining to waste management include:

- The White Paper on Integration Pollution and Waste Management.
- The National Environmental Management Waste Act (NEMWA).
- The National Waste Management Strategy.
- The Municipal Systems Act.

The administration of environmental laws in South Africa has in the past been described as fragmented and dispersed (DEA 2010a). Responsibility for the environment is divided between many different state departments, including the provincial municipalities. Although this state of affairs has not entirely changed, the Department of Environmental Affairs (DEA) coordinates all activities around environmental management. Environmental issues in South Africa are largely regulated by statute and the inclusion of an environmental clause in the Bill of Rights (RSA 1996) has been followed by the development of South Africa's environmental legal framework. The government's commitment to give effect to the environmental rights as enshrined in the constitution is evident from the enactment of various pieces of environmental legislation since 1996. The White Paper on Integrated Pollution and Waste Management (RSA, 2000b) provides clear guidance on the roles and responsibilities of the different spheres of government.

The National Environmental Management Waste Act (NEMWA) came into effect in 2009 to consolidate most of the previous waste legislation into one framework. NEMWA has been developed as part of the law reform process enacted through the White Paper on Integrated Pollution and Waste Management and the National Waste Management Strategy (NWMS). The purpose of the Act was to protect human health, well-being and the environment by providing reasonable measures for the minimization of the consumption of natural resources; the avoidance and minimization of the generation of waste; the recovery, re-use and recycling of waste and, the treatment and safe disposal of waste. The Act stipulates that each municipality must include in its integrated development plan (IDP) an integrated waste management plan that is consistent with the relevant provincial integrated waste management plan. The annual performance report which must be prepared in terms of the Municipal Systems Act (RSA 2000b) must contain information on the implementation of the municipal integrated waste management plan. The successful implementation of NEMWA goals largely depends on its translation into policy, strategy and municipal by-laws. Although the Act is informative about the requirements in the National Waste Management Strategy (NWMS), implementation is not quantified. The NWMS was developed to reduce the generation of waste and the environmental impact of all forms of waste and, thereby, ensure that the socio-economic development of South Africa, the health of the people and the quality of its environmental resources are no longer adversely affected by uncontrolled and uncoordinated waste management. The NWMS follows the waste management hierarchy approach.

The DEA is the key institution for waste management related functions in South Africa, including the development of the policy, strategy and legislation, coordination, enforcement, dissemination of information, monitoring, auditing, review and capacity building. The national government waste policy is clear about the requirements in terms of implementation at the provincial and local level. The province is also clear in terms of the penalty if a municipality is not complying with the national policy. Despite these the violation of the policy persists, which indicates that enforcement is not effective. Periodic reports from the Limpopo Province in terms of violations of waste management policy indicate evidence that private companies are also culprits. The penalties for non-compliance imposed on government seem to be inappropriate. There are national departments with waste-related responsibilities such as the Department of Water Affairs (DWA), which is responsible for the protection of the water resources from the effects of waste management practices. The Department of Mineral Resources (DMR) is responsible for the management of mining waste while the Department of Health (DOH) sets regulations and guidelines for medical waste and treatment facilities. The development of the necessary guidelines for all agricultural waste is the responsibility of the Department of Agriculture, Forestry and Fisheries.

The provincial government's specific functions include the development of provincial environmental implementation plans and reviewing integrated waste management plans received from the municipalities. Provincial governments assist in monitoring compliance and the development of guidelines and standards. In addition, they are responsible for the establishment, support, oversight systems and programmes for the implementation of waste collection services. The provincial waste management strategy is clear about the requirement of the waste management at local level but implementation seems to be inappropriate. Some of the local municipalities operate without integrated waste management plans. The provincial government ensures that municipalities adhere to the relevant environmental implementation plan (EIP) and environmental management plan (EMP) as well as the principles in the preparation of any policy or programme.

The minimum requirements of waste disposal by landfill provide applicable waste management specifications that must be met, as well as providing a point of departure against which environmentally acceptable waste disposal practices can be assessed before a waste disposal site permit is issued. Adherence to the minimum requirement conditions is required from all permit applicants. However, there is no specification for a landfill operational plan as

a requirement. There are municipalities that have been operating without a license for more than 20 years; yet such non-compliant facilities persist after the publication of annual landfill audit reports. The present policy does not have the option of requiring upgrading the landfill as a short term objective (DWAF 1998).

The Constitution of the Republic of South Africa assigns waste management services to local government (RSA, 1996). Powers at the local government level are split between district and local municipalities. The district municipality pursues the integrated, sustainable and equitable social and economic development of the district. It also determines waste disposal strategy, regulation of waste disposal, establishment, operation and control of waste disposal sites, bulk waste transfer facilities and waste disposal facilities for more than one local municipality in the district. Vhembe, Mopani and Capricorn district municipalities have facilities such as buy back centres and recycling facilities. The Integrated Development Plan (IDP) provides the basis for the managed development of the municipality and it was used by the political, business and community leadership to determine activities and operational plans and guides the allocation of resources (RSA 2000a). Reference to the IDP documents of 2012, pertaining to the study area, showed that waste management as an item does not appear in the top five priority list from the community needs assessment. Specifically local municipalities are responsible for compilation and implementation of general waste management plans and implementation of public awareness campaigns, collection of data for the South African Waste Information System (SAWIS), provision of waste collection services and the management of waste disposal facilities within their area of jurisdiction (DEA 2012c). District municipalities are also responsible for the implementation and enforcement of appropriate waste minimisation and recycling initiatives.

2.3 Dynamics of Waste Management

Environmental pressure groups have matured from what were perceived as badly informed reactionary groups in the early 1980s to well researched information sources, often aiding government agencies in environmental matters (RSA 2006). As a result, environmental issues are increasingly well publicised with wide-ranging implications for industry. When municipal waste management problems become complicated, waste policies also become more abundant and complex and decision-making in many countries has also undergone significant changes (Saed et al. 2009). Although many governments have made considerable efforts in tackling waste-related problems, there are still major gaps to be filled in this area. In most

developing countries, people still pay little attention to the natural environment (Marshall & Farahbakhsh 2013). There is, therefore, a need to encourage the uptake of waste management education so that when young people grow up they then also have love for the environment (Wagner & Arnold 2008).

Environmental protection systems came to their forefront in the 1970s, with an initial focus on eliminating uncontrolled disposal of waste, followed by the systematic upgrading of technical standards. The models developed during the 1980's extended the system boundaries by including municipal solid waste management (MSWM) at the system level. During the 1990's concepts like sustainable waste management, integrated waste management, and recycling were included in most models developed for the planning of MSWM. Most of the existing solid waste management systems critically evaluate the basic elements on the basis of the data waste generation, its characterisation, its collection, transportation, disposal sites and administration (Vaccari et al. 2013).

2.4 Waste Management System Compliance

The key features of the systems approach include interrelated activities which require inputs from a number of sectors. These sub-systems respond to externalities in diverse ways, leading to changes in structure and function. System analysis techniques have been used to deal with MWM streams through a range of integrative methodologies in the 19th Century. Seadon (2010), Shaw and Blundell (2010) and Pires et al. (2011) support the notion that models are based on the relationship between structure and behaviour in relation to changing conditions that interact with each other. However, the ability to manage the waste system's underlying relationship of waste management components systems lies in the potential of the municipality's waste stakeholder and institutional arrangements (Blengini et al. 2012). Advantages of systems models are that systems correspond with reality and support actions for minimising avoidable waste safely, and integrate other methods with approaches to the waste management hierarchy (Shaw & Blundell 2010; Pires et al. 2011).

Systems operate within the parameters of negative and positive feedback loops. A waste system is a collection of entities that includes five main components, input, process, output, outcome and impact (Figure 5). The on-going activities in the system are determined by the management of the waste and compliance as a control variable. The system variables often dictate the rates at which processes operate, and inter-relationships that represent the complex

connections among all components of a system. The negative feedback loop regulates the system and, therefore, the absence of feedback loops is a common cause of system malfunctions. Negative feedback provides an element of self-monitoring and self-regulation. Negative feedback loops can mitigate uncontrolled growth that may lead to system collapse (Kollikkathara et al. 2010). The ability of a negative feedback loop to correct system deviations depends on a combination of parameters and links within the boundaries. Among these, according to Meadows (2009), are the accuracy and speed of reporting, and the speed and power of the response. The directness and size of the correction instituted determines the strength of a negative feedback loop relative to the impact that it is designed to correct. This view is applicable to municipalities with appropriate inputs such as waste management capacity, policies, sufficient operational procedures and equipment. Within the system approach there is a process mapping that includes understanding, interpretation, adoption and implementation of the policy at each stage of the waste hierarchy. These result in efficient waste hierarchy management and human and environmental justice.

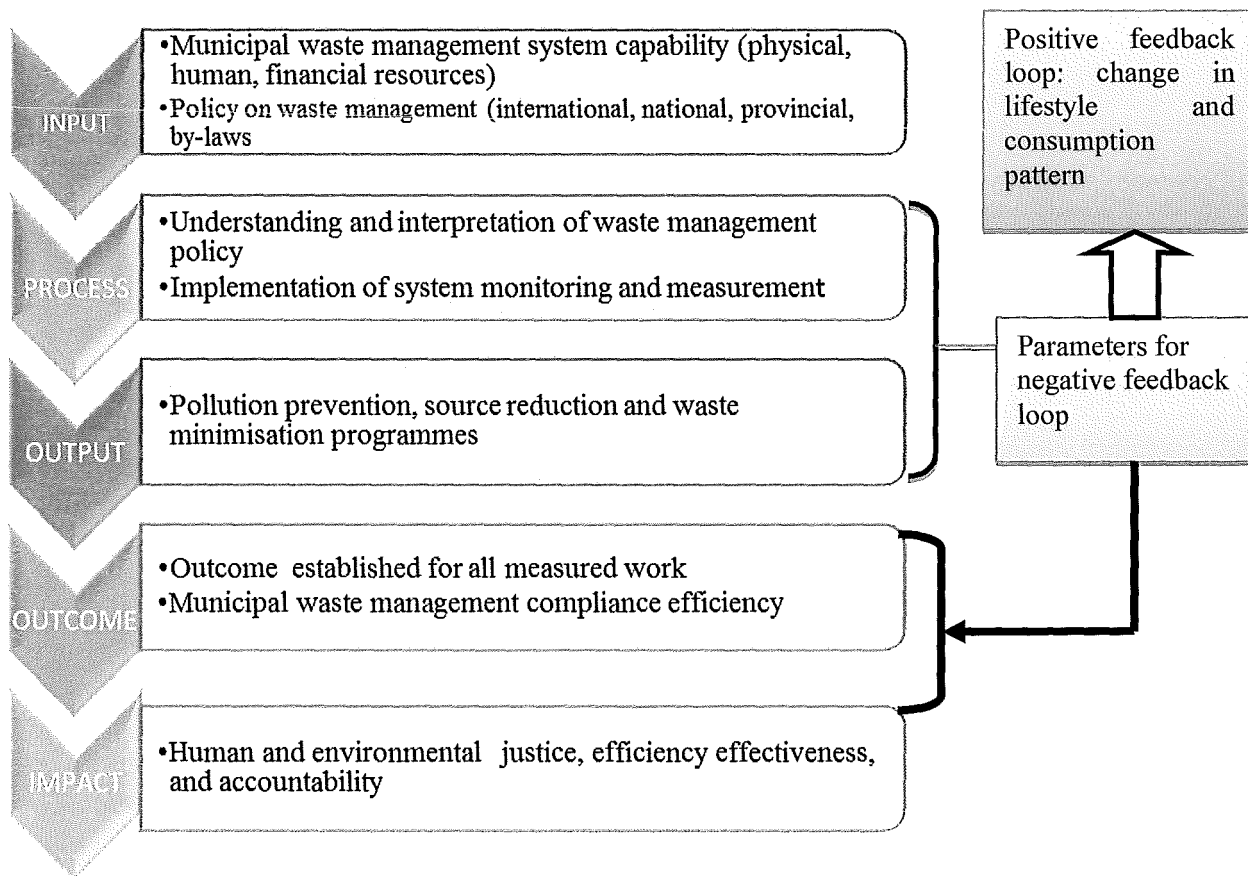


Figure 5: The Systems Model
Source: Adapted from Meadows 2009.

Applied to the municipal waste system, quick intervention response is an indication of proper planning and management strategies. Positive feedback loops reinforce actions in a system. The ultimate conclusion of an unchecked positive loop is the destruction of the system and hence, wherever there are positive feedback loops, there are negative feedback loops to provide balance (Figure 5). One way to lessen the speed of the loops is to reduce the gain around the positive loop and hence reduce growth (Seadon 2010). Therefore, reducing the negative loop in developing countries is not obvious because it solely depends on external social and economic factors that are the status and understanding of waste management by waste stakeholders (Pires et al. 2011).

According to Seadon (2010), the rules of the system define its scope, boundaries and degrees of freedom. A change in the rules of a system changes its behaviour. If the goal of a WMS is to reduce waste, then the system is seen in an isolated manner. However, boundaries are set so that the goals improve municipal waste management compliance. Setting waste system boundaries is characterised by identification of the waste management scope and nature of the system (which is crucial), followed by an analysis of the internal and external components that help it in the evaluation of action (Shaw & Blundell 2010).

The systems approach is implemented when an organization sets environmental objectives and targets guided by the standard requirements and demonstrates that such objectives have been achieved. Systems characteristics relate to the boundaries of the system depending on whether they are closed or open systems or subsystems (Meadows 2009). The systems approach has been largely used to model material and energy flow in the waste system. If planning for sustainable waste management is to address several interconnected components, it becomes increasingly necessary to understand the dynamic nature of their interactions. The structure and characteristics of the system are very important because they shape its direction (Marshall & Farahbakhsh 2013).

Evaluating the waste management action plan while, at the same time, identifying the existing gaps in policy and operation is also important. The proposal of the target and deliverables should lead to program implementation and maintenance. According to Pires et al. (2011), waste management in Denmark is well established with system boundaries but, undoubtedly, all boundaries overlap; hence there is a zone of interaction. Building on the

conceptual framework in Chapter 1, this study deals with both human and natural systems as applied to municipal waste management. This is often referred to as “*coupled human-environment systems*” (Chen et al. 2012; Binder et al. 2013; Chin et al. 2013; Smith 2013). Clearly any intervention in such a system has to appreciate the differences in behaviour and the limitations that arise in trying to engineer change. Cleary’s (2009) position is that comparison across the boundaries implies that system assessment tools have been applied to evaluate and assist in environmental decision making but it demands the examination of each phase in the “life” of the product, process or service under investigation. These statements correlate well with this study’s concept of process mapping, which was imbedded in the conceptual framework of this thesis in Section 1.3. The concept of process mapping has direct implications for the municipal waste hierarchy and compliance.

2.5 Performance of the Waste Management Hierarchy

Yan and Wan (2014) define process mapping as an approach to systematically analyse a particular process; that is plotting the flow and conditions within a system. It involves mapping each individual step, or entity operation, undertaken in that process in sequential succession. Once individual steps are identified, they can be analysed in more detail. Process mapping is an effective tool for systematically identifying environmental aspects. Identification of tasks associated with each phase of a process in the waste hierarchy is fundamental to a municipal waste management system. Contreras et al. (2008) presented an analytical hierarchy process to show the significance of analysing waste stakeholders preferences for the municipal waste management system. The value of process mapping is that it is systematic and comprehensive; it may well identify important environmental aspects that the system approach process would have missed. Materials accounting is helpful in indicating that maps have been developed completely and that processes are displayed in a sufficient level of detail to make optimum process improvements. Process maps also clearly illustrate to management the locations of potentially wasteful areas and inefficiencies of operations (Eriksson 2010).

The Waste Management Hierarchy (WMH; Figure 1) is a recognized model for conceptualizing waste reduction and it has been adopted by most industrialized nations. The rational philosophy of WMH advocates waste avoidance, minimization, re-use, recycling, recovering, treatment and disposal (Massarutto et al. 2011). The fundamental purpose for establishing hierarchical system measures is to improve the efficiency of the performance of

the municipal waste hierarchy towards a compliant operation management system. In terms of efficiency, work that is not measured or assessed cannot be managed because there is no objective information to determine its value. Zorpas and Lasaridi (2013) support the notion of measuring waste prevention activities and the impact of relevant implemented waste management activities on management performance and the natural environment. Measuring the operation system of the waste hierarchy in a waste management organization is valuable regardless of the outcomes because it helps. Godfrey et al. (2012a) indicate that collection, interpretation and internalisation of data can, through a process of learning, raise awareness. The best that can be accomplished with this type of activity is to supervise a level of effort because unmeasured work should be minimized or eliminated while desired performance outcomes must be established for all measured work (Cox et al. 2010a; Consoni et al. 2011a, b; Kurisu & Bortoleto 2011; Levanen & Hukknen 2013).

The outcomes of the waste hierarchy analysis provide the basis for establishing accountability to waste management hierarchy regulation. Abba et al. (2013) used the analytical hierarchy process (AHP) technique to structure and assess the views and judgements of stakeholders on the environmental impacts of solid waste disposal. The key points identified in Abba et al.'s (2013) study were that the desired outcomes are necessary for work evaluation and meaningful performance appraisal. Therefore, specific measurable targets which will indicate or confirm adherence to established standards are significant (Read et al. 2009). Defining performance in terms of desired results is how waste managers and supervisors could make their work assignments operational. Performance reporting and variance analyses could be accomplished and this would enable the initiation of timely corrective actions needed for effective management and control of waste disposal facilities (Wolsink 2010). Therefore, it is important for municipal waste managers to develop relevant waste management hierarchy measuring and monitoring tools (Tasaki & Yamakawa 2011).

Cox et al. (2010) have shown that activities that prevent avoidable waste from households should be identified as issues which management practice should address to minimize waste. In addition, physical activities in each stage were analysed by Cox et al. (2010) in order to identify aspects relevant to conditions expected in management practice. Evaluation of the waste systems provides information on strategy to assess if the right actions have been carried out effectively in achieving expected outcomes, efficiency in optimizing resources, client satisfaction and lessons learned (Jones et al. 2010).

DEA (2012) reported that out of all waste disposal facilities in South Africa, 56% were unlicensed. The majority of the existing disposal facilities were established before 1994 prior to the 1989 legislation, which means that they were not guided by the minimum requirements in the legislation. They cannot be licensed because they do not meet national standards/specifications and municipalities find it costly to upgrade them to reach these standards (DEAT 1989). This was one of the challenges contributing to delays in obtaining landfill licenses. In 2007 the capacity assessment estimated that the number of waste handling facilities was more than 2 000, of which 530 were licensed (DEAT, 2007). It was also recorded that the department has made significant progress in dealing with licensing backlogs and by 2011 there was no applications waiting for processing.

2.6 Monitoring Performance of the Waste Management System

According to Zorpas and Lasaridi (2013), monitoring is an on-going, systematic collection of information and is implemented following specific principles. It is aimed at improving the efficiency and effectiveness of an organisation based on targets set and planned activities. For this study, it is important to monitor performance of the waste management system at the level of individual municipalities in order to identify areas that need corrective interventions. Mendes et al. (2013) conducted a study on waste management performance in regions with strong seasonal variability. The study indicated that municipal solid waste management systems are well established throughout the EU directives and the application of performance indicators should allow service objectives to be quantified.

The purpose of monitoring the waste hierarchy aspects such as waste prevention is to enable the policy makers, local municipalities and experts to collect high quality data, indicate how to prioritise resources and to ensure that waste prevention is effective and bringing change (Cox et al. 2010). Waste management requires input from the monitoring system so that timely action may be taken. Monitoring a waste system requires a set of relevant parameters to achieve programme objectives. Monitoring efforts cost money and time and it is therefore, essential to make them cost-effective (OECD 1996). Principles of simplicity, time-lines, relevance, and accuracy will lead to cost-effectiveness. Monitoring must take into account the fact that those who provide information to the system should obtain a benefit; otherwise the quality of the information provided will decline. Waste monitoring is, in addition, concerned with the collection and analysis of data about waste while at the same time diagnosing

problems arising from the municipal waste management system design and suggesting alternative practical solutions.

Waste managers should plan ahead for monitoring; execute the monitoring plan, check the outcome and act to improve the process. The use of waste management monitoring indicators helps in measuring changes in a given situation. Such monitoring indicators are tools for evaluating the effects of an activity and the principal means by which a monitoring unit keeps track of system capability, effectiveness, and efficiency. The criteria for selecting indicators depend upon the purpose, resources, and time available. Indicators should be simple enough to be understood by non-specialists and clearly defined. They should be geared to the specific needs of decision makers and reflect changes only in the situation concerned and should measure specific conditions that the project aims to change. The value of indicators should stay constant so long as they are collected in identical conditions; no matter who does the collecting, the indicators should be objective and verifiable. Although several researchers, such as Gomez et al. (2009), have studied the importance of monitoring parts of the waste system, they do not provide quantification and measurements of performance in each stage of the waste hierarchy.

Organisational capability, effectiveness, efficiency, and impact, are basic components to monitoring and evaluation of operational management (Mendes et al. 2013). This includes operational efficiency such as the frequency of waste collection, availability of equipment, technical efficiency, and waste system induced changes such as waste minimisation, less time spent in collection and increase in revenue (Tasaki & Yamakawa 2011). Waste management systems and performance compliance depend directly on the degree to which goals are attained. Municipalities, however, have multiple goals in terms of their administrative and management mandates. Read et al. (2009) indicate that efficiency in waste management is usually measured in terms of the rates at which waste is prevented and minimized. Impact in waste management can be measured by a simple indicator, like the decrease in tons of waste handled per town for a specific period of observation. Such indicators provide ultimate tests for the success of waste management programmes (Farrelly & Tucker 2014).

The Waste Watch Report (RSA 2006) stated two types of data that can be used in monitoring and in informing decision makers about issues on the ground. These are the input data that describes the change in behaviour and the output data that measures the impacts. Therefore, it

is important for the Waste Management Hierarchy to be monitored to gather input and output data regularly not only to know the status of the system's capability at a certain point in time, but also to determine changes in-and-through time. Tasaki and Yamakawa (2011) state that setting indicators to measure progress in inputs, activities, outputs, outcomes, and goals is important in providing necessary feedback to the management system. This will inform managers about how to identify the parts of an organization that may not achieve results as planned. By measuring performance indicators on a regular basis, managers and decision makers can determine whether projects, programs, and policies are on track, off track, or even doing better than expected against the targets set for performance. Ultimately, it increases the likelihood of achieving the desired outcomes (Mendes et al. 2013).

2.7 Waste Management in Developed and Developing Countries

2.7.1 Developed Countries

According to Pires et al. (2011), the primary aim of waste policy in the European community (EU) is the prevention and reduction of waste production and its harmfulness. This could be achieved by employing clean technologies that conserve the use of natural resources, by an environmentally friendly product design and by appropriate techniques for the final disposal of dangerous substances contained in waste destined for recovery. Pires et al. (2011) reviewed waste management systems in the EU from a life cycle approach and with regard to regulations that promote wealth within waste management Systems engineering models. According to Massaruto et al. (2011) the system engineering models that contribute to effective solid waste management in Europe include cost benefit analysis, optimization model, simulation model, forecasting models and integrated models that improve synergistic connections.

These engineering models have been analysed by Massaruto et al. (2011). System assessment tools for solid waste management adopted in the EU include management information systems, decision support system and expert systems, scenario development, material flow analysis, life cycle assessment, risk assessment, environmental impact assessment, strategic environmental assessment, socio-economic assessment and sustainable assessment (Giugliano et al. 2011). Systems engineering models have not been applied to the same extent as system assessment tools in EU member states as they are mathematical in form, making it difficult to translate them for inclusion in waste plans.

According to ISO 14040 (2006), life cycle assessment (LCA) has been deemed the most popular system assessment tool in the EU so far. It is regarded as the normalized method in connection with the norm family. Models, from Sweden, were applied as system assessment tools in the EU for solid waste management (SWM) because of the possible linkage between SWM and energy recovery. It is, therefore, possible for systems engineering models to be linked with LCA to provide a fundamental understanding of environmental, technical, economic and social aspects of SWM in response to the challenges (Manaf et al. 2009). It should be noted that the assessment of SWM using system analysis techniques allows decision makers to learn about total system complexity. Quantifying the complexity factor requires evaluating interfaces, where system assessment tools provide a wealth of composite measures of complexity.

For the purposes of this study, combining human factors and physical-biochemical features in system engineering model with those well-defined procedures and components brings about a considerable contribution to the improvement of SWM (Arvind et al. 2011). However, this approach is not widespread because essentially hard systems thinking assumed that the world is a set of systems that can be engineered to reach easy to define goals and objectives, while performance can be measured quantitatively (Chai & Yeo 2012). The issue at hand may be more to do with the problem of how to link soft systems typical of municipal management approaches with hard systems associated with engineering models. The “*coupled human-environmental systems*” approach may provide an alternative means for bridging this gap. The same applies to the use of process mapping which in essence overrides design bottlenecks.

2.7.2 Developing Countries

Developing countries face mounting challenges in properly managing their waste, with a lot of efforts by these countries being directed towards reducing the final volumes and towards generating sufficient funds for waste management (Ball 2006). If most of the waste could be diverted for material and resource recovery, then a substantial reduction in final volumes of waste could be achieved in these countries. The recovered material and resources could be utilized to generate revenue to fund waste management. At present, developing countries struggle with these first steps. The resource value of waste which allows people to make a living from discarded materials across countries like Brazil, Egypt, Kenya, India, China and Indonesia is an established fact.

Wilson (2007) describes the widespread practice of indigenous waste recycling in several countries. According to Ball (2006), developing countries share common characteristics with regard to waste management. In general, there is lack of reliable information and statistics on waste. Often in most of these countries the first priority in development plans is on social and economic needs rather than waste management. There is evidence of low political will and inadequate allocation of resources to waste management (Nhamo et al. 2009; Troschinetz & Mihelcic 2009).

Urbanization is on the rise in Africa (Al-Khatib et al 2010; Jha et al. 2011; Nzeadibe & Anyandike 2012) and this trend is expected to continue in the future, along with the urban waste problem it creates. Concern about the urbanization is with the inability of infrastructure and land use planning methods to cope with urban growth (Nnorom & Osibanjo 2008). This is particularly urgent in slum areas, which constitute a big part of many of the cities and towns in Africa. Waste generation is expected to increase significantly as a result of rapid urbanization in Africa. This will further aggravate current capacity constraints in waste management. According to Nnorom and Osibanjo (2008), the fast growing use of ICT and rapid turn-over in technology (particularly computers and mobile phones) is creating a growing e-waste stream. The e-waste includes waste from electrical and electronic equipment (WEEE), for which there is no waste management capacity yet in developing countries. Effective management of e-waste in the developing countries demands the implementation of extended producer responsibility (EPR), the establishment of product reuse through remanufacturing and the introduction of efficient recycling facilities. Countries in Europe and Asia have put in place policies and take-back laws that require the manufacturer to take back the used products at its end of life (Al Khatib et al. 2010). This leads to disposal of both e-waste and municipal waste in dump sites. In the case of developing countries, while e-waste is already a recognised problem, the application of EPR is unlikely to be effective given that the bulk of such waste is of imported electronic appliances and devices. National regulations cannot be easily extrapolated to exporting countries. In any case, enforcement alone would require yet another institutional organ for handling e-waste.

Waste characteristics data specific to African cities are generally not available due to lack of capacity for data management (Marshall & Farahbakhsh 2013; Guerrero et al. 2013). It was also noted by Guerrero et al. (2013) that cities are composed of varieties of cultures and they,

therefore, need a mixture of waste management systems. But this position can be questioned given that it is not common practice to deliver a differentiated waste system that is sensitive to cultural diversity. The awareness of waste sorting at source and characterisation became serious in the 19th Century and the rate of adapting to the changes is often slow in developing countries (Scheinberg et al. 2011). The composition of the waste varies depending upon such diverse variables as urbanization, commercial enterprises, manufacturing and service sector activities. Solid waste management in most countries is characterized by inefficient collection methods, insufficient coverage of the collection system and improper disposal of municipal solid wastes (Laner et al. 2012). A study by Farrelly and Tucker (2014) in New Zealand suggests that sorting at source could be a priority that should start at home.

A review by Couth and Trois (2012) concluded that in Africa, in order to reduce carbon emissions in the majority of urban communities, the most practical and economic way to manage waste is to separate waste at collection points. The findings by Couth and Trois (2010b) further demonstrate that to improve waste management in developing countries, it is essential to set achievable standards and objectives. Indeed, the achievable standards will only be appropriate if they display requirements, quantification and measurements. Principles of waste management in developing countries include understanding the local conditions, obtaining official and political buy-in, and ensuring that the basic cleansing systems are in place (Arukwe et al. 2012; Yau 2010).

A rapid increase in volume and types of municipal waste as a result of continuous economic growth and urbanization is an escalating problem for national and local governments in developing and developed countries (Ezeah & Robert 2012; Bhuiyan 2010; Igoni et al. 2007). The growth of a city is characterized by an increase in its economic and developmental activities that are typically driven by the production and consumption patterns leading to an imbalance of expected waste management services and capacity (Zaman & Lehmann 2011). This is an indication of waste generation and consumption of resources. The case of Cameroon is distinctive with regard to waste management governance; similar to most countries in the Sub-Saharan Africa (Manga et al. 2008).

In the Southern Africa Development Communities (SADC) region, various country reports were reviewed by UNESCO (2009) to determine the current waste management situation. The results indicated that a number of initiatives have been put in place to facilitate the

development of waste management plans and improved services such as upgrading of collection systems and waste disposal sites (Karani & Jewasikewitz 2007). Waste management, pollution, inadequate access to sanitation services and poor urban conditions are identified as some of the major challenges to development in the SADC region. In order to address these challenges, SADC is committed to promoting sound environmental management through pollution control, waste management and environmental education. Waste Management is one of the priority issues affecting the region. The rising quality of life and high rates of resource consumption patterns have had an unintended and negative impact on the urban environment. They have resulted in generation of waste beyond the handling capacities of the majority of waste management authorities.

2.7.3 Waste Management in South Africa

Research by the CSIR showed that only 3.3% of South Africa's urban population frequently recycled household waste in 2010 (CSIR 2011). This finding is emphasised by the CSIR, which indicated that of the estimated 19 million tons of municipal waste generated in South Africa in 2011, about 25% were mainline recyclables such as glass, paper, tins and plastics. Separating recyclables at household level is a requirement in terms of the Waste Act of 2008. The National Waste Management Strategy of 2011 further requires that in four years time (i.e. by 2016) all metropolitan municipalities, secondary cities and large towns will have initiated programmes for waste separation at source (DEA 2011). In this CSIR study Polokwane municipality is regarded as a secondary city. Oelofse and Strydom (2010) pointed out that the participation of households in waste separation programmes will be crucial in attaining the 2016 target.

The results of a Statistics South Africa survey show that municipalities face a difficult task in creating public awareness around the requirements of the 2008 Waste Act (StatsSA 2010). In addition, the study indicates 67% of more than 2 000 urban South African households surveyed did not know where to dispose of their household recyclables. Furthermore, the majority of the participants in that study said that they did not know how nor what to recycle. This 2010 household survey by Statistics South Africa does not give a positive picture about attitudes and behaviour with regard to recycling. More than 73% of South Africans living in urban areas reported that they were not recycling at all, about 27% reported some recycling behaviour; and only 3.3% of the respondents indicated that they sort most or all of the selected five recyclables from their household waste and recycle it at a frequent basis.

Illegal dumping is wide spread in most of the underserved areas in South Africa and only 44% of the known public and private landfills are authorised through landfill site permits (RSA 2006). It seems the law enforcement has not been effective with regard to the management of landfill operations. But this is not unique to South Africa, as will be seen in later sections. Urbanization is an added problem as it directly feeds into the problem of uncontrolled waste generation.

Godfrey and Oelofse (2008) report on the status of waste service delivery and capacity at local government level in South Africa and showed that the waste service function is often not accounted for in small rural towns and staffing is often skewed towards labourers with little middle and top skills. There is a shift towards outsourcing of the recycling function to small community contractors to customise the understanding of waste minimisation before disposal. A total of 87% of municipalities do not have capacity or infrastructure to pursue waste minimization goals. More than 80% of the municipalities are initiating recycling but projects are struggling due to lack of capacity (RSA 2006). The argument on municipal ability is that capacity might be there but proper implementation and prioritisation of waste management are somewhat seriously superseded by political interest within a municipality. The country has adopted the National Waste Management Strategy (DEA 2011). The strategy is based on reuse, reduce and recycle; which can improve the quality of environmental resources that are affected by uncontrolled and uncoordinated waste management. Rhodes et al. (2014) reported that recycling is an essential element of long term solution to waste control.

Waste collection standards in South Africa fall within the framework of the National Domestic Waste Collection Standards (DEA 2010). The standards, procedures, processes and benchmarks are established to ensure that domestic waste collection services are fit for their intended purpose. The waste collection clause indicates that there is an obligation for the generator of waste to separate the waste at source. This must be encouraged and supported in line with the relevant industry waste management plan. The clause states that all domestic waste must be sorted at source in all metropolitan and secondary cities. The argument is that the exclusion of sorting at source by municipalities that do not qualify as secondary cities might create significant impact on the environment. A high volume of waste is generated in

low and middle income areas because of the expansion of urbanisation to rural areas; this is also influenced by the change in lifestyles.

The government of South Africa in 2010 published some national domestic waste collection standards that became effective on 01 February 2011 (DEA 2010). The standards stated that it is the responsibility of the service provider or municipality to provide clear guidelines to waste generators regarding waste classification, sorting of the waste, appropriate containers, and removal schedules for each type of waste; and for community involvement in recycling to be encouraged. “Receptacles for the storage of non-reusable and non-recyclable waste must be easily distinguishable from the storage of recyclable waste, and receptacles for the storage of non-recyclable waste at households must prevent pollution; be rigid and durable to avoid spillage and leaking; be covered, intact and not corroded or worn out. Receptacles should be marked by household members for ownership. Supplied bins must be kept safe and clean, the size of the household receptacle is 240L and the acceptable collection frequency in South African climatic conditions is once per week or else it becomes a health hazard. Communal collections points must be clearly demarcated with appropriate receptacles, and separation at source should be encouraged. Drop-off centres for recyclables not collected at the households must be accessible, clean and user friendly to the public. Waste must be collected and transported in closed vehicles. Occupational health and safety legislation must be adhered to by all waste collectors” (DEA 2010).

With regard to communication, the municipality must create awareness amongst households about the type of waste collection provided, separation at source, unacceptability of illegal dumping and littering, measures for illegal dumping and littering, cost of illegal dumping and littering and the advantage of reporting illegal dumping. Weekly collection must be done on the same day of the week according to the municipal schedule and when the schedule is interrupted or collection is missed for whatever reasons, the municipality must resume the services as soon as is practical and address all backlogs as a matter of priority before the next collection day. Waste that is not supposed to be in the receptacles, according to the by-laws, may not be removed (DEA 2010). This requirement may not be possible to municipalities that are expanding to the rural areas because they do not pay for refuse removal; instead they burn the waste or dig a hole. The system assessment tools adopted include environmental impact assessment, environmental management system, environmental auditing and waste

information system. Due to lack of capacity and inconsistency monitoring, most of the municipalities do not have these important documents (Couth & Trois 2010a).

2.7.4 Challenges in Municipal Solid Waste Management

Municipal Solid Waste (MSW) management is of critical concern in developed and developing countries and the biggest culprit of non-compliance in terms of planning, implementation and management. According to Godfrey and Oelofse (2008) and Ezeah and Roberts (2012) failing waste management services are a reality as piles of waste are found dumped next to the roads, rivers and many other spaces in cities. The waste management challenges identified in the literature were internal and external factors that hinder sustainable development of the municipal waste management system's efficiency. These include rapid urbanisation, financial management, equipment management, labour management and institutional behaviour. Other challenges are illegal dumping, appropriate waste collection strategies in informal settlements, lack of community education regarding illegal dumping, enforcement of appropriate legislation, the costs of establishing waste treatment and disposal facilities and the costs associated with waste collection (Couth & Trois 2010; Imam et al. 2008; Ezeah & Roberts 2012). The majority of SADC cities are now grappling with the problems of high volumes of waste, low capacity to management and the high costs involved in the management (UNESCO 2009). This is further exacerbated by the lack of proper disposal technologies and methodologies, inadequate manpower and equipment. This, coupled with poor enforcement, results in rampant illegal dumping of domestic and industrial waste that is a common practice. This has had serious health and environmental impacts resulting from littering, generation of foul smell and proliferation of pests and insects that transmit diseases. Information about the kinds of waste and amounts generated by SADC member states is not routinely collected and reported at present.

Urban populations are growing very fast in many countries of Africa, Asia, the Middle East, South America and Latin America with difficulties associated with providing an effective waste management system. This is caused by waste management capacity that is inadequate and does not keep pace with the growth of the urban population (Zotos et al. 2009). Challenges that influence waste management practices in developing countries may be seen as a combination of technical and managerial capacity challenges (Seng et al. 2010). In Bangladesh, 50% of the waste generated remains uncollected every day (Bhuiyan 2010).

Funding for waste management is always inadequate and real costs are never fully recovered. In order to be successful and sustainable, any future investments in equipment and technology must be preceded by background studies and surveys of the solid waste management situations in order to assure that the use of means is best suited to the capabilities of the countries and their people (Tai et al. 2011). The cost of provision of waste services remains an on-going problem contributed to by inadequate direct financial recovery of certain waste services such as removal of litter and illegal dumping. In some areas, the culture of not paying for the service is still dominant. The income for municipalities is mainly derived from revenue from service delivery and the equitable share from the Municipal Income Grant. However, municipalities serving relatively large numbers of poor households are unable to recover sufficient revenue to support delivery of a wide spectrum of services due to poverty within the community (Nahman & Godfrey 2010; Mahasa 2013). Non-compliance by local management remains a challenge and is compounded by human resource capacity (Godfrey & Oelefse 2008). Fees cannot be collected for implementing projects due to lack of capacity to eliminate the culture of not paying for the service received by the public. Political interference is one of the issues that impede good practice of local municipalities (Bosman & Boyd 2008).

The source of the solid waste management problem in the United States, for example, is due to the 'short circuit' to the price mechanism for choices concerning materials use and reuse caused by local governments that provide waste management services at a zero price. It is 'government failure' not 'market failure' that is the source of the current problem (Jamasp & Nepall 2010). There is a widespread lack of recognition that the costs of waste reduction at source will be lower than any other management option for initial levels of control. These derive from a lack of understanding on how consumer choices and willingness to pay for solid waste management services should fit into the overall solid waste management plan. Local conditions would dictate the levels of the rates. Residents are not able to separate the waste at the source as in Europe and they rely on future technologies to separate the waste by technological means. The technologies to separate 'mixed waste' into useable materials are poorly developed, and attempts in those directions failed in countries such as Germany, France and Austria. The 'contribution of the general public' by separating their waste at the source, at least in bioorganic 'wet waste' and in 'dry waste' categories, is required. Both fractions can be further treated through technical measures to achieve material and energy recovery. This collection of waste is the state of the art in all ecologically oriented

industrialised countries and is required to implement a cost-effective and economy-relevant waste treatment system, which complies with the objectives of a recycling economy and compliance (Vaccari et al. 2013).

Waste management is disadvantaged by lack of inter-departmental cooperation inadequate structures and unilateral decision (Da Zhu et al., 2008). Manga et al. (2008) report that too many ministerial departments with similar responsibilities of sustainable waste management and environmental protection leads to inefficiencies through duplication and wastage of both human and capital resources. According to Okot-Okumu and Nyenje (2011), in Uganda implementation of the national solid waste management strategy has not been effective due to factors such as participatory planning, social, technical and material factors. In South Africa and in many other developing countries, waste legislation is still focused on the “concentrate and contain” approach whereby un-treated and unsorted waste is disposed of in lined sanitary landfills equipped with biogas and leachate extraction systems. Bleck and Wettberg (2012) state that waste management procedures in developing countries are characterised by highly inefficiency in waste collection practices, lack of environmental control systems and, in general, lack of environmental and waste management awareness of the general public.

Usually, integrated waste management is not implemented in developing countries and very little information is available on composting, controlled sanitary landfills and the recovery of the landfill gas. Another major challenge is lack of municipal waste data records in terms of waste total volume and composition. Agamuthu et al. (2007) established that the effects of socioeconomic variables such as income, level of consumption, and cultural and educational environments on the generation of waste vary from place to place. Education and communication channels between sectors, especially government and civil society, are considered to be inefficient and inadequate. A lack of a right to know, secrecy and misinformation have also been major contributory factors to poor waste management practices in many developing countries. Phillipe and Culot (2009) studied household waste in Cape Haitian city and concluded that residents lacked knowledge of waste composition and characterisation and, therefore, local involvement was important in terms of problem definition, strategy and problem solutions.

The role of education and environmental awareness as well as public-private participation is a key in the improvement of waste management in developing countries. This is true more

especially if awareness is done from childhood education to build and customise citizens with a sense of caring for the environment. The inability to fully grasp the problems of waste generation and characterization has resulted in transforming SWM as one of the most compelling problems of urban environmental degradation (Seadon 2010). Manga et al. (2008) reports that in Cameroon, literature in respect of waste collection, transportation, treatment, reuse, recycling and disposal is scarce or non-existent, making it almost entirely difficult to evaluate or compare the current situation with other nations. In developing countries, population is outstripping services from the waste management local office (UNESCO 2009). In many African countries, there is limited or no formal waste treatment before disposal. Most people in Africa, due to poverty, cannot afford to pay for waste collection and disposal and generally.

One of the challenges facing local government in South Africa is institutional arrangements. Based on the literature a number of weaknesses exist in the institutional arrangements of the solid waste functions. These include operational, socio-economic, natural and institutional and regulatory, as well as the division of roles between district and local municipalities. Vagueness or overlapping in the assignment of responsibilities was identified, which tends to undermine accountability for environmental service delivery between district and local municipalities. In instances where district and local municipalities share responsibilities, a clear contracting framework is required to ensure that a single authority remains politically and administratively accountable for the service. However, such contracts are not the norm. A similar situation was identified by Ezeah and Roberts (2012) in their study done in Nigeria. Another challenge in South Africa was that there were more than 300 waste disposal facilities operating without a license due to challenges such as capacity, finances, institutional or lack of prioritisation of waste management in general. The national Department of Environmental Affairs, working with provincial departments responsible for waste management as well as local government, made an effort to reduce the number of unlicensed sites and the target was to have 80% of all waste disposal sites licensed by 2014 (DEA 2012a, b). The problems of unpermitted and insufficient landfill sites highlight the issues that major progress needs to be made with regard to the management of landfill sites and waste streams. Bosman and Boyd (2008) reports that challenges at the municipal level are grounded by institutional change and difficulty with meeting nationally-set objectives. Most municipalities require additional assistance with clarifying and operationalising their sustainable development mandates (Couth & Trois 2012).

The identified limitations in municipal waste management are a lack of information about the regulation requirement that commits stakeholders to separate waste at source, and stronger requirements for remediation as well as duty of care to the environment (Matete & Trois 2008). Municipalities often have limited capacities to ensure compliance and planning of sufficient landfill sites, and to prevent pollution of groundwater resources. Jamasb and Nepal (2010) argue that the problem of solid waste management is one of choice in that waste generation decisions are made by waste management authorities without understanding consumers. As a result, the determinants of waste flows are often incorrectly modelled, leading to excessive investment in end-of-the-pipe technologies such as recycling, incineration, and land-filling. A key component of increased efficiency in solid waste management is the involvement of all stakeholders including the waste generators, waste processors, formal and informal sectors, financial institutions and private initiatives such as non-governmental and community based organizations (Kurusu & Bortoleto 2011). They all have a significant role to play in improving services and systems and ensuring that more sustainable waste management services are developed and delivered (Cherian & Jacob 2012; Ezeah and Roberts 2012).

2.8 Waste Modelling

During the 1960s, the environmental movement started to take awareness of environmental issues on board. Research by Banar et al. (2009) confirms that the modelling of solid waste management that started in the 1970s increased with the development of computer models around the 1980s. The models that are commonly used in municipal waste management are decision support models. Weng and Fujiwara (2011) note that after 1990, three models played a major role in the decision making of waste management: life cycle assessment (LCA), cost benefit analysis (CBA) and multi-criteria decision making (MCDM). The life cycle is defined as the causative and interlinked stages of a product system, from raw material acquisition, generation of natural resources to the final disposal. The element of compliance in the LCA of the municipal waste management system does not come out clearly from the literature on LCA (Pickin 2008; Yuan et al. 2011).

The implementation of LCA places little attention on environmental legal requirements and compliance (Blengini et al. 2012). Winkler & Billitewiski (2007) argue that not all models fall into conventional categories. In order to carry out an LCA, it is necessary to compile an

inventory of relevant inputs and outputs, to evaluate their potential environmental impacts and to interpret the results of the inventory and impacts in relation to the specific objectives of the study. LCA cannot assess the actual environmental effects of the service system. However, it is important to consider when, where and how wastes are released into the environment. Tools such as risk assessments are able to predict the actual environmental effects and according to Cleary (2009), the life cycle stages of MSW management commonly include collection, transportation to a sorting facility, sorting, transportation to a treatment facility and treatment potentially including recycling, biological treatment, thermal treatment and land-filling.

According to Almansa and Martinez (2011), cost benefit analysis (CBA) is another approach that assists in making economic decisions in waste management. Regarded as a common platform in support of decision making, the process involves weighing the total expected costs against the total expected benefits of one or more actions in order to choose the most profitable option. It is often used to evaluate the desirability and efficiency of a given intervention relative to the status quo. Weng and Fujiwara (2011) point out that maximizing economic efficiency is usually the overriding factor in CBA. Gomes et al. (2008) provide an overview of the systematic decision analytical framework that incorporates the use of multi-criteria analysis (MCA) based decision making in waste management. Linkov and Seager (2009) suggest that most MCA models are flexible and it is easy to expand on them. The term “decision analysis” is used to refer to a set of quantitative methods for analysing decisions, rather than a description of how unaided decisions are made. It involves people, processes and tools within complex, environmental decisions. Waste management problems require the consideration of numerous factors, including environmental, economics, and social (Roussat et al. 2009). This is appropriate if public participation and consultation influence the decision making process. Karmperis et al. (2013) reviewed decision support models for solid waste management and analysed the LCA, CBA and MCA, as well as similarities and possible combinations that bring game-theoretic approaches to the forefront. Their study shows that the approaches have advantages that promote the inclusion of various groups of waste stakeholders in decision making; that is “decision making in multi stakeholders situations”. Yet, compliance in the waste management system goes beyond decision making and has to include considerations of the actual behaviour through time of the “waste chain” itself. Modelling approaches that give priority to decision making but do not link the process to the waste chain may be inadequate (Yan & Wan 2014).

The Environmental Protection Agency of the USA created a waste reduction model (WARM) to help solid waste planners and organizations to track and voluntarily report greenhouse gas (GHG) emission reductions (EPA 2011). The WARM circulated the total GHG emission of baseline and alternative waste management practices, source reduction, recycling, combustion, composting and landfilling. The model calculates emissions in metric tons of carbon equivalent (MTCE), metric tons of carbon dioxide equivalent (MTCO₂E), and energy units (millions BTU) across a wide range of material types commonly found in municipal solid waste. Consonni et al. (2011) and Consonni and Vigano (2011) supported the idea of material and energy recovery. The implication is that it is possible to inspire waste generators that after waste generation, the available waste could be converted into energy before disposal at a landfill.

2.9 Knowledge Gaps

Gaps in knowledge of the theoretical framework of waste management system in South Africa have been established by the literature review. Studies reporting characterisation of waste streams are practically lacking. The use of process mapping and of systems analysis in studying the interface along the waste chain remains an un-researched area. The absence-until recently - of a centralised system of reporting data, has meant that typical analytical studies widespread in developed countries hardly apply in the case of South Africa. The measurement of the performance of the waste hierarchy, where this occurs and is reported, deals with the municipal solid waste *system as a whole*: no information is reported in the literature about the actual dynamics of this and the changing trends affecting its efficiency in different areas. A knowledge gap is noted with reference to quantification and measurement of efficiency at each stage of waste hierarchy is not articulated to ensure consistency during the assessment of progress. Underlying this issue is the problem of specification with respect to quantitative parameters as reported in Mudau et al. (2013).

2. 10 Concluding Remarks

This chapter has provided a review of the state of knowledge in the context of the research problem of the study. A wide cross section of research papers has been cited to highlight a series of knowledge gaps in the existing state of literature. In subsequent sections of this thesis, the gaps reported in section 2.9 are addressed. Ultimately, this study should add value to the state of understanding in the field of municipal waste management systems

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

The literature review presented in Chapter 2 identified key issues that are relevant to the study of solid waste management system compliance. These include capacity of municipal waste management authorities in managing solid waste, availability of waste management facilities, and service delivery compliance in the waste chain process. An appropriate methodology was developed to collect data on these key issues. In the light of this, the study gathered data from secondary and primary sources. The chapter outlines these techniques, with appropriate justifications. The research design and methodology are explained so as to indicate what was needed to answer the research questions and achieve a systematic management of data collection and analysis.

3.2 Research Design

The research sought to find out whether the municipalities in the study comply with waste management requirements in legislation, and to establish the reasons for non compliance in the case of non compliance. This research employed a descriptive research design. Descriptive research is concerned with measuring a variable or set of variables and describing them as they exist naturally. It is not concerned with the relationships between the variables but with the description of the variables. The measurement and description of the variables may be carried out qualitatively or quantitatively (Gravetter & Forzano 2012). The design was considered appropriate after paying attention to the characteristics of the data and the units of measurement. The study was based on field surveys allowing for observation and measurement with respect to waste generation, waste collection, waste storage, waste transport, waste processing and final landfill sites. In addition to observation questionnaires were administered to households, waste supervisors, waste managers and waste general workers. Some of these sources of data generated data values suitable for the application of statistical analysis. The data collected from questionnaires was coded and subjected to both descriptive and inferential statistics for analysis.

3.3 Data Sources

Primary data were collected through preliminary field observations, then detailed field observations and face-to-face interviews using questionnaires. The preliminary field

observation involved reconnaissance visits in parts of the study area (Thohoyandou, Giyani, Louis Trichardt, Polokwane, Musina; Figure 4b) to assess the prevalence of waste in residential areas, communal waste collection skips, dustbins, illegal dump sites, landfill sites, the state of public spaces in terms of littering, and waste in private and government institutions and business area. During transect walks in the area in this reconnaissance, photographs of heaps of solid waste in dump sites, solid waste skips overflowing with solid waste, and solid waste scattered in between houses were taken. The photographs were later included in the analysis of data gathered from the field. This preliminary reconnaissance helped in the identification of the nature of the waste problems and guided the formulation of questionnaires.

The source of secondary information for the study was current books, journals, and statistics from official publications, and reports from national and international institutions. Nine local municipalities were selected for the study, as shown in Figure 4b. The selection of these municipalities is detailed under Sampling Methods (Section 3.7). From the waste management directorates of the nine local municipalities, primary data was collected using questionnaires that were administered to managers, supervisors and service workers. Questionnaires were also administered to households in the study area. Secondary data and information on waste policies and guidelines, statistics on personnel, annual budgets, waste collection and disposal volumes, and reporting protocols were obtained from municipal annual reports for the period 2001 to 2011 (10 years).

The questionnaires (Appendices 1- 4) were administered to general workers, supervisors and local managers of the waste management directorate in each of the nine local municipalities. The questionnaires sought information about the operations of the waste management system in terms of stages, inputs, processes and outputs. Detailed field observations were then conducted, using a checklist (Appendix 5). The observations involved inspecting and recording the characteristics of individual operations involving waste management, the labour component per stage, equipment and implements used, time spent, inputs at each stage and outputs from collection sites up to final disposal. The result was process mapping of waste from generation, waste storage facilities, handling and collection, transportation, waste recycling and final waste disposal sites.

Data from the questionnaires that were administered to the waste managers, supervisors, service workers and households (using Appendices 1-4) generated the required information to address objective 3 on factors that influence municipality waste management system performance, both in physical and in managerial terms. The responses to the questions were summarized in terms of frequencies and numeric codes that were assigned, to facilitate quantitative analysis. Descriptive statistics were then generated for each municipality.

3.4 Population

The universe identified for this study is infinite, which means the study items are not certain because the urban population is growing fast every day while some people are migrating out of town and province (Yin 2009). The population of the study was categorised into three clusters: (i) district and local municipalities in the study area (ii) the waste management directorates in the study area (iii) the households in the urban areas and waste disposal facilities.

3.5 Units of Analysis

Units of analysis were generated on the basis of the populations stipulated in Section 3.4. For the purposes of this study, four units were identified: (i) households (ii) workplace groups (iii) municipalities, and (iv) waste management facilities. Households are composed of family units, and from them data on waste related variables were collected and analysed. The workplace groups are a wider unit of analysis: they were made up of general (service) workers, managers and supervisors. With respect to municipal organisations, a distinction was made between the local municipality and its waste management directorate. Each of these was a distinct 'organisation' with specific functions to deliver. Waste management facilities included temporary storage (collection) sites, processing centres, buy-back centres, illegal waste dump, and landfill sites.

3.6 Variable Measurement Scales

The specific variables were measured on ordinal rating scales. These ranged between three and five rank ordered scale points, as indicated in Appendices 1-5. Compliance with waste management policy standards was the dependent variable that was affected by the specific variables in Appendices 1-5. Several factors may lead to lack of compliance with waste management and other requirements standards by the municipality in South Africa. These factors, therefore, became the independent variables in this research. They include awareness

of waste policy and standards, capacity may fail to comply with waste management policy standards due to lack of awareness of existence of such standards. The higher the awareness of legal framework, the length of adoption of the policy standards, the higher the likelihood of compliance by the municipality waste officers.

3.7 Sampling Methods

Effective sampling (Leedy & Ormrod 2010) was conducted from the units of analysis to ensure that the elements selected for a sample accurately represent the parameters of the population they were selected from. The study used both probability and non-probability sampling methods (Table 4), which complemented each other.

- **Selection of Municipalities**

Judgemental sampling was used to select the district municipalities to include in the study. The selection criterion was the perceived urbanization levels as indicated by the existence of major urban centres (towns, cities). Limpopo Province is made up of five (5) districts: Capricorn, Greater Sekhukhune, Mopani, Vhembe and Waterberg (Figure 4a). Based on the extent of urbanisation selection criterion, the three more urbanized district municipalities were selected: Capricorn, Mopani and Vhembe (Figure 4b). The three district municipalities that were selected contained a combined total of 14 local municipalities: Aganang, Ba-Phalaborwa, Blouberg, Greater Giyani, Greater Letaba, Greater Tzaneen, Lepele-Nkumpi, Makhado, Maruleng, Molemole, Musina, Mutale, Polokwane, and Thulamela. Out of these local municipalities, Aganang, Greater Letaba, Maruleng, Molemole and Mutaba had no major urban centres (towns). For this reason, these five local municipalities were excluded from the study, using judgemental sampling on the basis of urbanization, leaving the 9 local municipalities shown in Figure 4b.

- **Municipal Waste Managers and Supervisors**

All municipal waste managers and supervisors in the nine local municipalities that were selected were interviewed. There was one manager per local municipality, which brought the total number of managers that were used in the study to nine. The number of supervisors per local municipality ranged from three to six depending on the total number of areas supervised. There was a combined total number of thirty one (31) supervisors including the superintendent from the nine municipalities were interviewed. This number was judged as

manageable to collect data from and, therefore, no sampling was performed to select participants; the whole population of 31 was used.

Table 4: Summary of Sampling Methods that were used in the Study

Sample frame (population)	Sampling method	Sample size
Five district municipalities	Judgemental sampling	3
14 local municipalities in the 3 districts (see Figure 4a)	Judgemental sampling	9
All waste managers from 9 local municipalities	None (i.e. whole population)	9
All supervisors from 9 local municipalities	None (i.e. whole population)	31
All permanent door-to-door waste collectors and litter pickers from 9 municipalities in the study.	Simple random sampling	72
All households that waste is collected at least once per week from 9 municipalities in the study	Systematic sampling	461
All municipal disposal facilities from 9 municipalities in the study	None (i.e. whole population)	9

- **Municipal Service Workers**

Service workers included drivers, door-to-door waste loaders and litter pickers. Personnel lists for each category of service workers were obtained from the local municipality waste directorates. The staff members on the lists were coded with numbers and a table of random digits used to select a random sample of 30% for each category of workers. These were then combined into a single sample of service workers, which amounted to a total of 72.

- **Households**

For the residential areas, stratified sampling method was used in selecting households where waste is collected by the local municipalities or a private company at least once per week. Four natural groupings were identified; (i) predominantly white (ii) African townships (iii) newly established middle class formal housing and (iv) rural areas.

A numbered list of all designated residential units or blocks in each of the three clusters was obtained from the municipal authorities. Systematic sampling was then used in selecting households to participate in the study. The first step in the process was to determine the sample size. The sample size was calculated using Equation 1 (Krejcie & Morgan 1970).

$$SS = \frac{Z^2 P(1-P)}{C^2}$$

Equation (1)

Where:

SS = sample size,

Z = Z-value (= 1.96 for a 95% confidence level); the Z value represents the probability that the sample will fall within a certain distribution,

P = percentage of households where municipal waste is removed once a week ($P = 50\% = 0.5$),

C = confidence interval, expressed as a decimal (0.05 for 95% confidence level; +/- 5 percentage points).

Using Equation 1, the household sample size was calculated as follows, for the 95% confidence level:

$$ss = \frac{(1.96)^2(0.5)(1 - 0.5)}{(0.05)^2}$$

= 384 households; plus 20% of 384 (i.e. 77) = 461 households.

An additional of 20% was used as contingency for the questionnaires that might be missing. In general, bigger samples are better in terms of the three factors of representativeness, statistical analysis and accuracy. The 20% that was added to the value obtained using Equation 1 was to increase the number of respondents in municipalities that scored very small sample sizes (Bhattacharjee 2012). Although Capricorn District Municipality had the highest number of households, one of its local municipalities (Blouberg) had a very low number of households. The distribution of the 461 in the three district municipalities and 9 local municipalities under study is shown in Tables 5 and 6. Polokwane local municipality constituted the highest number (158) in the sample, with Blouberg and Greater Giyani local municipalities constituting the lowest numbers (29 each).

Systematic sampling is where every k^{th} item is selected into the sample. The first element was selected randomly so as to determine the starting point from which the every k^{th} item is selected. Every population element had to be assigned some unique numbers for easier identification (Bhattacharjee 2012). In this study each household was assigned a unique

numeric code in ascending order starting from 1 to total number of household per selected cluster (blocks, units, zones or sections) in a specific municipality and was subjected to systematic sampling household was selected. The sampling interval (k) was the value given under the Total Households per District column in Table 6.

Table 5: Household Sample Sizes for the Three District Municipalities in the Study

District	Total number of households	Proportional distribution	Number of households per district
Mopani	32751	25.3%	116
Vhembe	38706	29.9%	138
Capricorn	58077	44.8%	207
Total = 129 534		100%	Sample total: 461

Table 6: Distribution of the Household Sample Size per Local Municipality

Local Municipality	Number of households	Total households per district
LIM334: Ba-Phalaborwa Local Municipality	13817	46
LIM331: Greater Giyani Local Municipality	7412	29
LIM333: Greater Tzaneen Local Municipality	11522	41
	Sub-total 32751	Sub-total =116
LIM351: Blouberg Local Municipality	3346	29
LIM355: Lepele-Nkumpi Local Municipality	7389	40
LIM354: Polokwane Local Municipality	47342	138
	Sub-total 58077	Sub-total = 207
LIM344: Makhado Local Municipality	9998	36
LIM341: Musina Local Municipality	9406	34
LIM343: Thulamela Local Municipality	19302	68
	Subtotal 38701	Sub-total = 138
	GRAND TOTAL 129534	Total = 461

3.8 Pilot Study

The data collection instruments used were questionnaires and an observation schedule. These instruments are shown in Appendices 1-5. To test the validity of each of the instruments, a pilot study was done before the actual data collection process was undertaken in order to test the feasibility of the instruments. A small number of participants were engaged to test the questionnaires and gather information using the observation schedule prior to the actual collection of data. Five participants from Thulamela municipality were engaged in the pilot study: one waste manager, two supervisors and two service workers. All the questionnaires were administered verbally by the researcher, in a bilingual manner with the researcher asking the questions in English and then translating into the local language *Tshi-Venda* and the respondents responding in English or Venda depending on the language they were most comfortable with. Using feedback from the pilot study, corrections were effected on each of the collection instruments where necessary to improve comprehension or thoroughness of the data collection.

3.9 Ethics Considerations

The four principles of research ethics (Leedy & Ormrod 2013), namely autonomy (respect for the person - a notion of human dignity), beneficence (benefit to the research participant), non-maleficence (absence of harm to the research participant) and justice (notably distributive justice - equal distribution of risks and benefits between communities) were adhered to. The research participants were informed about the purpose of the study and their rights in the context of the first three ethics principles were stated clearly. The fourth principle of distributive justice did not arise in this kind of research. The consent to participate in the study was sought and participants were informed that participation was voluntary. However, participants were encouraged to take part in the study. They were also informed that they had the right to withdraw their participation in the study should they wish to do so at any given time of the study. The entire conduct of the research strictly adhered to the dictates of these guiding principles in order to conform to the ethical conventions of scientific research.

The safety, rights and dignity of participants was a primary concern. All information that was obtained from the study regarding individuals and organisations was kept strictly confidential and securely store in the researcher's electronic personalised and protected file. Unless prior information and explicit consent was given, research information was not presented in a manner that could potentially identify any person(s). The questions were administered within

the participating municipal offices, disposal sites and households. The Ethics Clearance Certificate obtained (NWU-00123-13-A9) is attached as Appendix 6.

3.10 Data Collection

3.10.1 Observation

An observation schedule (Appendix 5) was used for obtaining information on waste management issues first hand in the field. This included the behaviour displayed by the public, the general compliance conditions of the disposal facilities, the operation of disposal facilities and littering and illegal dumping in public places. In all the 9 local municipalities in the study (Figure 4b), municipal waste disposal sites, main roads, residential streets and open spaces were included for the observations.

The observation that was done was covert but with the permission of the municipal waste manager. Waste disposal facilities were visited three times for observations after the pilot study. Only two visits without the knowledge of the landfill service workers were made. In an attempt to be as objective as possible, the observer avoided influencing those observed. The researcher aimed at neutrality so that the researcher's presence should not affect the behaviour of those under observation. Participants were given time to get used to the presence of the researcher because disposal facilities and public places were visited only twice per week for three weeks with a one month interval in between observations. All observations took place in 2012.

Disposal facilities were visited to observe the extent to which municipal contracted companies adhered to the management, operational policy and procedure for waste disposal by landfill. Observation was also done on waste receiving, offloading and exit procedures. The observations were all conducted in the main residential and commercial streets and around illegal dump sites. The objective was to evaluate the effectiveness of the existing municipal waste programmes to reduce illegal waste disposal. In public places, two observations per day for three weeks were made, again with a one month interval in between. The observer recorded problematic areas and the conditions before, during, and after programmes to determine whether there was any improvement or whether the problem persisted even after the programme had been terminated. Reliability was established because two independent observers (the researcher and the assistant researcher) recorded information and later cross-checked the extent to which there was agreement between the two data sets.

3.10.2 Administration of Questionnaires

The questionnaires were administered using the face-to-face (one-on-one) method. The advantage of this method was that, as the participants were responding, the researcher was able to note specific reactions, clarify questions and judge when respondents were not giving honest answers.

3.11 Data Analysis

Data from the stages of the waste hierarchy was captured in SPSS (Statistical Package for the Social Sciences) for further statistical analysis. In Microsoft Excel, summary statistics were generated per question. Fisher's exact test value was computed (as in Appendix 7), because of the small sample size which was 9 municipalities' managers and 31 supervisors. Moreover, the hypothesis formulated was directional and, therefore, the Fisher's exact test was therein more suitable than the *Chi*-square value (Field 2009). When the expected frequency is too low in the *Chi*-square test, it probably means that the sample size is too small and that the distribution of the test statistics is too deviant from a chi-square distribution to be of any use. The sample size of this study was small because there were nine managers and 31 supervisors. Fisher's exact test was used because it has the assumption similar to that of a Chi-square. Fisher came up with a method for computing the exact probability of the Chi-square statistic that is accurate when the sample size is small (Field 2009). In small samples, the approximation is not good enough, making significance test of the chi-square distribution inaccurate.

3.12 Summary

This chapter has provided the details of the methodological approaches that were used in investigating the research problem. Population characteristics influenced the sampling procedures and were considered in the sampling process. Furthermore, the scope and procedures for data collection and data analysis strategies have been explained in the chapter. The research design and sampling procedures have been described on the basis of the research questions formulated in Chapter One. The variables of the study have been outlined and the research design ensured that the evidence enabled the researcher to answer the research questions clearly. Quality control measures for data collection and analysis ensured high accuracy in the collected data.

CHAPTER 4

WASTE MANAGEMENT SYSTEM AND COMPLIANCE

4.1 Introduction

This chapter first presents results on the waste management system design at the municipal level. Then the data generated from the questionnaires in Appendices 1-4 and from field observations using the observation schedule in Appendix 5 are presented. These results address objective 1, which was about waste management compliance levels. The results of analysis are then discussed in the context, first, of objective 1 and, second, of the wider research problem that was being tackled by the study.

4.2 Waste Management System Design

Table 7 is a summary list of participants identified by questionnaire respondents as role players in the waste chain in the study area, and it indicates that private companies, non-governmental organisations and individual community members are involved in the recycling and recovery of waste, with the exception of the government. Municipalities are involved in waste collection, transportation, disposal, finance, awareness and information. Technical expertise was identified as being available at government level but there were serious constraints at the municipal level, especially with respect to landfill sites. Private companies are the dominant service providers of technical expertise and municipalities where collection and landfill operations are outsourced appeared to be more efficient than the rest (detailed in Table 13) because Greater Tzaneen and Polokwane municipalities had the highest percentage in terms of compliance.

Therefore, the integration of role players (government, the sector, NGO's, and the community) helps in the effective application of the national waste management policy and the local municipality Integrated Waste Management Plan (IWMP). The system theory landscape is based in the concepts of purpose, structure, state and performance of the municipality (Nurminen & Pongracz, 2004) in implementation of the national waste policy at the local level. Solid waste management has been the responsibility of local governments. The type of service which various institutions provide is characterised into two areas: waste chain and support services.

Table 7: Institutions Involved in the Waste Chain.

	Service Provider			Individual / community
	Government	Private	NGOs	
Collection	x	x		
Transportation	x	x		
Recycling/ Recovery		x	x	x
Disposal	x	x		
SUPPORT SERVICES				
Awareness	x	x	x	
Information	x	x	x	
Technical expertise	x	x		
Finance	x			

At the municipality level, the role players in waste management include the municipality itself, households, business and institutions. The system elements covered overlapping dimensions across environment, health, social, economic, cultural, technology, demographic, production, political and legal spheres. System elements embrace prevention, generation, source separation, reuse, recovery, recycling, storage, collection, transfer, treatment and disposal of waste. Functions of these entities are carried out through management planning, applying, and operating individual and interconnected components. Proper combination of the components allows the flexibility needed to efficiently handle all forms of waste generated for a given local authority through IWMP. Waste stakeholders identified by the supervisors (Figure 6) were business, industries, institutions and households. Supervisors from all (nine) municipalities indicated that the identified role players were not playing a satisfactory role in achieving the objectives of the national and local waste management policy in terms of putting more effort towards waste prevention and minimisation.

The results also showed that very little waste in the study area was being sent to transfer stations, recycling and recovery facilities from sources of generation. All the existing recycling facilities were privately owned. The consequence of this is poor performance of municipalities in terms of compliance with the waste hierarchy policy. The only municipalities that were found to be engaging the households slightly in waste management

activities were Greater Tzaneen and Ba-Phalaborwa. Results indicate that the households were contributing to waste management by participating in community Eco clubs.

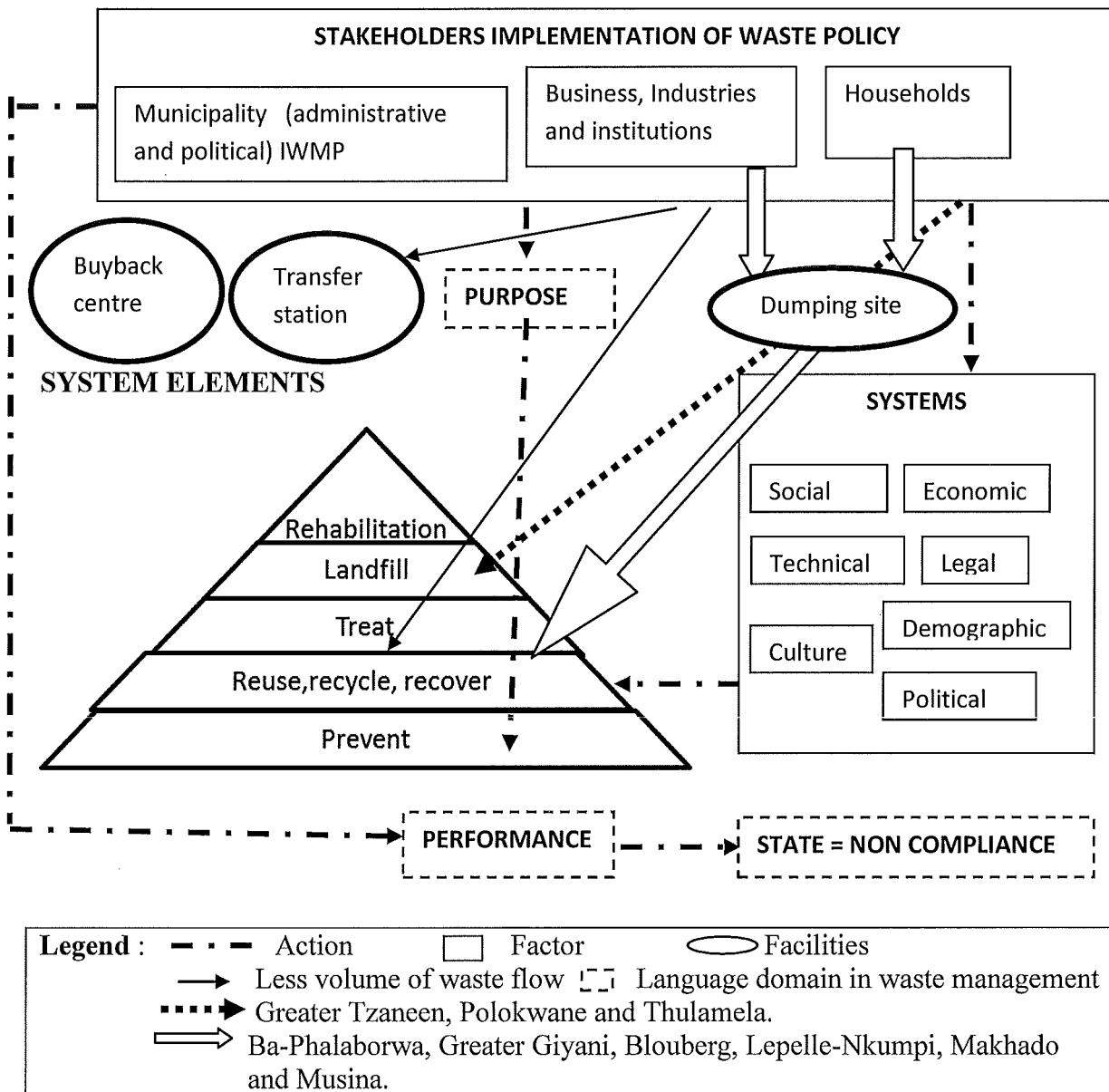


Figure 6: Analytical framework of the waste management system design.
 Source: Fieldwork.

The analytical framework in Figure 6 presents the existing waste management system design of the municipalities in the study area. The study area is dominated by participants from the informal sector who collect and recycle municipal waste. Many people work daily on the streets and in the landfills in search of recyclable materials. Therefore, there is a need for integration of the informal low-cost waste collection sector into the formal waste collection sector. This has been successful in most cities such as in Ciudad Juarez (Mexico), where

informal collectors were organised into a recycling cooperative which obtained a concession arrangement to operate from the city landfill and also in Medellin (Colombia), where they were organised into “small firms for collecting commercial wastes and for purchasing recyclable materials door-to-door” (Mariwah 2012).

4.3 Waste Management Performance

The purpose of all municipal waste management systems is to prevent and minimise waste from harming the environment and human beings by reducing the volume of waste coming to the disposal facility. The results indicate that waste generated from all households and businesses in the nine municipalities was collected at source and transported directly to the landfill and dumping sites, as illustrated in Figure 6. Very little waste is recovered by private companies and small business enterprises for recycling before it reaches the disposal facilities. High volumes of waste are recovered at the landfill and dumping sites in all the municipalities in the study (e.g. as in Plate 1). These results are evidence of non-compliance with the IWMP requirements and waste hierarchy that call for the least volume of waste reaching a disposal facility.



Plate 1: Recovered Waste from Disposal Facility in Greater Giyani and Ba-Phalaborwa.

Source: Fieldwork (2012).

Responses from the supervisors consistently projected the view that one of the reasons preventing better performance in waste management was the lack of integration between the municipal waste directorate, private service providers and informal operators. The results with regard to the relationship between the municipalities, businesses, households and institutions were that municipal structures were not a coordinated and enabling waste management environment. None of the municipalities kept actual records on the operations of private recycling companies within their area.

The responses from waste managers indicated that only three municipalities (Thulamela, Greater Tzaneen and Ba-Phalaborwa) recognised waste prevention as a priority. The remaining six municipalities were giving it a low ranking in both planning and operations. This means low levels of effort towards waste prevention. Thulamela was observed to have colour coded bins at designated public places but this was fruitless because the bins had no separate divisions inside (see Plate 2). The study consequently infers that commitment given to waste prevention and information dissemination to the stakeholders was not adequate to achieve the goals of waste hierarchy. The significance of these results to the study is that they bring the idea of establishing service level agreement between the municipality and other waste role players. Municipal monitoring and supervision of project specifications and implementation of standards by the service provider should be adhered to in order to avoid failures in project output.

Figure 7 shows the materials recovered in the study area by the recyclers for sale. Glass bottles are the main material which was recovered in all the municipalities in the study. Bottles are crashed manually and packed in 1 tonne bags. Plastic bottles and card boxes are second from glass as the main recovered material. From observations made at Lepelle-Nkumpi Local Municipality's disposal facility there were many plastic bottles that were not collected, maybe because there were no middle men to transport the material to Gauteng Province. The least reclaimed material was paper, because only three municipalities were reclaiming white papers and these were Thulamela, Ba-Phalaborwa and Greater Tzaneen. All these recovered materials were eventually sent to the market in Gauteng Province. This was a clear indication of the lack of institutions for paper recycling in Limpopo Province. There was no active recycling plant identified in Limpopo Province; the only identified infrastructure for recycling was waste compaction sites. The significance of the variable is that reclaimed materials destined for the recycling facilities reduce the volume of waste going

to the landfill. Furthermore, there could be creation of jobs for operators and income generation when recyclers send the materials to the buyback centres. Distance to the recycling plant is jeopardising economic potential from the recovered items. Lange et al. (2014) present similar results about distance playing a major role for recycling potential than recycling intention.

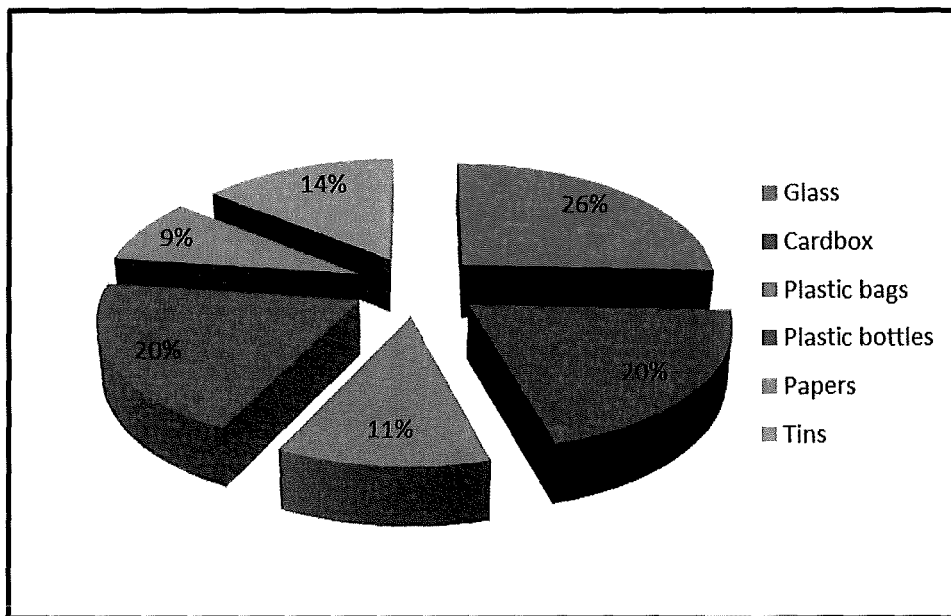


Figure 7: Recyclable items.
Source: Fieldwork.

4.4 Delivery System Structure

The appropriate municipal waste management system components for implementing waste policy and IWMP that were identified from the study were managerial capacity and technical capacity. Figure 8 shows the levels of education of municipal staff. In all nine municipalities in the study area the waste management division was being run by either a senior community services general managers or a director who was in charge of many other divisions such as sports and recreation, waste and environment, and traffic and horticulture. This varied according to the municipality. The responses from the supervisors and managers showed that 55% of the managers and 54% of the supervisors had the requisite tertiary qualifications for waste management. The results suggest that there is improvement in staffing since 2000 through capacitating municipalities with appropriately trained personnel. In Musina, Thulamela, Makhado and Lepelle-Nkumpi Local Municipalities there were no sufficient capacity appointed for the positions. The person responsible for waste management in those municipalities occupied senior management positions in other sections. Clearly, this would

appear to indicate a serious constraint in the skills base of the waste management directorates of these municipalities. According to the IWMP each municipality should have a Waste Manager and a Waste Officer. The conditions on the ground are far from this ideal, once again, pointing to the issue of non-compliance. In Figure 9 waste managers from the study area proposed more effective municipal waste management organogram is presented, based on the short-falls identified in the study area.

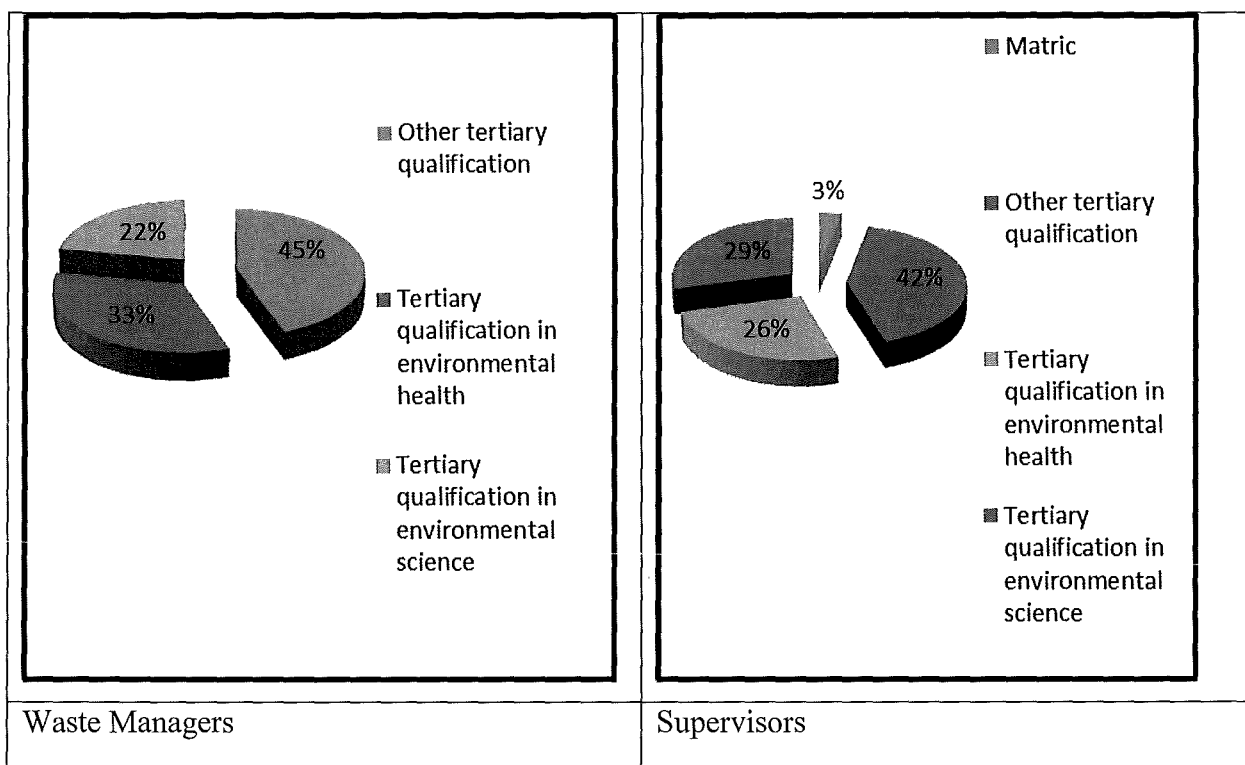


Figure 8: Education levels of waste management personnel.
Source: Fieldwork.

Responses from supervisors revealed that almost all the municipalities studied were restructuring their waste line management organogram. These included Greater Giyani, Blouberg, Ba-Phalaborwa and Polokwane Local Municipalities. These municipalities were restructuring their systems into two focus areas: operations and awareness. The existing waste line management was not appropriately structured to address the requirements of the IWMP in terms of human resources. Some municipalities were doing well because of their working experience in this regard. Waste managers further indicated that they attended relevant short courses and seminars to improve their technical skills.

Responses from service workers showed the dominant age group in the 20-49 groups, accounting for 61% of all service workers. Furthermore, responses from the service workers

that were interviewed indicated that 78% never received any training relevant to waste handling. A well trained labour force is critical in achieving performance efficiencies. The performance of municipalities may be handicapped by constraints arising out of a poorly trained labour force. These findings correspond with those by Jamasb & Nepall (2010) who state that municipalities often have limitations in capacity to ensure compliance. Waste management specialisation is an area that overlaps between environmental health and environmental sciences.

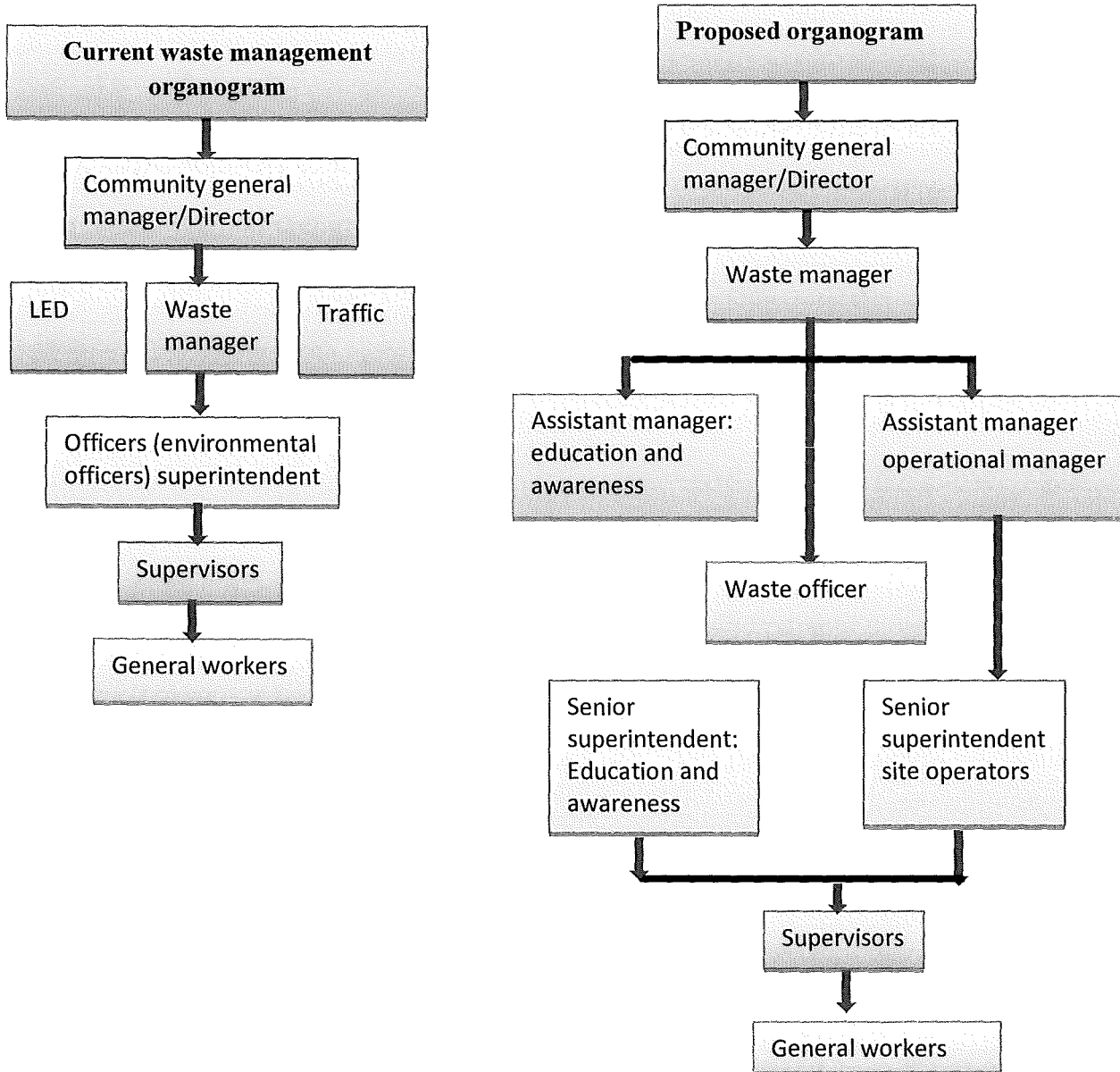


Figure 9: Proposed Waste Management Directorate organogram.

Source: Fieldwork.

One of the major reasons for the inadequate personnel base is the issue municipal finance. But even at the best of times, the service has been unable to attract the right people (particularly at the technical level). This finding concurs with Mahasa (2013) who report constrained budget allocations for waste management in the Free State province, South Africa. Overall, these results point to internal organisational weaknesses linked to the technical skill base of senior management responsible for municipal waste, inadequately trained service workers, problems of integrating the activities linked to waste service delivery, limited control over the activities of private waste recyclers, and priority allocated to waste management at the municipal level. These have a cumulative impact on the status of compliance.

4.5 Policy Documents

Data on availability of policy documents was collected from municipality waste managers using the questionnaire in Appendix 1. Waste policy documents constitute the key sources of information for the key elements of, control, support and intervention strategies at the level of individual municipalities. The responses from the managers indicated that only two municipalities, Thulamela and Greater Giyani, had up-to-date IWMP documents. The responses showed that these two local municipalities had received financial and technical support from *Indalo Yethu*, an independent trust fund of the national Department of Environmental Affairs (DEA).

About 78% of the municipalities (Makhado, Musina, Blouberg, Lepelle-Nkumpi, Polokwane, Greater Tzaneen and Ba-Phalaborwa) reported that they were developing their IWMP and confirmed that they were relying on the already existing district IWMP as a guide. The IWMP from the seven municipalities was supposed to be in place by 2010 before the IDP document, so that the items that needed consideration are incorporated in the 5 years IDP document of 2011-2015. However, the municipal IDP document is reviewed every year in order to accommodate pressing issues within a year instead of waiting for the cycle of five years. Municipalities delay in developing and implementing an IWMP at local level, which affects waste management efficiency. The responses showed inherent problems of capacity at the level of individual municipalities, which in turn undermines movement towards waste management. The effect of not having an IWMP is that there will be no proper implementation of the waste hierarchy and the target of zero waste will be difficult to achieve. In place of the IWMP, municipal waste by-law documents existed in all the

municipalities in the study area but they were not effective. In the absence of the IWMP waste by-laws cannot be aligned properly with the national waste policy. The responses from the managers further showed evidence of inadequate implementation and this confirms difficulties in succession planning. Availability of an IWMP is an indication of a waste management directorate that can achieve development, because it can attract funds from the external donors.

The findings from the responses are supported by results of Fisher's Exact Test with respect to hypothesis 1, which states that municipalities with an integrated waste management plan (IWMP) are more likely to comply with the national waste management policy of 2008. The null hypothesis stated that municipalities with an IWMP are less likely to comply than municipalities without an IWMP. Fisher's Exact Test results, shown in Table 8, indicated a *p* value of 0.002 which is less than 0.05. Therefore the null hypothesis was rejected and the alternative hypothesis accepted. There is, consequently, clear evidence of an association between availability of an IWMP in a municipality and compliance with the national waste policy.

Table 8: Fisher's Exact Test on Compliance and IWMP.

	Value	df	Asymp. Sig. (2- sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	9.644 ^a	1	.002		
Continuity Correction ^b	7.160	1	.007		
Likelihood Ratio	12.390	1	.000		
Fisher's Exact Test				.002	.002
Linear-by-Linear Association	9.333	1	.002		
N of Valid Cases	31				

^a 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.39.

^b Computed only for a 2x2 table.

The IWMP document contains information about gaps identified in the implementation of the waste management hierarchy and alternatives to bridge the identified gaps. Additionally, it contains goals and objectives, short term, medium and long-term targets together with implementation strategies. Therefore, a municipality with an IWMP, such as Thulamela, is more likely to comply with the national waste policy because an IWMP's goals and objectives are aligned with the national policy. Further, it makes integration of waste management specified targets to be integrated into the municipal master plan, which is the Integrated Development Plan (IDP).

None of the municipalities in the study area had a waste hierarchy guide to assist them with operations and management of the system. A well quantified and measurable policy requirement such as the waste hierarchy guide with quantitative measures helps to eliminate common misunderstandings of policy requirements. Specification is critical in identifying expectations and establishing boundaries. In an earlier work (Mudau et al. 2013) the need for quantifiable parameters for waste management is emphasized. Clear procedures actually allow managers to control compliance in advance and prevent the municipality from making costly mistakes. Lack of policies and procedures promote non-compliance with the waste hierarchy and inconsistency in day-to-day operations. The results further communicate lack of clarity to waste practitioners when dealing with accountability of activities that are of critical importance to the municipality, such as legal liabilities, regulatory requirements and serious consequences to the environment and human health. The slow pace of national policy, and its slow adaptation and implementation at local government level impedes achievements of national policy expectations.

4.6 Compliance and Enforcement

Responses from managers indicated an inability to establish, implement and maintain required documents, contributing to non-compliance with legal and managerial requirements. These results are agreeable with those by Godfrey & Oelefse (2008), who stated that in South Africa non-compliance by local government remains a challenge and is due to inappropriate human resource capacity.

Understanding the requirements and implementing the waste management policy, with reference to compliance and enforcement, is important. This is because waste prevention and least disposal are driven by municipal waste management compliance and enforcement

documents and their implementation. Compliance and enforcement referred to adherence to the Waste Management Policy Act number 59 of 2008. It included compliance with both the waste collection standards and waste sector plans as part of the stages in the waste hierarchy that form an integral part of an IWMP. A compliance control document, supplemented by a waste hierarchy guide, is essential for the optimal performance of a municipality. Furthermore, these documents identify the key activities and provide a general strategy to decision-makers on how to handle issues as they arise. This makes them a strategic link between the waste management goals and day-to-day operations. Therefore, it is important to understand and interpret national policy at local level because well drafted policies such as waste by-laws and an Integrated Waste Management Plan (IWMP) let the end users understand their roles and responsibilities within predefined limits. This allows management to guide operations without persistent management intervention.

Responses from supervisors indicated that only two municipalities (Thulamela & Greater Giyani) out of the nine municipalities were slightly complying with respect to being in possession of an operational IWMP. With respect to the existence of an operational waste recycling facility, five municipalities (Greater Tzaneen, Ba-Phalaborwa, Makhado, Polokwane and Thulamela) out of the nine partially met compliance requirements. None of the municipalities had both an IWMP and a recycling facility. All the identified existing solid waste recycling centres in the study area were privately owned, and they acted as buyback centres where people were free to deliver specified recyclable materials in exchange for money.

Compliance level was assessed based on the following: availability of an IWMP, existence of a landfill licence for the existing (operating) disposal facility, compliance and enforcement, waste by-laws, existence of education and awareness programmes, adequacy of waste management capacity, and recycling activities. All of these assessment criteria are requirements in waste management legislation and, therefore, are elements that direct the waste hierarchy and inform the development of the goals of the national, provincial and local government waste management and operation policies. Compliance scores were arranged on an interval (ascending order) scale from level 1 (best) to 7 (least) in terms of compliance. The municipalities that scored the least compliance level, at position 6, and with 15 – 30% compliance levels, were Blouberg, Lepelle-Nkumpi, Makhado, Greater Giyani and Musina.

Ba-Phalaborwa was at level 5 with a compliance level interval of 30-45%, Greater Tzaneen was 4th (46 – 60%), Polokwane 3rd (60 75%), and Thulamela 2nd (76 – 90).

Supervisors were asked to provide explanations as to their low level of compliance. Results showed that 52% reported the absence of an IWMP in the municipality, while 29% believed that lack of human resources and technical skills were a major cause. Only 19% claimed that a heavy workload due to under-staffing made it difficult for them to develop IWMP's. At a second level, the responses from supervisors showed that lack of enforcement procedures (54%) and the lack of institutional capacity (56%) jointly contributed to poor waste management enforcement. The three main challenges to effective enforcement of waste by-laws in all local municipalities in the study area were lack of an enforcement structure, lack of penalty information and dissemination and, lastly, delay in national policy adaptation and implementation at local level. Lack of monitoring of policy implementation by the province within the time frame was not considered a priority.

In spite of these results that painted a gloomy picture, the responses on enforcement as a high priority in municipal waste management provided mixed results. Almost 44% of supervisors stated that enforcement is slightly regarded a priority while 56% indicated that enforcement is not a priority at all. In addition, managers' responses indicated that prioritisation of preventing and minimising waste information was low and all municipalities in the study admitted that they had not disseminated information on waste liability to the public. The results on the level of prioritisation raise issues about the integration of municipal management with local politics and governance which in turn impacts on resource allocations through the annual budget. This is similar to the findings by Bosman & Boyd (2008) who alleged that political interference is one of the issues that hinder virtuous practice of local municipalities. Protection of the environment and good practice of waste management could be attained by compliance with environmental laws and other requirements. The purpose of compliance and enforcement is to achieve effective waste management in accordance with the legal requirements.

4.7 Summary

On the basis of the results and discussion in this chapter, objective 1 has been addressed. This objective centred on the compliance of the existing municipal waste management systems with the national waste policy and the IWMP. The results highlight the importance of

designing policy compliance requirements. This helps the institution in mitigation of penalties in the event of breach of national policies and further protects human health and the environment by improving the public's behaviour towards the environment through regulatory and non-regulatory means.

CHAPTER 5

THE MUNICIPAL WASTE CHAIN

5.1 Introduction

This chapter presents results and a discussion addressing objective 2 which focussed on the analysis of the waste management conveyance belt. The core aspects of the waste hierarchy (Figure 1) are avoiding and minimising waste during production, reusing, recycling, recovering, handling, storing, collecting, transporting, and the disposal and remediation of waste. The chapter is presented within two frameworks: the waste hierarchy and process mapping.

The waste hierarchy is a useful framework that has become a cornerstone of waste management in South Africa. It sets out the order in which options for refuse management could be considered based on environmental impact. All waste role players must apply the waste management hierarchy in making decisions on how to manage waste. The annual performance report which must be prepared in terms of Section 46 of the Municipal Systems Act maintains that municipalities should have information on the implementation of the municipal integrated waste management plan. Institutional arrangements and service delivery play a major role in compliance and enforcement of the Waste Act of 2008. National waste collection standards, among other things, include storage of waste on the premises of waste generators, transportation and the disposal facilities.

5.2 Application of the Waste Hierarchy Principles

Operational procedures and checklists of each stage of the waste hierarchy was one of the assessment criteria in determining municipality compliance with waste legislation and in assessing delivery of the waste management service. None of the municipalities in the study had a checklist for monthly operational management of the existing waste recycling facilities. Therefore, it is difficult to determine operational performance and how it integrates with other processes. From the field observations and responses from the supervisors there was no evidence to show proper internal system networks for waste processes to lead to adherence to the waste hierarchy. No adherence to the waste hierarchy was observed in the municipalities during the field work to assess the components of municipal waste management system design. Couth and Trois (2012) identified a similar situation in their study, and they state that

most municipalities in South Africa require extra assistance with illustrative and operative sustainable development mandates. The field work in Limpopo Province established that the waste handling process was traditional in nature because waste was generated and transferred directly to the disposal facilities, as shown in Figure 10.

Hypothesis 2 states that the existence of an operational waste management plan enhances the effectiveness of waste management in the municipality. The null hypothesis was that there is no relationship between waste management efficiency and the availability of an operational waste management plan. Fisher’s Exact Test in Table 9 confirms the relationship between compliance and the availability of a waste management operational plan. The *p*-value of 0.00 leads to the rejection of the null hypothesis. An operational plan is a management tool that can be audited internally in order to inform the management about the performance of waste management directorate in relation to waste legislature and other requirements.

Table 9: Fisher’s Exact Test on Operational Plan and Waste System Efficiency.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	27.231 ^a	1	.000		
Continuity Correction ^b	23.593	1	.000		
Likelihood Ratio	35.336	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	26.353	1	.000		
N of Valid Cases	31				

^a 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.77.

^b Computed only for a 2x2 table.

5.3 Process Mapping Framework

Figure 10 shows a waste management process mapping that summarizes the waste management chain in the municipalities in the study area. The process map shown is a systematic design of the flow and delivery mechanism of municipal waste, paying attention to the stages within, the linkages across and the imbedded constraints and efficiencies therein.

Process mapping allows for analysis of details in search of bottlenecks that interrupt the interaction of system functions. Applied to the municipal waste chain, it becomes an appropriate vehicle for tracing the movement of waste from source (generation) to final disposal. Multi-disciplinary in its usage, it is commonly associated with project management, waste management, manufacturing processes and in civil engineering works. The waste process mapping that was derived by this study (as in Figure 10) is in line with findings in China by Yuan and Weng (2014), who reported that tracking and depleting the value flow cycle of the elements provides useful information for decision makers.

PROCESS MAPPING

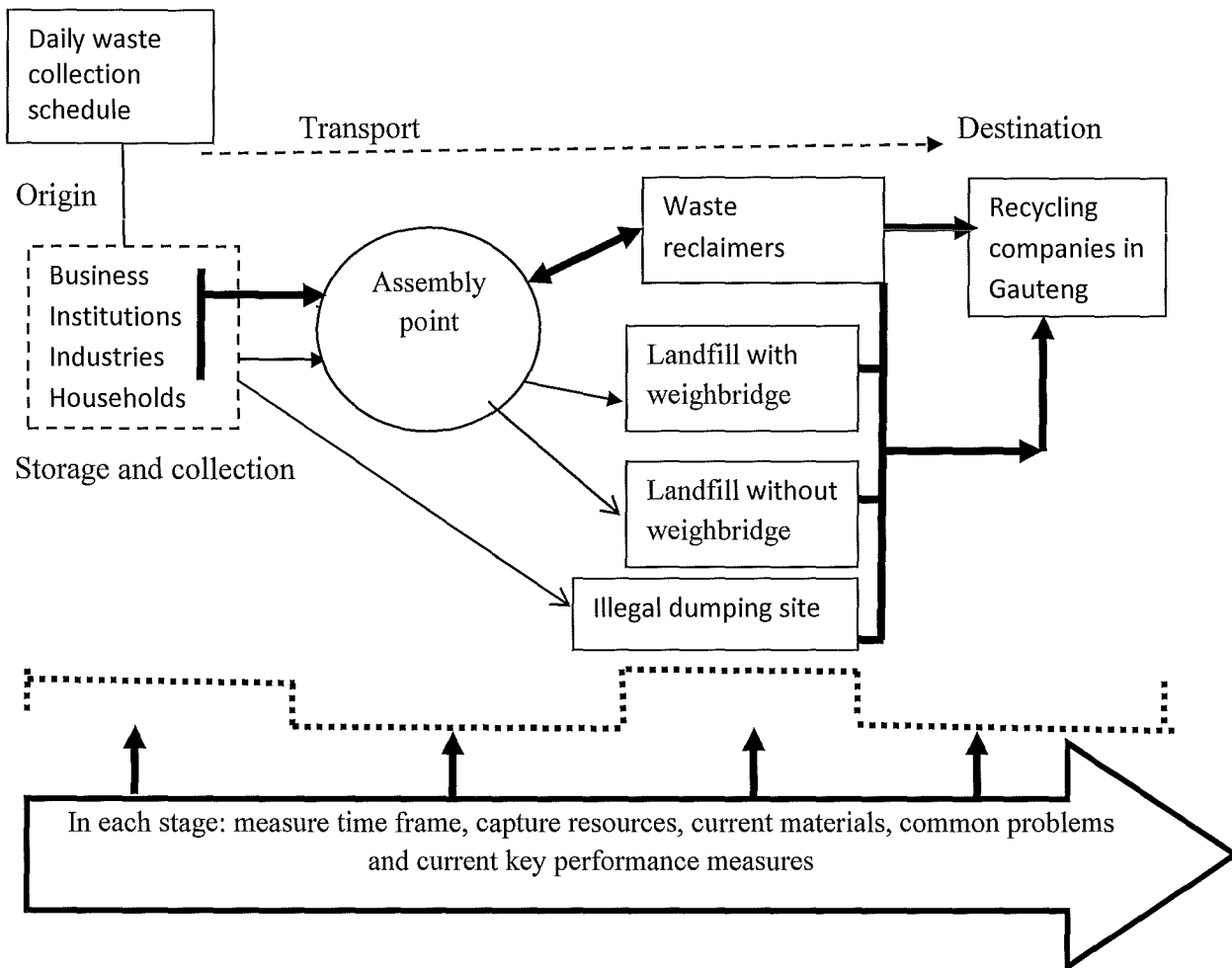


Figure 10: Waste process mapping for municipalities in the study area. Source: Fieldwork.

5.4 The State of Components of the Waste Hierarchy

5.4.1 Waste Prevention and Minimisation

From the household questionnaires, almost 63% of respondents said that they were definitely willing to separate waste at source always, whereas 33% of the households said they may separate it sometimes (Figure 11). Almost 56% of the household indicated that the most common information known by them about waste management was “do not litter” instead of prevention and minimisation. Households respondents who acknowledged that there was dissemination of information about waste prevention constituted only 13%. Additionally the field observations identified that in Thulamela Local Municipality, there were colour coded waste bins in one of the streets in town (Plate 2). The colour coded bins did not have different compartments inside but outside, the message was to separate waste at source and this was an indication of giving a wrong message to the public .

The significance of the results is that the element of monitoring of projects by municipalities is important. Municipalities may also specify the right type of colour coded individual waste bins or communal skip bins to encourage separation at source. This is possible if there are arrangements for separate transportation of sorted waste to the waste processing facilities. All the municipalities in the study area had a new landfill site with a building plan that included a buyback centre on site. Re-usable and recyclable waste can be reclaimed before the waste reaches the landfill site. In order to ensure maximum diversion of re-usable and recyclable waste from ending up at the landfill, a wide range of re-use and recycling programmes, including composting should be initiated.

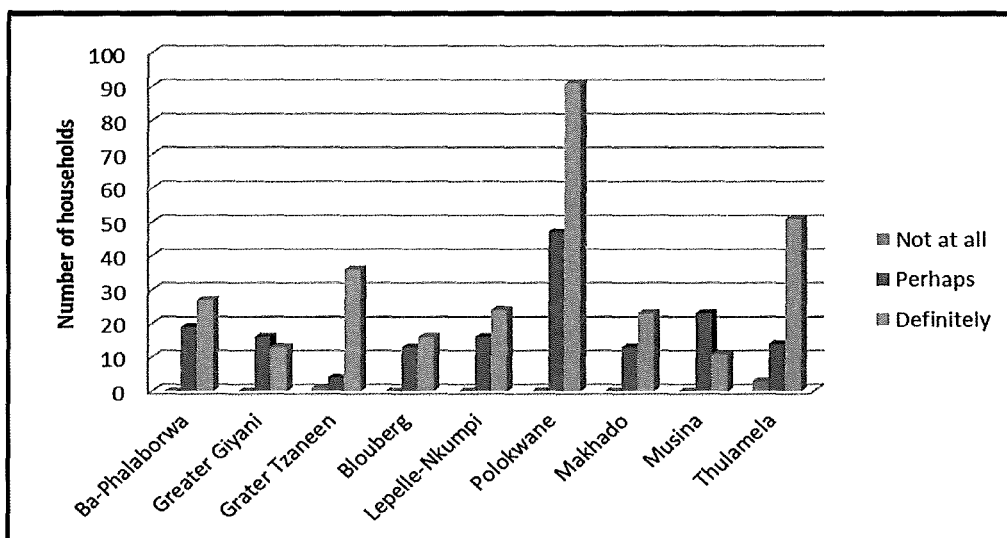


Figure 11: Household response on sorting waste at source.

Source: Fieldwork.

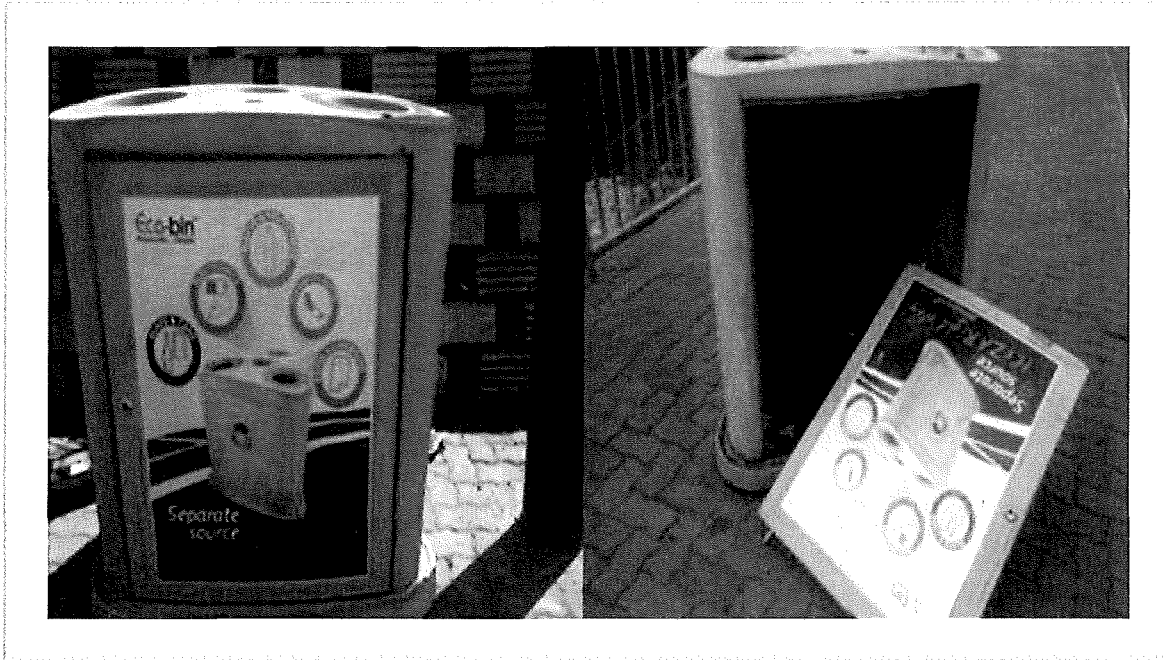


Plate 2: Colour Coded Waste Bins at Thohoyandou (Thulamela Municipality).
Source: Fieldwork (2012).



Plate 3: Recycling Facility in Ba-Phalaborwa Municipality.
Source: Fieldwork (2012).

Although recycling will not eliminate the need for landfills, a waste management system that includes recycling will certainly extend the life of existing landfills and decrease the total amount paid by municipalities in tipping fees. Planners should secure markets for recyclable materials before a recycling program is implemented to avoid storage and handling problems by recyclers. At present, composting of waste is done but the volumes are insignificant. Quiros et al. (2014) report that in European countries, at least 40% of the biodegradable waste still ends up at landfill sites. This suggests that composting as a waste management activity is still not common in both developed and developing countries. If composting could become more common, a significant portion of the waste stream would be diverted before reaching the landfill. Ba-Phalaborwa, Polokwane and Makhado Local Municipalities each had an effective compaction and preparation plant for card boxes; plastics and paper for recycling (e.g. see Plate 3). A private company then collects the materials for delivery to factories in Gauteng Province. This is an indication of lack of recycling facilities in the province. Garden waste that is collected from households and business areas is turned into compost. Composting of garden waste was well established in Phalaborwa and Polokwane municipalities.

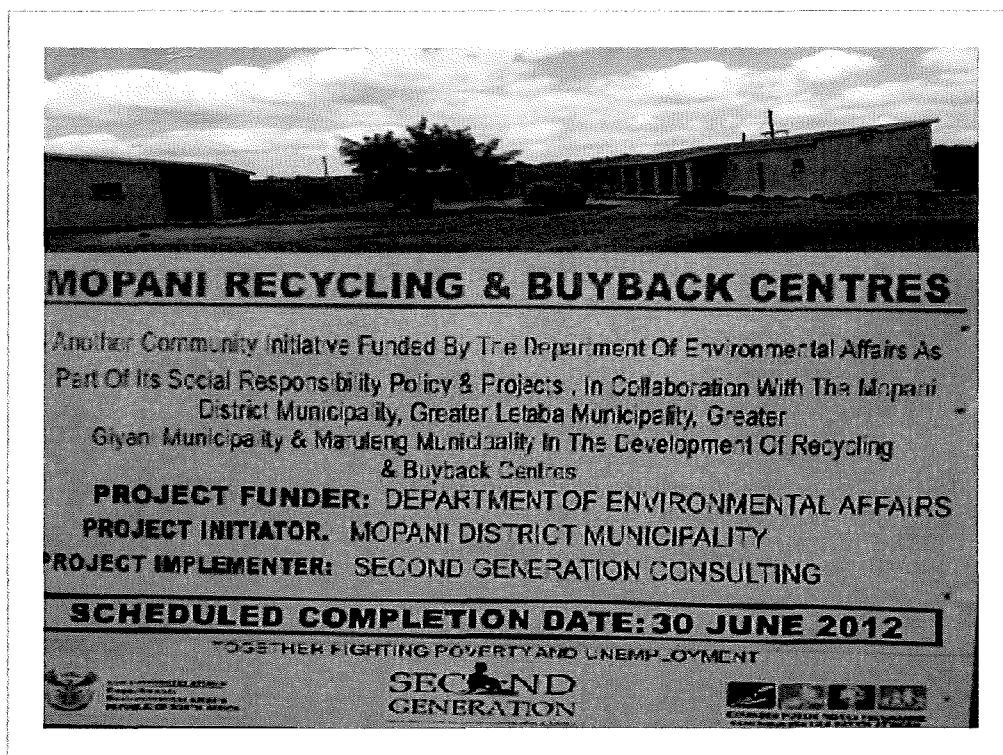


Plate 4: Mopani Buyback Centre at Giyani.
Source: Fieldwork.

In Phalaborwa readily available water, electricity, and sludge assist to turn organic waste into usable clean compost that is sold to the public. Communities are also engaged in composting kitchen waste for use in vegetable gardens. Preparation for waste minimisation was underway in Mopani district; at the time of data collection it was the only district with a buyback centre structure which was almost complete (Plate 4). In Vhembe and Capricorn district municipalities, plans to construct buyback centres were in place but there were still delays in starting the actual construction. The implications of the results were that the bulk of the waste was still taken to landfill sites rather than being taken to recycling facilities.

Hypothesis 3 states that municipalities with recycling facilities have higher compliance with waste management legislation than those without recycling facilities. The null hypothesis stated that there is no relationship between recycling facility availability and compliance with waste management legislation. The *p*-value for the association between recycling facilities and compliance (Table 10) was 0.033 which is significant. The null hypothesis is, therefore, rejected. The inference is that when there is a recycling facility or a buyback centre within the municipality's jurisdiction more waste is likely to be diverted of generation to the recycling facilities. The probability of households sorting waste at source is likely to increase in these circumstances as a result. Recycling facilities can be owned by the municipality. However, at the time of this study all the recycling facilities were privately owned and based only in urban areas.

Table 10: Fisher's Exact Test on Compliance and Recycling Facilities.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
	Value	df			
Pearson Chi-Square	4.973 ^a	1	.026		
Continuity Correction ^b	3.172	1	.075		
Likelihood Ratio	7.220	1	.007		
Fisher's Exact Test				.033	.029
Linear-by-Linear Association	4.813	1	.028		
N of Valid Cases	31				

^a 2 cells (50.0%) have expected count less than 5. The minimum expected count is 2.48.

^b Computed only for a 2x2 table.

Separation of waste at source could be encouraged to improve the quality of recycling material. This could be done by raising public awareness and educating all producers of waste. Provision of waste separation receptacles is very crucial to encourage separation at source. Municipalities could make use of colour coded waste bins or different plastic bags for recyclable materials. The collection schedule for recyclables could be set up by the municipality.

Responses from the households showed that there was an urgent need to educate people about the different types of waste and how to separate them. Education and awareness can contribute to the improvement of the working conditions of the waste collectors and can create a clean environment for all. This is supported by Wagner & Arnold (2008). Greater-Tzaneen and Ba-Phalaborwa were the only municipalities that had eco clubs and this contributed to better waste management practices. In Ba-Phalaborwa Local Municipality adoption of schools into eco-club programmes was in conjunction with the provincial Department of Local Economic Development and Tourism.

These results in Figure 11 are an indication of the commitment of households to reduce waste before it is transported to the recycling facilities and disposal sites. In rural areas door to door collection of recyclables might not be practical however the municipality could make use of two-bags system; one bag for recyclables and another bag for general waste.

5.4.2 Waste Generation

None of the municipalities in the study area kept records on waste generation as per the different generators of waste (institutions, households, businesses and industries). Data generated from the managers' responses and the field observations indicated that the type of waste generated was general waste that included paper, glass, plastics, tins, garden waste, building materials and food. Polokwane and Greater Tzaneen were the only municipalities with waste weighbridges. Waste data for Thulamela and Makhado were simple estimates. The two municipalities simply relied on service workers who counted the vehicles that disposed of waste at their landfill sites and the estimates were based on these counts. The field observations, however, showed that such records were crude and could not be used to compare waste volumes delivered at landfill sites across the study area. Medical waste was collected by private contractors' at all provincial hospitals, private medical practitioners, veterinary clinics, mortuaries and medical laboratories. Contractors transported the medical

waste from different municipalities to Tshwane Metropolitan Municipality where they were incinerated. At the Tzaneen landfill site, it was observed that there was a temporary storage facility for medical waste.

From the official municipal records type of waste and volumes generated and reclaimed varied across the different local municipalities. The local municipality that generated the highest amount of waste was Polokwane. This municipality had the largest urban centre (Polokwane city; Figure 4b) by population size. Records from Polokwane Local Municipality indicated an increase in the volume of waste generated between 2008 and 2012 (Figure 12). In 2008 the volume of waste was 207 000 m³, then 225 000 m³ in 2009, 252 000 m³ in 2010, 270 000 m³ in 2011, and 315 000 m³ in 2012.

Waste data for Ba-Phalaborwa and Musina local municipalities (both Class B3 municipalities; Table 2) were not available during data collection. Both local municipalities had very small towns. Figure 13 illustrates the annual waste generated by the Class B4 local municipalities in the study area. The data on waste generation depicted in Figures 12 and 13 was collected from the waste managers. It can be inferred from the waste generation results that there was no intervention in terms of waste reduction in all the municipalities. The calculated rates of increase in waste generated per annum ranged from 6% to 9% between 2008 and 2012 (Figure 14). The effort to achieve the Polokwane Declaration of zero waste by 2020 implies that municipal capacity planning should be considered in order for proper technical management to be achieved. Waste data from Blouberg and Lepelle-Nkumpi local municipalities were not available because the two municipalities were not recording waste disposed of in their facilities. Data on increase in waste volume levels helps to inform waste management decision makers in planning for the flow of waste in the chain. Godfrey et al. (2012a) state that it is crucial to have waste data as it has a significant impact in building knowledge.

5.4.3 Waste Storage and Collection

The by-laws of each municipality stipulated a requirement of a storage bin. It was the responsibility of the households to place rubbish bins or plastic bags outside of their homes (next to the street) for subsequent collection. From all the municipalities in the study, household waste was collected once per week on a specific day for each suburb, block or unit. Waste in the central business district area was collected on a daily basis.

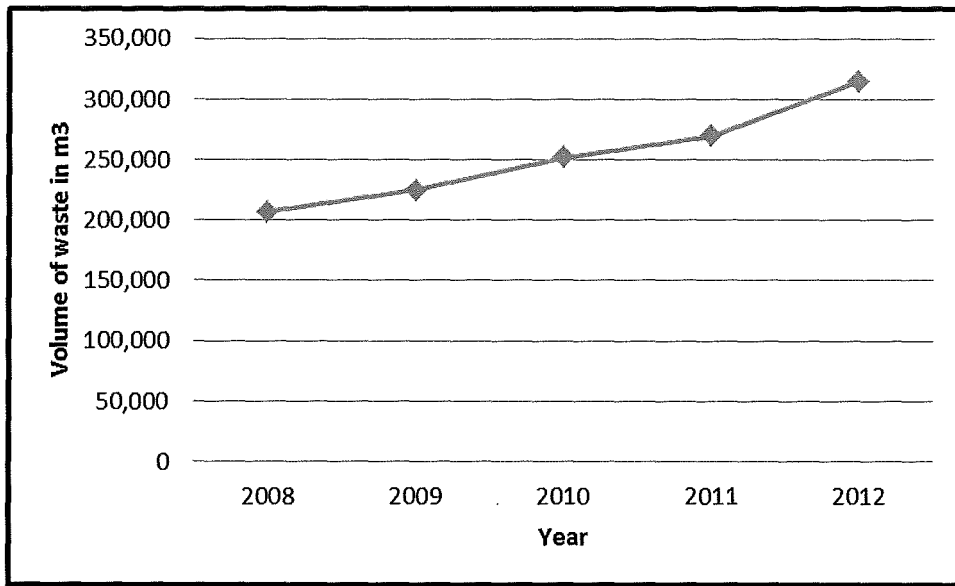


Figure 12: Volume of waste generated by Polokwane Local Municipality, 2008-2012.
Source: Fieldwork.

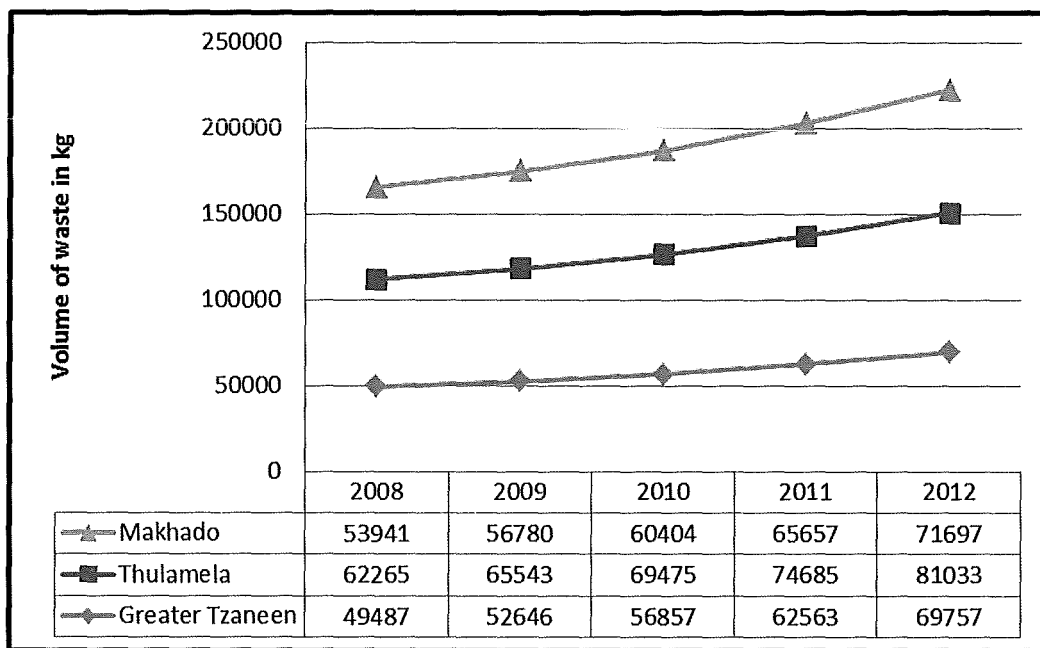


Figure 13: Waste generation by Category B4 Municipalities in the study area, 2008-2012.
Source: Fieldwork.

It was observed that each compactor truck had an average of 3 to 4 service workers, two service workers collected waste from one street and put the refuse plastic bags in one place along the road at the interval of four to six households. This procedure was practiced in Tzaneen, Polokwane (see Plate 5), Makhado and Ba-Phalabora. It was observed that this

saved time as compared to a truck that stops and loads waste refuse bags at each household. At the collection points, service workers in all the municipalities stated that they preferred refuse plastic bags because they were easier to load than metal or plastic bins. From the observations, it was noted that waste collected from households, businesses and institutions was mixed waste and it was creating difficulties for the reclaimers to collect recyclable waste at the disposal facilities.

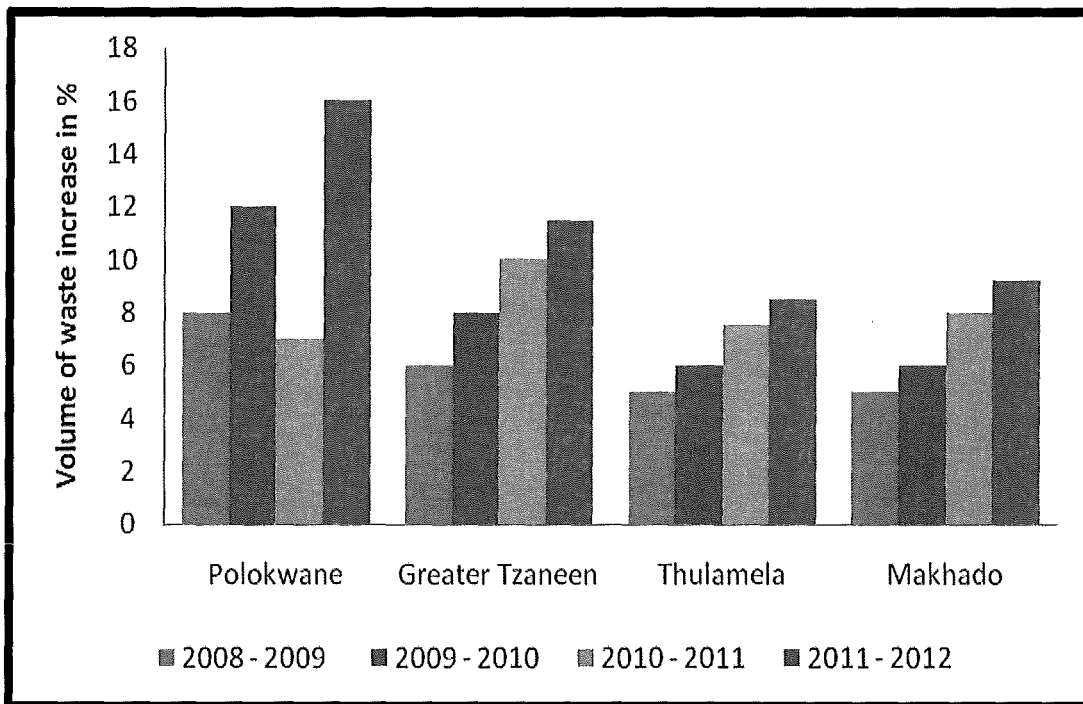


Figure 14: Increase in waste generation for four local municipalities.
Source: Municipal Reports (2012).

The waste conveyance belt from the businesses and institutions made arrangements with waste reclaimers who collected waste directly from their premises. In some municipalities, litter pickers, mainly in town, separated waste from the shops' temporary storages (cades), particularly plastics and cardboard. Poor enforcement of the waste collection policy was also influencing households to use receptacles that were not specified in the municipal by-laws. The responses from the waste managers showed that enforcement of waste collection by-laws remains poor. The practice of imposing penalties on offenders was almost non-existent and Makhado was the only municipality that was providing each household with two plastic refuse bags. This created uniformity, as the bags were easy to load into trucks.



Plate 5: Household waste collection point in Polokwane.
Source: Fieldwork (2012).

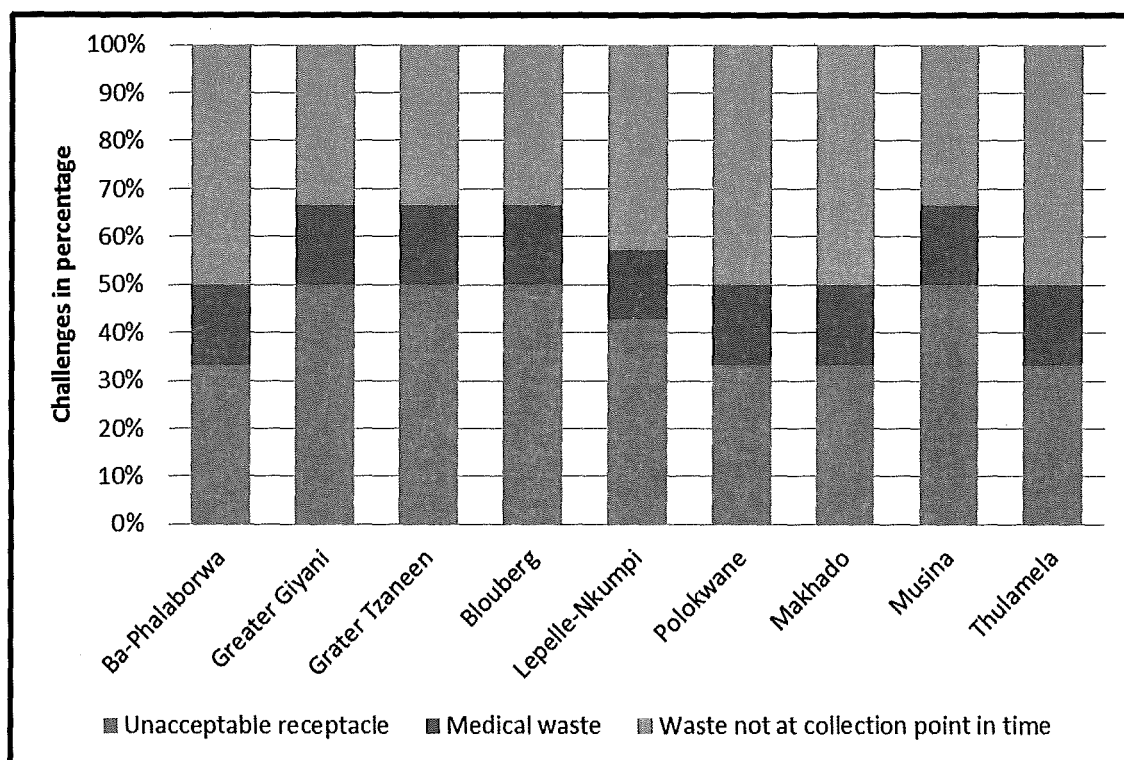


Figure 15: Summary of challenges faced by waste collectors.
Source: Fieldwork.

Service workers pointed out that it appeared that their visibility in public places made the public to believe that littering was not wrong since there were people paid to pick up the waste. The workers stated that this was the main challenge that they faced. However, in some areas, there were very few or no facilities to dispose of waste, which contributed to the littering. The results highlight the importance of penalty enforcement. Municipalities could take in making available colour-coded waste bins with different compartments to avoid littering and to promote a clean environment. Door-to-door waste collectors reported that they encountered problems with torn plastic bags due to large amounts of domestic waste. The most dominant challenges faced by waste collectors in the study area are indicated in Figure 15. They include unacceptable receptacles, and waste bins which are not at the collection point in time. The least challenge was medical waste from households; this waste was generated by community members who were using syringes for insulin, and other medications. But this response by the waste collectors is problematic because it may in fact indicate their low levels of risk awareness. Ball (2000) indicated that other parts of the developing world have similar low levels of risk awareness by different categories of medical workers in hospital settings. Service workers further indicated that in some municipalities, there were general practitioners within the residential areas, who sometimes mix their general waste with medical waste.

Based on results from the study area residents of core urban areas have relatively better access to refuse removal services while those in peri-urban and rural areas have limited access to these formal services. Waste service backlogs were identified during field observations in all the municipalities in the study area. This has an effect on the quality of life, the environment and human health. All managers reported low levels of waste service coverage and that urban growth was seriously out stripping waste service capacity.

Greater Tzaneen is an example of municipalities which are complying with the waste regulations better than other municipalities in the study area. From the field observations Greater Tzaneen was managing waste collection well because collection was by a private company that had four transfer stations at Nkowankowa, Letsetele, Lenyenye and Hannesburg (Plate 6). Given that the track record of South African municipalities in service delivery has generally been unimpressive since 2000, it is understandable why a private contractor appears to be doing better than formal local municipalities. Underlying this, however, is the fact that private business is driven by the profit motive and the desire to attain

high efficiencies in order to lower operational costs. Such circumstances do not apply to local municipalities, where the work ethic is different. This partly explains the poor performance of the municipalities.

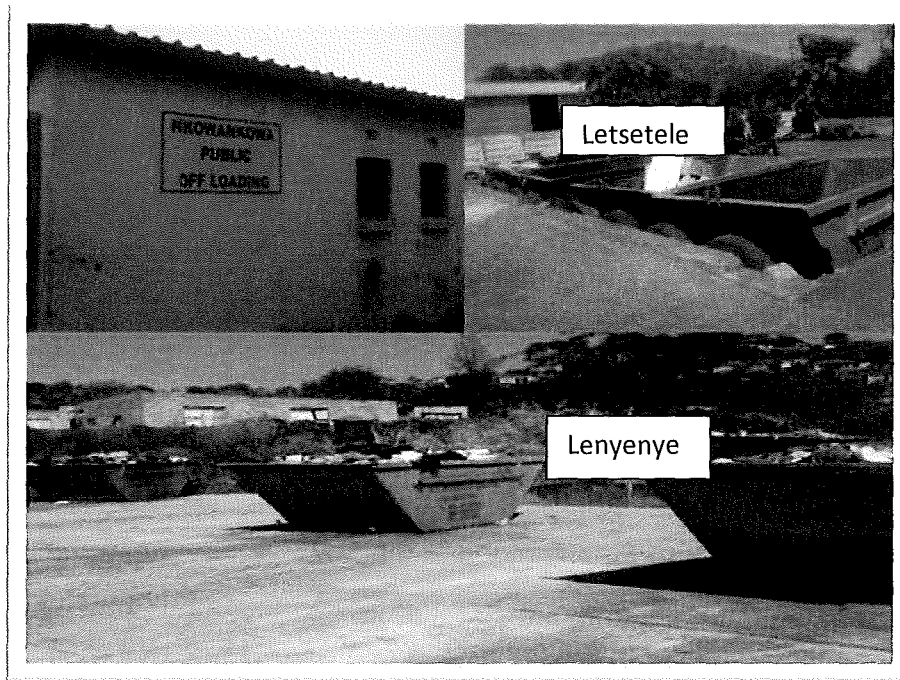


Plate 6: Greater Tzaneen Waste Transfer Stations. Source: Fieldwork (2012).

The responses by service workers further indicated that their duty hours varied from three to eight hours per day depending on municipal internal arrangements. They were hired either on permanent or on contract terms. Contract terms and working conditions varied according to the municipal needs and budget. In some municipalities such as Thulamela and Makhado, the service workers worked on shift basis until 20:00 pm. The shift schedule was specifically for litter pickers in the business areas. Urban residential areas on the other hand were serviced during morning hours. In spite of this arrangement, it was noted during observations that the towns were generally dirty as a result of littering, especially at locations with large concentrations of members of the public. This would appear to indicate that municipalities have not yet been successful in instilling a sense of cleanliness amongst the general public through awareness campaigns.

5.4.4 Transportation

The vehicles that all municipalities were using to collect waste from households were compactors (Plate 7). Compactors were observed as a suitable vehicle because they are

covered trucks. When transporting waste, the most common problem was liquid leaking from the truck and very few respondents indicated that shortage of compactor trucks was a problem. In Polokwane, there were four cooperatives responsible for waste collection in the city. The municipality had 12 compactors to collect waste in the residential areas, 3 loadlagers that collected solid waste from the skips in the factories and some residential areas, 7 grabs that collected waste from the transfer stations and illegal dumping areas and 3 multi-lifts for waste bins in the industrial area.

Table 11 shows the municipal rear end compactor and household waste collection ratios in the study area. The number of compactors needed (for 100% waste collection service delivery) indicated in Table 11 was calculated based on five working days (Monday to Friday). The number of compactors needed to address waste collection backlog was determined based on the 2011 Municipal waste sector plan requirements. An increase in number of compactors to the numbers indicated in Table 11 will contribute to job creation because one compactor truck needs one driver and four to five labourers. The study found that there are large discrepancies between compactor trucks required and the actual number of trucks in operation (Table 11). Even though some municipalities such as Greater Giyani use 4 ton trucks for waste collection in business areas, the number does not come close to that as specified in the municipal sector plan. Consequently, workers complained of working over and above their normal working hours without adequate compensation.

The waste management system cannot achieve requisite compliance targets if there is not enough equipment in place. Thulamela and Makhado had the highest number of compactors required relative to the specification in the waste sector plan (DEA 2011). These municipalities had the highest number of households without access to waste removal. Furthermore the two municipalities were dominated by households in rural areas and, as a result, waste loading, compaction & transportation were constrained. The available equipment is far short of what is required to quickly move waste along the waste chain and avoid pile ups of uncollected waste.

Polokwane had the lowest number of compactors needed because it was a secondary city. It had 12 compactors which were operating. Overall, lack of technical capacity contributes to an increase in uncollected waste at temporary storage sites. The imbalance between equipment capacity and the volume of waste generated has forced many municipalities to burn waste at

collection sites. This has adverse environmental effects in terms of air pollution. Some municipalities such as Ba-Phalaborwa, Polokwane and Lepelle-Nkumpi had identified illegal dumping hot spots where skip bins were subsequently installed in order to facilitate the collection of the waste.

Table 11: Municipal Rear End Compactor and Household Waste Collection Ratio.

Municipality	Population as of 2011	Households without access to Refuse removal	Number of Compactors in Operation	Number of compactors (needed) = household /5 day/750
Ba-Phalaborwa	13 817	33 791	4	09
Greater Giyani	7 412	57 537	1	15
Greater Tzaneen	11 522	89 831	2	24
Blouberg	3 346	35 597	2	09
Lepelle-Nkumpi	7 389	58 484	2	15
Polokwane	47 342	11 531	12	03
Makhado	9 998	114 060	5	30
Musina	9 406	14 201	4	04
Thulamela	19 302	137 852	9	37

Source: Fieldwork 2012.

Greater Tzaneen had a contracted company for waste collection. The municipality's jurisdiction included areas that were still under traditional authorities but residential areas that are less than 5 km from town are proclaimed as urban areas. A poor condition of the roads was noticed during field observations in these areas. Responses from supervisors confirmed that the state of some of the roads was a severe handicap in waste collection. The worst road conditions were recorded for Ba-Phalaborwa, Makhado (Madombizha) and Thulamela (Thohoyandou Unit C and E).



Plate 7: Equipment for Waste Collection and Transportation.
 Source: Fieldwork (2012), (Notes: Thulamela and Giyani Municipalities).

Where distances are large, refuse transfer stations and baling sites can be used to consolidate loads for transportation to disposal sites. Municipalities can make use of different types of vehicle to complement each other in collection and transportation of waste. This could involve a compactor truck in the urban areas, tractors and trailers in areas with poor condition roads, and the use of a local contractor in the rural areas. The use of dual collection transportation system, where a truck is partitioned to collect both recyclables and non-recyclables at once, has been proven to be effective in other municipalities. Such a system does not only save time but also saves operational costs. Making use of complementary transport systems and using labour intensive methods for collection could be explored. For municipalities to comply with waste management regulations there should be collection of waste from each and every household in their area of jurisdiction at least once per week.

5.4.5 Waste Disposal Facilities

The waste disposal facilities in the study area are shown in Figure 16. Six disposal sites had no formal permits to operate and were not classified according to regulations because they

were dumping sites. The failure of municipalities to get permits for their landfills indicates that such facilities do not meet the required technical specifications as per national environmental regulations. At present key landfill policy objectives include reducing environmental impacts, and diverting waste from landfill through recovery and recycling. The fact that many municipalities do not have landfill permits, which are a requirement since 1990, points to problems of installing the requisite infrastructure for a modern waste management system. It does not adversely reflect on the effectiveness or otherwise of the governments waste policy. Rather, it is in the implementation mechanisms where policy has to be translated into planning interventions that the real problem resides. Even where a municipality has put in place the necessary plans, financial constraints arising out of budgetary resource allocations may constrain the building of landfill sites.

Information from the field observations using the observation schedule in Appendix 5 provided observation data from disposal facilities and levels of compliance with the national standards of waste disposal by landfill. The observations identified the levels of operational deviation from the general requirements of waste disposal by landfill. Thulamela, Greater Tzaneen and Polokwane were the only municipalities with landfill permits. Seven municipalities in the study area owned disposal facilities that were not permitted as landfills. Such sites are classified as dumping sites. Disposal facilities are environmentally acceptable if properly managed, in accordance with permit conditions and within the stipulations of the minimum requirements of waste disposal by landfill (DWAF 1998).

At the entrance of every disposal facility, there should be an information board. Plate 8 shows examples of a dumping facility with a board with sufficient information (right) and one without sufficient information (left). Lack of information boards at the disposal facility entrance contributes to illegal dumping and the disposal of unacceptable waste at the site. Municipalities that had sufficient information boards are Greater-Tzaneen, Thulamela and Polokwane; while those that had no such information included Greater Giyani, Musina, Makhado and Ba-Phalaborwa. In Blouberg, and Lepelle-Nkumpi there were no information boards at their disposal facilities because what they had were just open dump sites without fences.

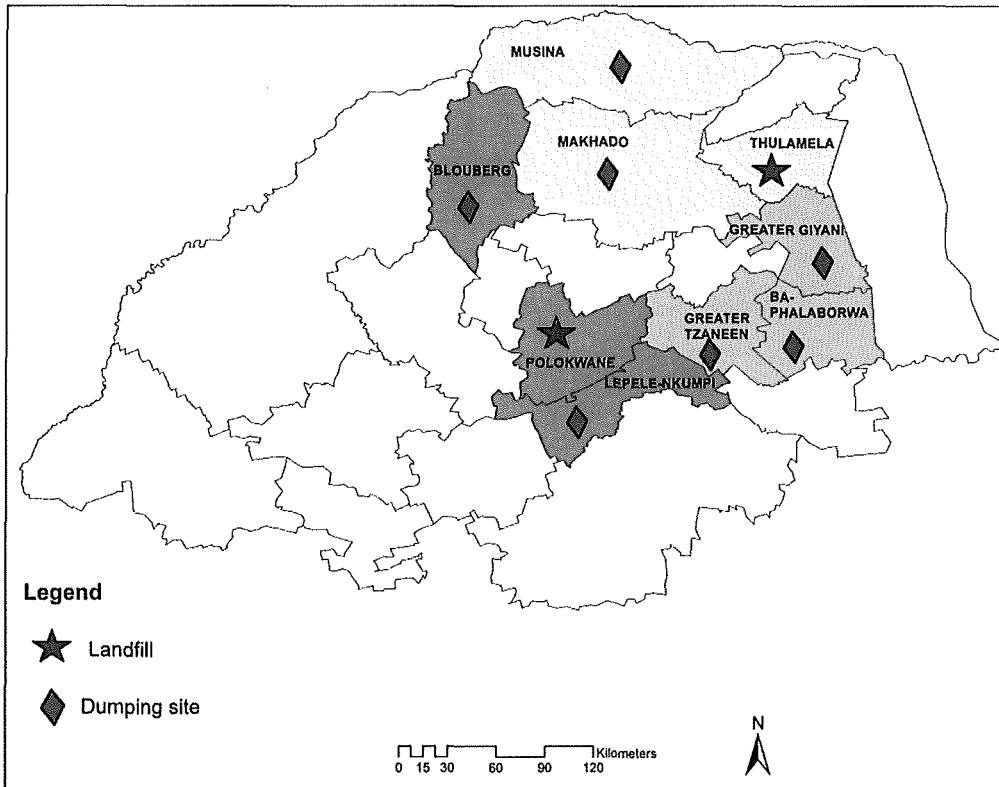


Figure 16: Waste disposal facilities in the study area.

A weighbridge (Plate 9) is an important infrastructure for any waste management information system. Out of the nine municipalities in the study, only two municipalities had weighbridges to measure waste delivered at the disposal facility. These were Greater Tzaneen and Polokwane. Results showed that the actual volume of waste generated was being recorded in municipalities with weighbridges, and these included Polokwane and Greater Tzaneen. For Thulamela and Makhado municipalities estimated data was being generated. Some municipalities did not have data because the security officers at the disposal facilities were not recording vehicles disposing of waste at their sites.

These results provide an indication of the lack of monitoring and enforcement of waste disposal by landfill regulations. Morris and Barlaz (2011) stress the importance of the performance of a landfill in the municipal waste management system. A weighbridge is a potentially useful source of information that cannot be overlooked in the waste management stream. It gives the local authority information for purposes of planning waste management.

Municipalities need information on the type and quantities of waste delivered at their disposal facilities before they can put in place regulations to reduce waste. Sufficient information is necessary because it triggers action if it is used in a productive way. Jamasb & Nepall (2010) are in agreement with this view. They reported that municipalities often have inadequate abilities to ensure compliance and planning of sufficient disposal sites.

Table 12: Fisher’s Exact Test on Compliance with Weighbridge Availability Onsite.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	13.459 ^a	1	.000	.000	.000
Continuity Correction ^b	10.644	1	.001		
Likelihood Ratio	14.240	1	.000	.000	.000
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	13.025 ^c	1	.000	.000	.000
N of Valid Cases	31				

^a 1 cell (25.0%) have expected count less than 5. The minimum expected count is 3.48.

^b Computed only for a 2x2 table.

^c The standardized statistic is 3.609.

Research hypothesis 4 stated that municipalities with an operational weighbridge system at municipal landfill sites are more likely to comply with licensing requirements than those without such a system. The null hypothesis stated that there is no difference in municipality compliance with licensing requirements between municipalities with a weighbridge and those without it. Table 12 indicates that there is a clear relationship between weighbridge availability in a landfill and compliance with the landfill license conditions. The p-value is 0.00, which is less than 0.05, and this leads to the rejection of the null hypothesis. The conclusion is that there is an association between weighbridge availability and compliance with landfill license conditions. Therefore, a municipality with a weighbridge is more likely to comply with the landfill licence conditions because installation of a weighbridge inspires the development and implementation of the landfill operational plan and management of the waste data. Landfill license conditions are aligned with the National Waste Management policy and the National Environmental Management Act (NEMA). Accurate data is required by the South African Waste Information System (SAWIS) (DEA 2012).

Landfill signage is a requirement on the license conditions in the regulations. An example of a sufficient onsite signage at the disposal facility was identified in Greater Tzaneen municipality. Inside the disposal facility, there was signage to give directions to the waste disposers. These included general waste, wet cell, dog pit and garden refuse. Onsite signage avoids incidents of waste being disposed of in the wrong cell or place. Thulamela and Greater Tzaneen were the only municipalities with enough and directive signs to different disposal cells. In Makhado, Polokwane and Ba-Phalaborwa, the signs were not clear enough while Musina, Greater Giyani, Blouberg and Lepelle-Nkumpi had no signage at all. Lack of appropriate signage at disposal facilities might influence waste disposers to dispose of waste in wrong places. In most of the municipalities where there was not enough signage, waste such as tyres, construction and demolition waste, shrubs and paper were found dumped in one place within the disposal facility. These municipalities included Greater Giyani, Lepelle-Nkumpi, and Blouberg.

The municipalities with adequate signage were also found to be communicating efficiently with the public who dispose of waste at their disposal facilities. These included Greater Tzaneen and Thulamela. The general compliance levels at the disposal facilities (Table 13) were assessed based on three quantities: information management (signage outside and inside the facility), operations (presence of a weighbridge, keeping of records on waste volumes delivered) and infrastructure (office at site, security fencing, controlled entry, and lighting). Data obtained using the observation schedule was supplemented by secondary data retrieved from official records held at the individual facility. Each compliance criterion was scored at 33.3% while the sub-elements in each criterion were apportioned accordingly. The results are summarized in Figure 17.

Table 13: Disposal Facilities Compliance Level per Local Municipality.

Municipalities	BP	GG	GT	B	LP	PLK	M	Mu	T
Compliance level	16%	14%	89%	5%	0%	61%	23%	17%	59%

BP = Ba-Phalaborwa GG = Greater Giyani GT = Greater Tzaneen B = Blouberg
 LP= Lepelle-Nkumpi PLK = Polokwane M= Makhado Mu = Musina T = Thulamela

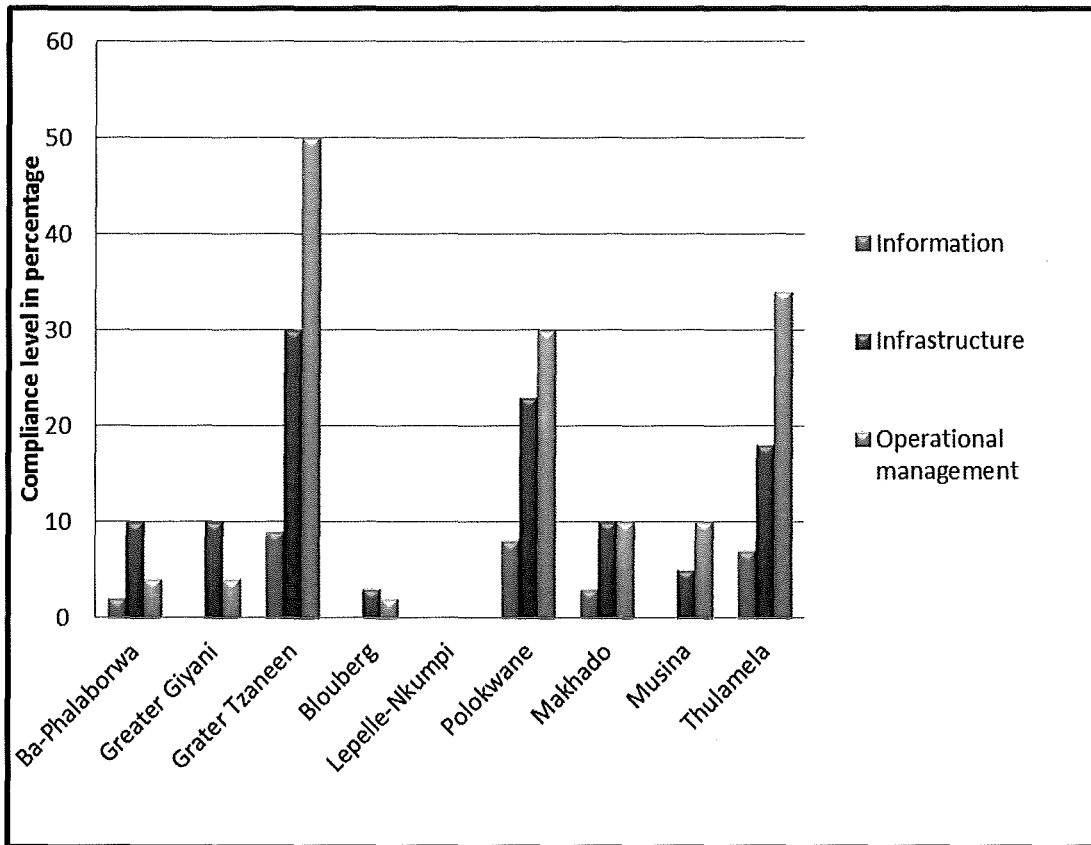


Figure 17: Disposal facility compliance levels by category in the study area.
Source: Fieldwork.

The most compliant municipality was found to be the Greater Tzaneen, with an overall performance of 89%, followed by Polokwane with 61% and then Thulamela with 59%. The municipality with the lowest levels of compliance was Lepelle-Nkumpi (with 0% compliance level) because of a dumping site without a fence and a security officer to monitor waste which was disposed of on a daily basis. Blouberg Local Municipality had a compliance level of 5%, owing to its dumping site that did not have a fence although a security officer was always present.

Municipal compliance with specific environmental regulations that govern the management of municipal landfill sites is generally very poor in the study area. The laxity with which operations are carried out shows that municipal waste directorates have not invested much in enforcement of waste regulations. The same applies to the issue of imposing penalties on offenders. The importance of the results is that it was noticed that the national government was very lenient on local government structures that poorly implemented its policies. General waste disposal sites and landfills in South Africa have indications of inadequate operational management. These points to the need for measuring and quantifying national policy

requirements, in order to identify limitations that lead to inaccurate operation of a waste disposal site. In every disposal facility of the study area, there were uncontrolled waste reclaimers. Controlled reclaimers were only found in well fenced disposal facilities that included those in Greater Giyani, Greater Tzaneen, Ba-Phalaborwa, Thulamela, and Makhado local municipalities. The municipalities that were observed to have organised recyclers in hierarchical order were Ba-Phalaborwa followed by Greater Giyani, Thulamela and Musina.

Municipalities that do not invest in recycling and proper waste control miss out on an opportunity for revenue from recycling. They also miss out on job opportunities that come from recycling, composting and businesses that work with them.

Evidence of non-compliance at waste disposal facilities is depicted in Plate 10. Leachate accumulation was identified at the Thulamela landfill. Animals were found at the Blouberg and Lepelle-Nkumpi landfills, while in Greater Giyani and Lepelle-Nkumpi there was evidence of burning of waste onsite. Surface water could be contaminated if waste ends up in water bodies, resulting in change in the chemical composition of the water. This can have ecosystem effects on organisms that depend on the water. Contamination of soil can harm plants when they take up the contamination through their roots. If humans eat plants and animals that have been in contact with such polluted soils, there can be negative impact on their health. Formation of leachate, a very harmful mixture of chemicals, may result in hazardous substances entering surface water, groundwater or soil. Leachate has negative impacts on ground water. Boreholes at the landfill sites are important for checking whether groundwater contamination has occurred. The municipalities that had boreholes onsite for water monitoring were Thulamela, Polokwane, Greater Tzaneen and Ba-Phalaborwa. However, there were no records on water monitoring as required by disposal by landfill legislature (DWAF 1998).

Non compliance is also subject to prosecution under Section 41 of the Constitution of South Africa which indicates that the spheres of government should avoid holding each other legally accountable (RSA 1996). This has ethical implications due to the fact that the constitution is the supreme law of the land. Given this basis, if the government itself is not complying with both administrative and legal requirements it should be held legally accountable, just like the private sector. The clause seems to be contravening various bills of

rights that have significant constitutional bearing, such as environmental quality and human rights.



Plate 10: Evidence of Non-Compliance at Disposal Facilities.

Source: Fieldwork (2012).

5.5 Summary

On the basis of the findings objective 2 has been addressed in this chapter. The chapter analysed municipal waste management processes systematically, by considering the flow of solid waste from source to destination. Departures from standards as per waste management regulations were identified when mapping the conveyance belt at each individual phase of operation.

CHAPTER 6

MUNICIPAL WASTE SYSTEM OPERATIONS

6.1 Introduction

In Chapter 5 the basic elements of the solid waste management system in the studied municipalities were presented and analysed in the context of objective 2. These elements included waste minimization, generation, collection, transportation, and waste disposal sites. Weaknesses were identified at the administration and operations level. This chapter presents and discusses results with respect to objective 3 of the study, which was about evaluating the factors that influence the performance of the municipality waste management system.

6.2 Internal Factors that Influence the Waste Management System

The discussion of objective 3 is based on the responses from the waste management supervisors (Appendix 2). The supervisors were asked to rank the factors that influence the effectiveness of the waste management system. From the responses, two different categories of ranking order were developed: Group A and Group B (Figure 18).

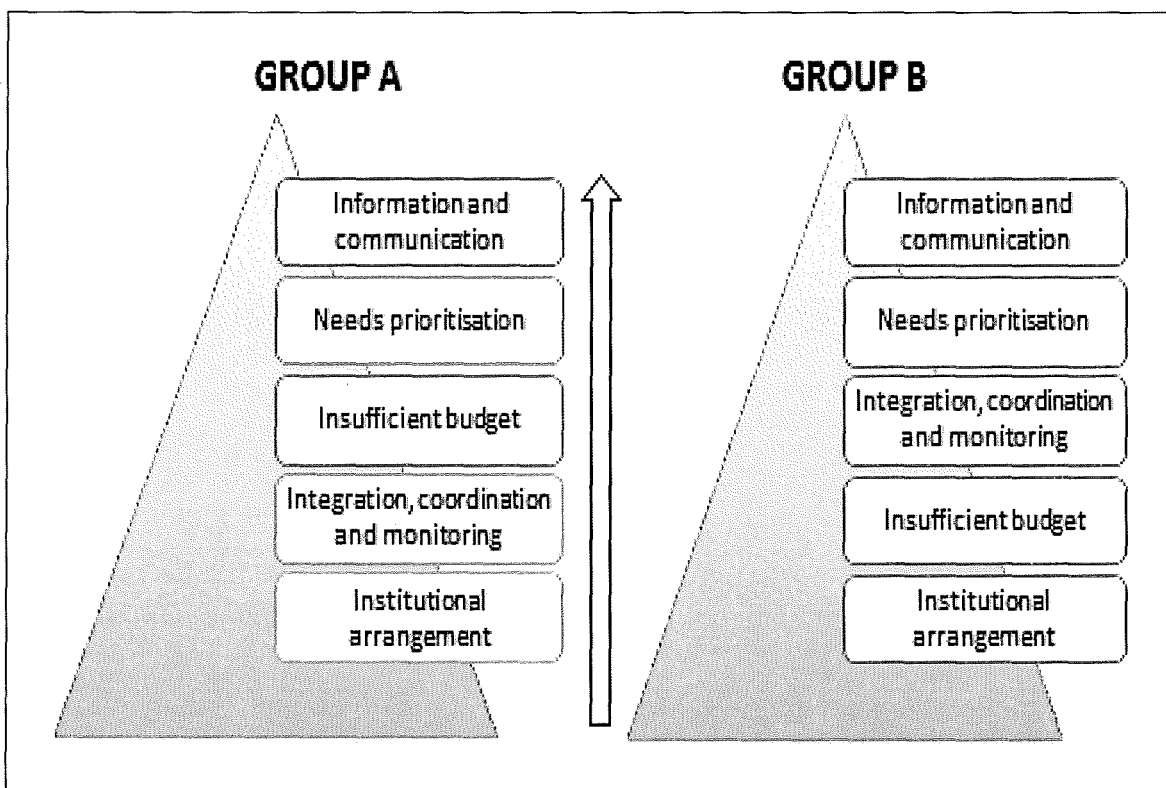


Figure 18: Ranking of internal factors by group.
Source: Fieldwork.

The internal factors that were identified from the supervisor responses included the institutional arrangement and policy, capacity, insufficient budget, municipal needs prioritisation, and communication. These factors affect the municipal waste system differently and the degree to which they can be controlled varies depending on the level of understanding, and the coping strategies in place. From the data collected, the municipalities in Group A were Greater Tzaneen, Greater Giyani, Polokwane and Thulamela. The municipalities in Group B were Ba-Phalaborwa, Blouberg, Lepelle-Nkumpi, Musina, and Makhado. The only difference between these two ranking orders was that in Group A, insufficient budget was ranked number 3 (meaning it was a moderately influential factor) while in Group B it was ranked higher, at number 2 together with institutional arrangement.

6.2.1 Policy

The municipalities in both Groups A and B in Figure 18 indicated that the major problem affecting their internal systems was the institutional arrangement. Institutional arrangement in this study referred to the composition of the municipal structure in accordance with the South African Municipal Structures Act of 2000. The municipal management was composed of political, socio-economic and administrative structures. Understanding the logic of the structure was much more challenging than observing the deficiencies measured against expected outcomes. Municipalities have visible formal appearances (administrative) together with informal and often hidden (political) elements that underline performance. Figure 19 show the results from the supervisors' interview schedule (Appendix 2). Some of the municipal waste officials from the study area believed that there was inappropriate balance of power between administrative and political structures within the municipality. This in turn had an immediate negative effect waste management service delivery.

The results show that internal political dynamics require the municipal councillors to support the system and make resources available for the success of waste management. Furthermore, the study found that some of the municipal staff did not comply with the municipal requirements and existing principles of the waste policy because of a conflict of interests due to political issues. It was noted that it was much easier to identify evidence of poor performance than to trace its origins in terms of the municipality divisions and sections. Therefore, integration, coordination and monitoring of the national waste policy at local municipalities require a higher level of some political buy-in by management officials. For example, at the time of conducting fieldwork for this study, the provincial department

responsible for environmental affairs was closing down unlicensed municipal disposal facilities but without an alternative for them.

6.2.2 Capacity

Responses from the supervisors indicated that the budget allocated for waste management was unrealistic and not based on requirements. This tended to slow down the ability of the waste directorate to deliver an efficient service. They further stated that an insufficient personnel compliment specifically for waste management and shortfalls in the required equipment for waste handling and loading compromised the quality of performance. The results are significant in that municipalities are not recovering their money from the waste tariffs. All managers reported that waste stakeholders were not paying their refuse removal tariffs properly. The failure of local municipalities to put in place systems for tariff collections indicates severe waste management incompetence. The implication is a serious shortfall in financing operations and in the required technical equipment. Municipalities that have expanded to the traditional leaders' areas of jurisdiction were the ones experiencing huge backlogs.

6.2.3 Integration, Coordination and Monitoring

The municipalities in Group A in Figure 18 ranked integration, coordination and monitoring of the waste management requirements as the second most important factor while those in Group B it was in third position. If waste management was considered a key priority in the Group A municipalities, there would have been effective implementation and monitoring of the waste management policy and related regulatory issues. Therefore, the municipalities in the study area still show weaknesses in integration, coordination and monitoring of waste management systems. Group B municipalities down rated integration, coordination and monitoring in the internal management system but instead, regarded an insufficient budget as more critical in explaining system behaviour. In Group B municipalities the finance was very crucial for the smooth running of the system.

6.2.4 Prioritization of Municipal Needs

Responses from the managers indicated that municipalities often tend to implement tangible and visible development projects with reference to their priority needs. Apart from the basic needs such as water and electricity, tangible projects include roads, parks and, cemeteries. Often a healthy natural environment is dependent on the knowledge and cultural background of the public. It is, therefore, necessary to acknowledge a visibly clean town because indirectly this talks to the status of public health and the success in waste management. The colour coded waste bins might be used effectively if there are buyback centres for recycling. It was clear from the managers responses that tangible assets of the municipality form its greatest strengths because municipal institutional arrangements also gain strength in terms of service delivery. The municipal intangible assets that should be of high priority include assets such as caring for the environment and education and awareness.

6.2.5 Information and Communication

Managers' responses indicated that information and communication were regarded as having low influence on the normal functions of the municipal waste management system. This gives the impression that information and communication strategies are taken for granted. However, the availability and dissemination of information and communication strategies are very crucial in addressing the need for waste minimization. This applies to waste generation and disposal of waste generated and disposed of at the disposal sites. The managers confirmed the validity of the data generated from questionnaires that were administered to households when they stated that the most common source of waste management information was not from the municipalities.

Municipalities need to communicate effectively through well-known media outlets and convey the message of waste prevention and minimisation simply and precisely. They can use advertisements on television that can stay in the minds of the members of the public for a long time. The advertisements can be used to draw the public's attention in the area of waste management. From the results, it can be concluded that the general public can only be partly to blame for their non-compliance with waste management because they might not have been aware of what was expected of them. Therefore, in municipalities, there is a need to identify potential communication strategies for use in effectively reaching out to the general public.

Hypothesis 5 stated that internal managerial attributes are the most important in explaining the efficiency of the waste management system than external factors. The null hypothesis stated that internal managerial attributes have no significant influence on the efficiency of the municipal waste management system compared to external factors. Fisher's Exact Test in (Table 14) confirms that internal managerial weaknesses and external weaknesses equally explain efficiency of the waste management system. The *p*-value of 0.285 (which is greater than 0.05) indicates non-significance. Therefore, the null hypothesis is accepted. The internal municipal weaknesses include lack of personnel capacity, which partly explains the failure to develop individual IWMPs, lack of consistency in enforcement, failure to secure the requisite landfill license and inadequate landfill operational plans. The external limiting factors include ignorance by the public and lack of public interest in paying waste tariffs.

Table 14: Fisher's Exact Test on Limiting Factors and Waste System Efficiency.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.642 ^a	1	.200		
Continuity Correction ^b	.847	1	.357		
Likelihood Ratio	1.659	1	.198		
Fisher's Exact Test				.285	.179
N of Valid Cases	31				

^a 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.77.

^b Computed only for a 2x2 table.

6.3 External Factors that Influence the Waste Management System

External drivers in municipal waste management are outside influences that have an impact on the municipal waste management system. These are problems and opportunities that often arise outside the municipality's institutional structures. These include social and economic aspects which change the living conditions of members of the public. Figure 19 ranks the external factors that can influence the municipal waste management system.

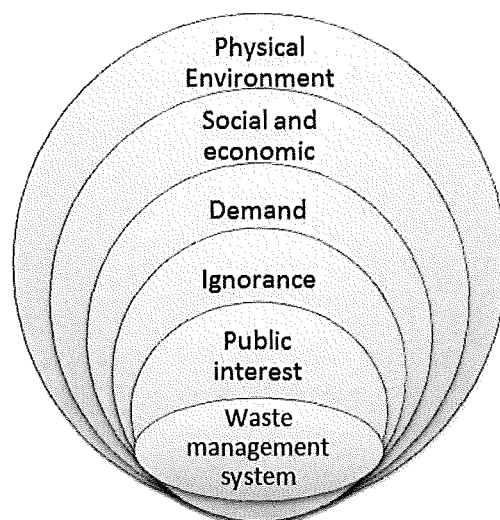


Figure 19: Ranking of external drivers.
Source: Fieldwork

6.3.1 Public Interest

Interest is one of the fundamental driving forces that push individuals to take action and pursue particular goals. Lack of public interest in waste management denotes the absence of a desire to comply with the municipal waste management by-laws. Godfrey et al. (2012b) reported that the availability of data or information is very important to human behaviour. This is one of the main reasons for distortions in waste policy implementation. People who lack interest tend to be passive and often come up with many excuses why they cannot attend waste awareness campaigns and/or sort waste at source. On the other hand, people with interest in waste management tend to be energetic and positive about it. Responses from households indicated that the majority of households were willing to sort waste at source. Therefore, this could be used as a starting point for further initiatives. A notable outcome of lack of interest in waste awareness campaigns is the persistence of illegal dumping and littering.

6.3.2 Demand for Service

Factors affecting system performance include the demand for a specific action and the system's responses to the demand. Urban growth is outstripping municipal capacity and it is one of the major problems resulting in inadequate waste management. Achieving equity in service levels to previously disadvantaged areas was also registered as a persistent problem in this study. But differential service delivery systems, widespread across South Africa's urban areas, appear to indicate higher quality of service for districts where households pay

municipal rates. The responses from the waste managers did not indicate this fact as an explanatory factor. While the demand for waste services will increase with increasing urbanisation, the areas that are able and willing to pay municipal rates will get preference in service delivery.

6.3.3 Social and Economic Drivers

From the waste supervisors' responses, it was established that most of the municipalities experiencing rapid urbanisation still had a significant rural population component. The size, composition and socio-economic status of communities and their existing community structures play a major role in influencing commitment to waste management. Leadership structures and the prevailing norms and traditions also affect the waste system in most municipalities. Although they are under the jurisdiction of the municipality, some communities are still strongly connected to their traditional structures and norms. Waste which is not collected during collection day is normally dumped at the nearest open space while others burn it in their yards, perhaps as a traditional (cultural) norm. Other socio-economic factors that come to influence waste management are issues of race, class, and social positions. They tend to undermine the scientific basis that could inform waste management and disposal. As long as waste management decisions are interfered with by forces external to the management of municipal waste, achieving a sustainable waste system will remain just an ideal.

In some areas in Thulamela and Makhado municipalities, the frequency of waste collection was as low as once per month due partly to problems of accessibility. There were rural areas that had been proclaimed urban by their municipalities. In these areas, a kerbside collection service should have an appropriate type of storage container or a raised platform for refuse plastic bags. They would avoid roaming dogs tearing off the refuse plastic bags. Climatic conditions and frequency of service in areas where there is a hot humid climate coupled with communities that use a predominance of fresh unprocessed foods, require waste collections at more frequent intervals.

6.4 Illegal Waste Disposal

From the field observations using the checklist in Appendix 5, illegal dumping was widespread in open spaces at the edge of residential areas and at road junctions. In Lepelle-Nkumpi Local Municipality, a dumping site was observed to be less than 200 meters from a

residential area. Illegal dumping is still very common in that area, as pictorially illustrated in Plate 11.



Plate 11: Evidence of Illegal Dumping in the Study Area.
Source: Fieldwork (2012).

From the household responses, indications were that where waste was not collected by the municipality, 34% of the respondents disposed of it at the nearest open space, 29% kept the waste until the next collection day, whereas 24% burnt the waste and only 14% took their waste to the legal disposal facilities (Figure 20). Disposable napkins, as seen in Plate 11, were problematic because of the smell. Therefore, residents tend to dump them illegally in the bush or in rivers because they could not burn them. The napkins seem to be affordable and save time and cost in washing baby linen. This is one of the reasons why there was a high volume of napkins introduced to the general waste stream of household waste. In Blouberg and Lepelle-Nkumpi municipalities, the illegal dumping spots were just next to residential areas and very close to the municipal dumping site (less than one km). Although the municipalities have placed skip bins in hot spots, some of the waste is not thrown inside the skip (Plate 8).

Household respondents gave a range of reasons for illegal dumping of waste; these are summarised in Figure 21. Almost 21% of illegal dumping was caused by the inconsistency in the municipality waste collecting scheduled due to bad weather, vehicle breakdowns, public holidays and frequent strikes by service provider. Household respondents alleged that their ignorance and poor sense of caring for the environment accounted for 25% of illegal dumping. The variety of reasons for illegal dumping is an indication of deviations from the long-term policy requirements of local municipalities. Therefore, intervention is needed to reduce the effects of the limiting factors. The limited involvement of the public in municipal waste education manifests in the persistence of illegal dumping. From the household responses 25% of the respondents admitted that lack of public appreciation of the environment was a major limiting factor on the effectiveness of the waste system.

Households are an important stakeholder in a municipality. Therefore, it is important for the municipalities to be aware of the households' social, economic, cultural and political circumstances in order to work with them effectively. Ward councillors and street committees should be educated to become agents of change towards compliance with waste regulations and implementation of enforcement of penalties for non-adherence to them. They would then pass this information on to their communities. Municipalities without community involvement cannot sustain a successful waste management system.

6.5 Education and Awareness

At least 79% of the households indicated that they had never attended any education and awareness meetings, and 61% stated that they had never heard about a waste awareness campaign, while 11% had never attended because they were busy with some other issues (Figure 22). Some of the respondents stated that they just did not attend the meeting but gave no reasons. This public factor is one of the external factors that contributed to problems in the functioning of the municipal waste system. The results suggest that households are generally not interested in attending municipal gatherings although they are stakeholders of waste management. Furthermore, the results portray a poor working relationship between the municipalities and the community they serve.

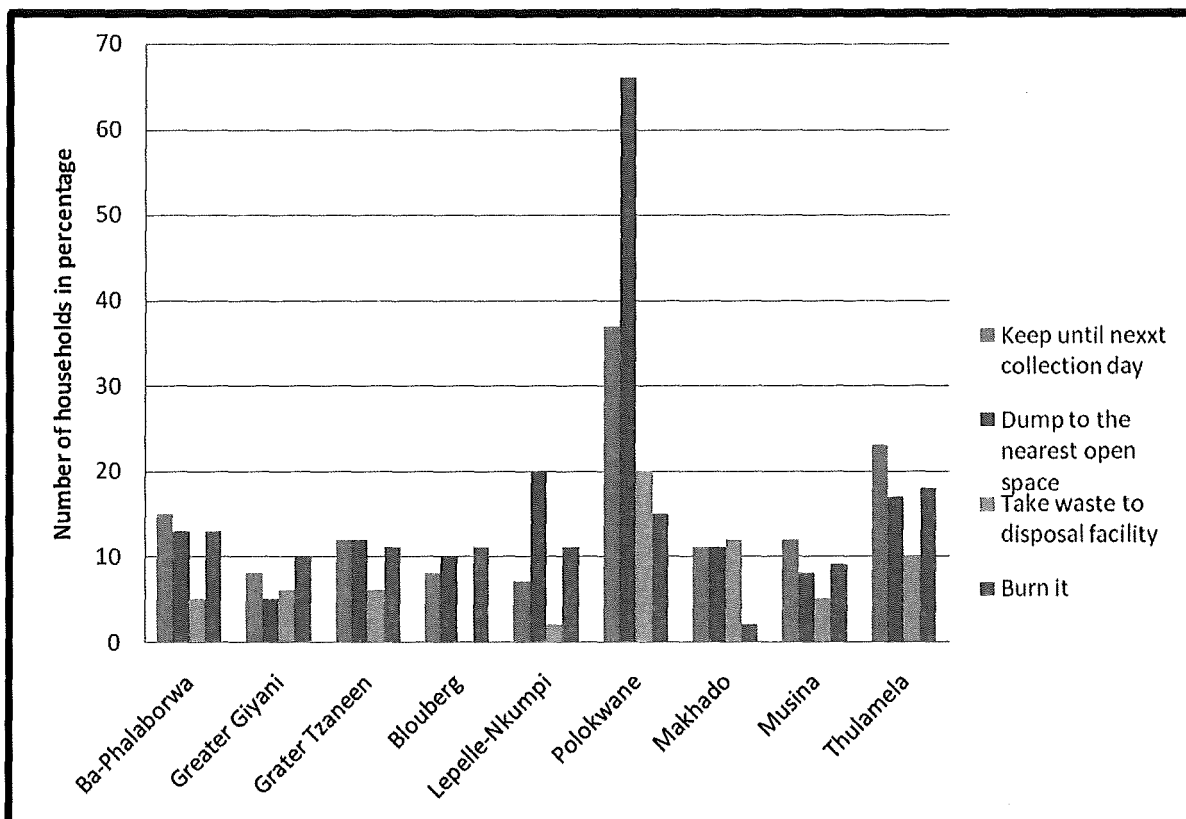


Figure 20: Summary of actions taken by households if waste bin is not collected.
Source: Fieldwork.

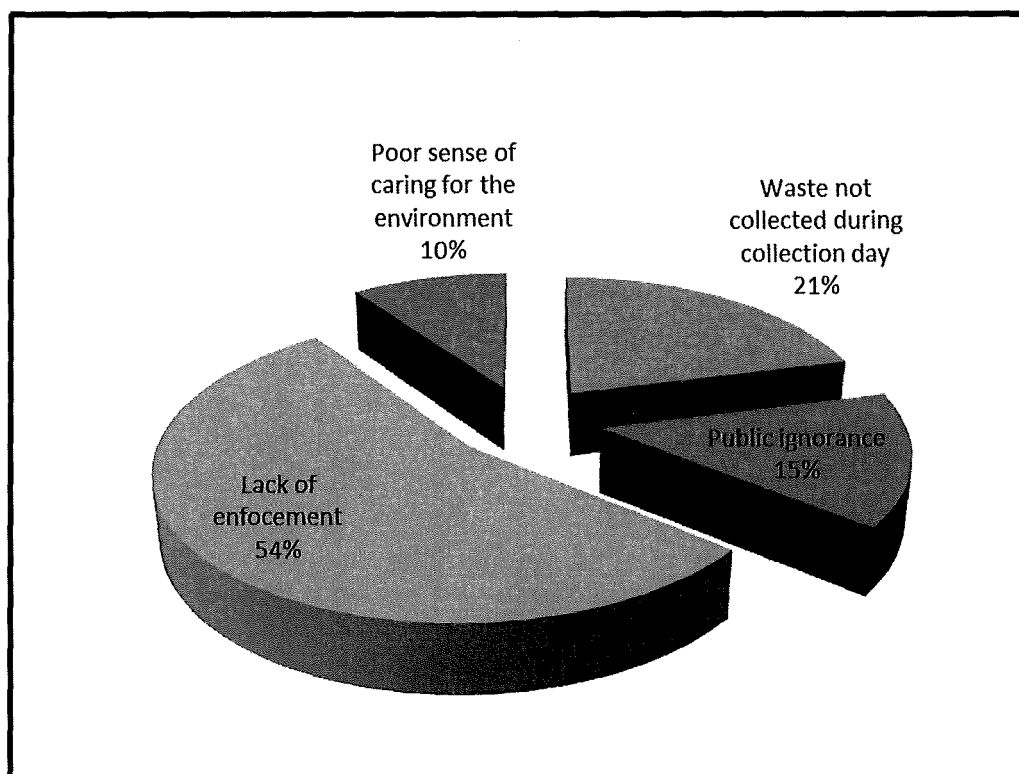


Figure 21: Household views on causes of illegal dumping.
Source: Fieldwork.

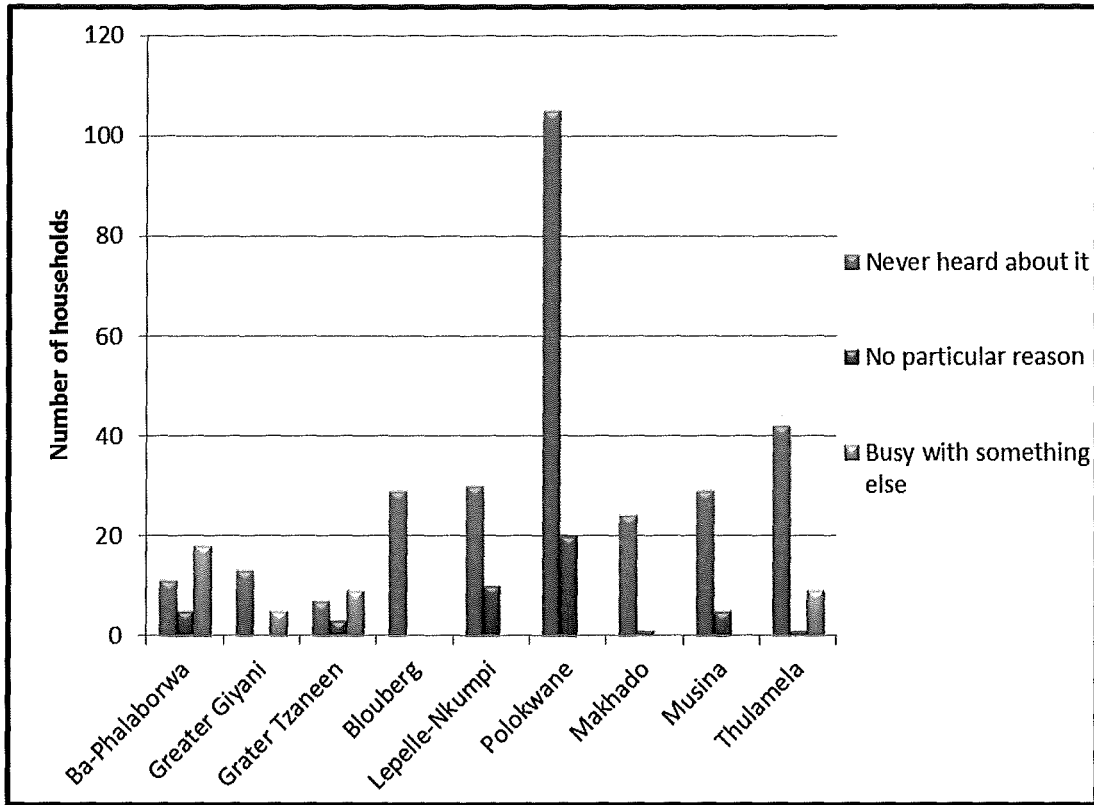


Figure 22: Household responses on waste management education and awareness.
Source: Fieldwork

In addition Contreras et al. (2008) stressed the importance of analysing waste role players needs in municipal waste management system. The municipality should create awareness amongst households about the type of waste collection provided, separation at source, unacceptability of illegal dumping and littering, and penalties for illegal dumping and littering. Zavodska et al. (2014) also emphasise the importance of increasing environmental education and awareness, using the cases of Ireland and the Czech Republic.

Figure 23 summarises the household responses on the information about waste management that they often heard about or saw every day. Information boards written “do not litter” and “littering is prohibited” constituted 56%, while “recycle” constituted 22%. The information meant to prevent waste dumping and minimise waste generation should ideally have scored the highest value. Unfortunately, this accounted for a mere 13%. These figures confirm responses by the municipal waste managers who reported that waste prevention was not given high priority during planning. It was worth noting that the waste hierarchy guide with policy impact measurement requirements might be an alternative for effective implementation of the requirements of the waste hierarchy at municipal level.

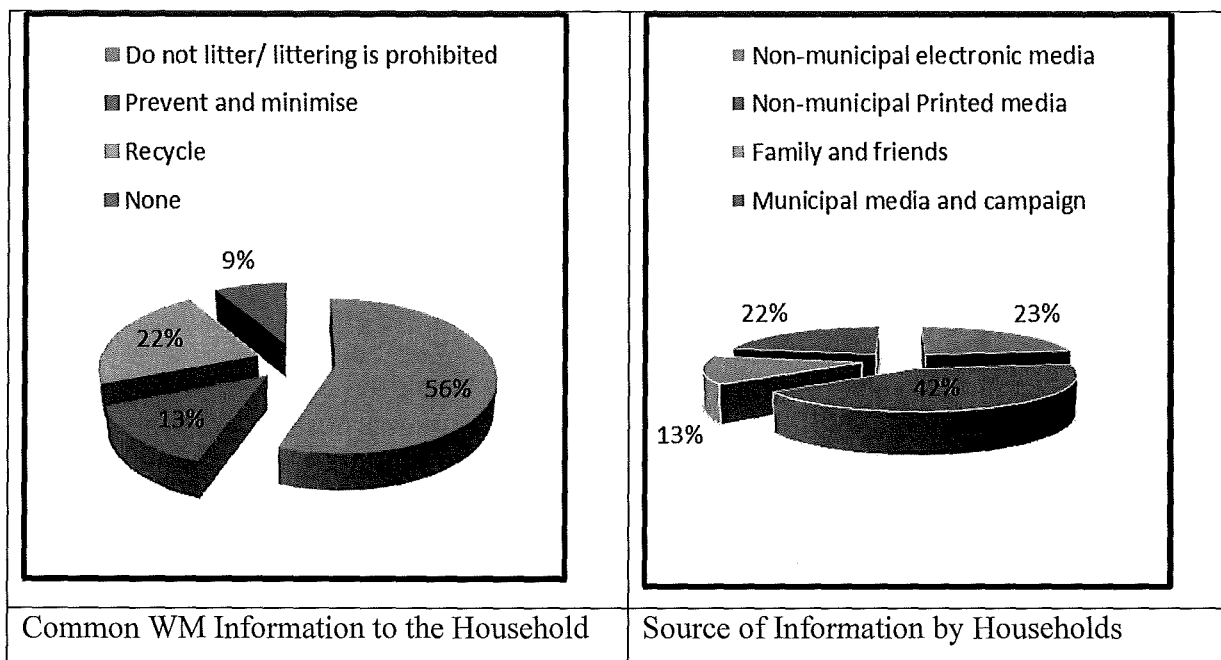


Figure 23: Household responses on their sources of waste management information
Source: Fieldwork.

The household responses in Figure 23 indicate that the main source of education and awareness amounting to 78% (sum of 23%, 42% and 13%) was from the non-municipal communication media while only 22% was from the municipal media. This is an indication of insufficient dissemination of waste management information by the municipalities to the the general public. Municipalities should spend time and money in raising awareness of environmental hazards from waste through radio, TV, cellphones, social media and other communication channels. Information can be disseminated through exhibitions, flyers, booklets, door to door campaigns and competitions. This could conscientise people on the dangers of waste. Information is a powerful tool for change and, therefore, the public needs to be motivated and equiped with the skills, confidence and knowledge required to change. The results correspond with those by Godfrey and Scott (2011) who reported the importance of improving waste management through process learning.

Weekly collection of waste should be done on the same day of the week according to the municipal schedule. When the schedule is interrupted or collection is missed for whatever reasons, the municipality should resume the services as soon as is practical and address all backlogs as a matter of priority before the next collection day. The waste collection clause indicates that there is an obligation for the waste generator to separate waste at source. This should be encouraged and supported. Without sorting at source municipalities that do not qualify as secondary cities might create significant impacts on the environment. A high

volume of waste is generated in low and middle income areas because of the expansion of urban lifestyles into rural areas. Public participation is one of the core concepts of good governance and it is critical to the effective enforcement of waste management policy.

6.6 Behaviour of the Municipal Waste Management System

Responses from the managers and the field observations provided information about the behaviour of the municipal waste management system. The behaviour of the municipal waste management system was influenced by the interplay of internal and external factors. In all the studied municipalities, there was a persistence of delay in policy implementation, as well as non-compliance with the principles of the waste hierarchy, resulting in environmentally detrimental behaviour. Persistence of delay was observed in the understanding of waste policy, its adoption and implementation. Littering and illegal dumping was created by internal and external factors including system design.

Balancing feedbacks such as an effective intervention was not observed from the existing inflow to the system, resulting in bringing the system back into the balance. By introducing goal seeking support factors such as waste policy requirements, quantification of key parameters and capacity building, balancing feedbacks can be introduced. Reinforcing feedback limiting factors can influence growth of the system. Responses from all municipal managers in the study illustrate persistent delays in the adoption of waste management policy, and in understanding and implementing it as the major limiting factors to the system's potential exponential growth. Delays have complex effects on stability and retard the system. Replacing a delay by some finite-dimensional approximation such as increasing the number of litter pickers instead of education and awareness, and enforcement, were identified as some of the sources of the fixes that fail. There are known and unknown delays; therefore, it is important to strive for a system which is free of delays. But this presupposes that such issues are understood and factored into the design stage itself. Stability of the waste management system behaviour is based on the characteristics of the delay. Therefore, it is important to identify bottlenecks along the entire waste chain.

In Figure 24, the various waste role-players pull the system towards diverse goals and this results in resistance against the waste management policy and, consequently, non compliance. The results of the study show that the performance of the local government in this study was

not satisfactory due to limiting factors such as lack of capacity to understand and implement the policy, institutional arrangement and public attitudes.

The negative feedback loop regulates the system and its absence is a common cause of system malfunctions. Negative feedback provides an element of self-monitoring and self-regulation. Therefore, reducing the loop in poorly performing municipalities is not obvious because it solely depends on external social and economic factors. The reason is that the status and understanding of waste management by waste management system drivers define its scope, boundaries and degrees of freedom. A change in the rules of a system changes the behaviour of the system. The system goals conform to the goals of the whole system. If the goal of a WMS is to reduce waste, then the system is seen in an isolated manner. However, boundaries are set so that the goals improve municipal waste management compliance.

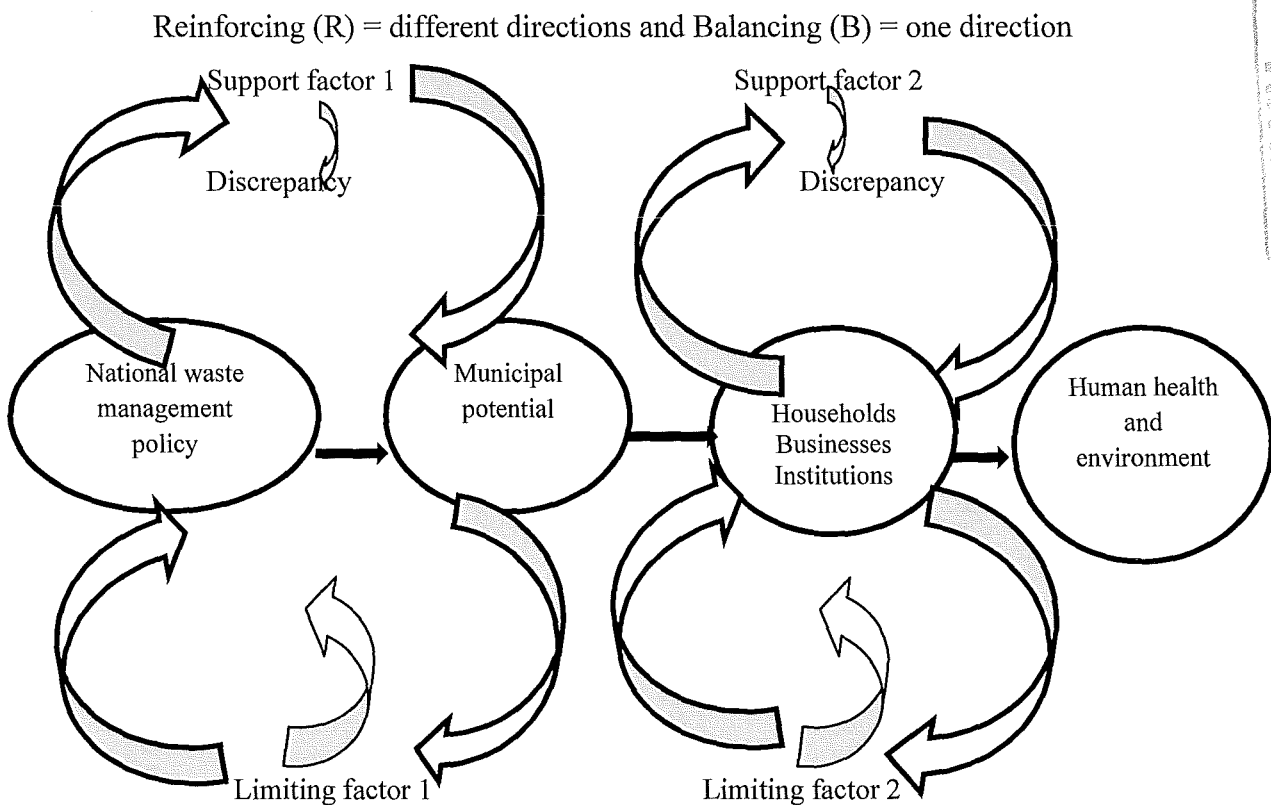


Figure 24: Municipal waste system behaviour.
Source: Fieldwork.

6.7 Summary

On the basis of the results and the discussion thereof, objective 3 has been addressed. The outcomes from the analysis and discussion of data pertaining to objective 3 has identified

internal and external weaknesses that impair the performance of the municipal waste management. Delays in local waste policy development and implementation were influenced by internal factors that included inappropriate prioritisation of municipal needs, a constrained institutional structure, insufficient managerial capacity and lack of waste data. External factors included lack of public interest, and ignorance by the public about caring for the environment. In the next chapter, an alternative waste management framework is developed. The framework is built on the existing system but with improved and re-configured inputs put together to enhance the ability of municipalities to deliver an efficient waste service that complies with national standards.

CHAPTER 7

MUNICIPAL WASTE MANAGEMENT FRAMEWORK

7.1 Introduction

In this chapter, a summary of the key findings of the study is presented, with specific focus on the municipal waste chain and the management of waste along the chain. The processes in the municipal waste chain, the interfaces between them and the identified limitations identified through data analysis in Chapters 4-6 are focussed on. This is followed by reference to applicable theory in respect of the environmental systems framework. A survey of the current waste management frameworks is presented, then the rationale for a framework is provided, and thereafter a characterization of what it is meant to address is presented. The key input elements for the framework are then developed from the limitations identified in this study, followed by the assumptions of the proposed framework as generated from the findings. They are listed first and then placed in the wider context of similar environmental-process frameworks already in use, and the requirements for compliance. Then the framework is presented, with indications of its application potentials. The translation of the framework into reality (practice) is assessed, and the limitations thereof pointed out.

A framework that could facilitate waste management compliance is important. The waste management compliance framework addresses the municipal regulatory standards relevant to the national waste management policy, provincial and local government processes and internal controls needed to be in place to enable adherence to these standards.

7.2 Summary of the Key Findings of the Study

Based on data analysis in Chapters 4-6, the following are the key findings of this study:

- There are inherent problems of design in the municipal waste management system currently in place.
- The prioritization of needs by municipal waste management directorates is not appropriate for an efficient waste management system.
- There are weaknesses in the internal institutional structure of the municipal waste management system.
- There is insufficient capacity, both technical and managerial, in individual municipal waste management directorates.

- Local municipalities in the study area do not comply with the minimum national standards for waste management.
- The minimum national standards for waste management do not provide a quantification schedule of measurable elements for testing compliance.
- The state of municipal waste data generation, storage and data usage systems is poor.
- There are low levels of environmental awareness in the general public with regard to waste management.

Excluding environmental awareness, these findings can be grouped under the following three components of the waste management system:

- *The managerial component* – which deals with the day-to-day operations of the waste directorate first and then the municipality in its totality. Managers ensure that the system operates as per its specification of duties, responsibilities and accountabilities. Maintaining smooth running of the organization is its most important mandate.
- *The technical component* – which deals with issues of equipment, expertise, tools, and delivery schedules, maintenance of equipment, support infrastructure, waste treatment, and landfill design and associated technical issues.
- *The institutional component* – this is the overall structure within which the management of the entire municipality falls. It provides the systems for personnel, finance, safety, security, infrastructure and services necessary for the operations of a modern urban settlement. Its responsibilities, therefore, go beyond waste management and it is required to allocate resources across competing needs on a continual basis.

7.3 System Framework Underlying Theoretical Base

A system may be closed or open depending on its type. In the case of the waste management system, it is an open system in terms of both physical and social components. Therefore, its physical components can be treated like those in any other system (natural or man-made) (Marshall & Farahbakhsh 2013). The system elements can be identified, measured, manipulated and re-engineered to cause predetermined system outputs at the end. Its social identity brings in the human element in terms of people, firms, organizations, settlements, information flows and how these change in time and space. The social component is far more difficult to control as a system element because the behaviour of the players does not often follow natural laws as is common in sciences such as physics and chemistry. Using a

platform of rational behaviour, the probability of certain outcomes can still be predicted in terms of general patterns. This calls for a flexible and multi-dimensional system that must be responsive to these two contradictory behavioural characteristics (Drack & Schwarz 2010).

Both systems dealt with in the field of environmental science are space bound and change with time, and the space-time-continuum allows for the possibility of integrating the social and the physical components of the waste chain in practice. A waste chain as a physical-social system is made up of processes (phases/stages) and the interfaces that separate different processes as waste moves from generation to final disposal. Each of these processes can be characterized as shown in Figure 25. The interface represents the gap or pause between the end of one process and the initiation of another process. In practice, there are also certain processes operating within the interface to impact on further stages downstream.

7.4 Current Waste Management Frameworks

The existing 2013 European Union Waste Framework is in form of legislative framework and it provides guidelines for the collection, transport, recovery and disposal of waste, and includes a common definition of waste. The directive requires all member states to take the necessary measures to ensure that waste is recovered or disposed of without endangering human health or causing harm to the environment and includes permitting, registration and inspection requirements. The directive also requires member states to take appropriate measures to encourage, firstly, the prevention or reduction of waste production and its harmfulness and, secondly, the recovery of waste by means of recycling, re-use or reclamation or any other process, with a view to extracting secondary raw materials, or the use of waste as a source of energy. The directive's requirements are supplemented by other directives for specific waste streams.

There are five steps of dealing with waste, ranked according to environmental impact - the Waste Hierarchy (Figure 1). Prevention, which offers the best outcomes for the environment is at the top of the priority order, followed by preparing for re-use, recycling, other recovery and disposal, in descending order of environmental preference. The waste hierarchy has been transposed into law in many countries including South Africa. In Europe the regulations came into force on 29 March 2011. The provisions relating to the hierarchy came into force on 28 September 2011. In South Africa it was regulated in 2008 through the Waste Management Act Number 58. The Polluter Pays Principle was developed to reduce the volume of waste

generated. If a business or organisation (including local authorities on behalf of householders) produces or handles waste (this includes importing, producing, carrying, keeping or treating waste; dealers or brokers who have control of waste, and anyone responsible for the transfer of waste), it must take all such measures as are reasonable in the circumstances to prevent waste and to apply the waste hierarchy when waste is transferred. Kurdve (2014) emphasised the importance of value stream mapping for continuous improvement in the system.

7.5 The Proposed Waste Compliance Framework (WACOF)

The proposed framework is termed the Waste Compliance Framework (WACOF). It is a waste process-interface-response framework. The framework builds upon the knowledge of the existing frameworks currently in use. It is meant as a supplement where traditional waste frameworks are not capable of handling the demands that the waste chain may generate. The proposed framework is not meant to be a blueprint for all waste management challenges. Instead, it is a framework developed for the waste chain with the sole purpose of minimizing the deviations between current municipal compliance standards and national minimum waste standards. This framework is summarized in Figure 25, and is a compliance monitoring framework with parameters that modify the degree and the direction of the performance of the local municipal waste management system. This framework is able to handle dynamic system constraints, which depend on the circumstances, by reducing and eliminating the factors that limit the smooth flow of waste across the waste management chain.

The WACOF framework in Figure 25 has, as its basis, the national waste management policy of 2008 (Act number 59) which is informed by the Constitution of the Republic of South Africa (Act number 108 section 24). The national waste management policy responded to the country's international environmental policies. The national policies cascade to the lower spheres of government, that is, the province, district and the local municipalities which are responsible for implementation. This is accompanied by a core service process which is a waste management legal framework for the province, district and local authority. The implementation of the policy at the local municipalities was expected to be through an IWMP, which is a document that needs to be approved by the municipal council and, thereafter, by the Mayoral Executive Committee (MEC) in order to be incorporated into the municipal Integrated Development Plan. The IWMP defines the local municipality waste stakeholders' critical needs, performances, as well as scrutinizing the waste hierarchy service

process (DEA 2012). There is also a platform for the support system from the province, district and independent environmental support groups. In the WACOF framework, the emphasis is on implementation of the Waste Hierarchy, and quantifying activities by focusing on the data and facts. Nurturing and support by the upper spheres of government is incorporated so as to promote continuous quality improvement. This is because the findings of the study indicated that local municipalities were insubstantial in terms of policy implementation.

The question of how the system is made aware of the waste management procedures that must be performed and how the system determines who should perform should be addressed. The WACOF framework identifies leverage that will enable efficient changes in a system by quantifying and measuring compliance performance at each stage of the system. This is indicated in Figure 25 by the longest arrow pointing downwards (labelled “Measure the indicators of compliance in each stage”). However, solution lies in weakening or eliminating the cause of the limiting factors in the system, which is the scalability.

Identification of the potential indicators of compliance in each stage, and quantification and measurement, should be done for activities that an organization will be able to influence. These activities include waste prevention activities, and data on waste reduced at each stage of the chain until disposal. Municipalities should determine the context of effectiveness by measuring each success goal to give an indicator of performance. Data should be available and reliable in order to align the actual outcome and the desired performance outcomes. Thereafter, analysis of the impact of change, with reference to management and waste hierarchy operational compliance, should be conducted. If the system conforms to the standard set, then the efficiency should be maintained. If not, a review looking for the gaps and areas of improvement is needed.

The WACOF framework approaches this task through an indirect route. It targets the systematic reduction and removal of constraints to the flow of waste in order to develop an efficient waste delivery system. But for this to be achieved, it is necessary to appreciate the context of systems and sub-systems within which the individual waste directorates of municipalities exist and operate.

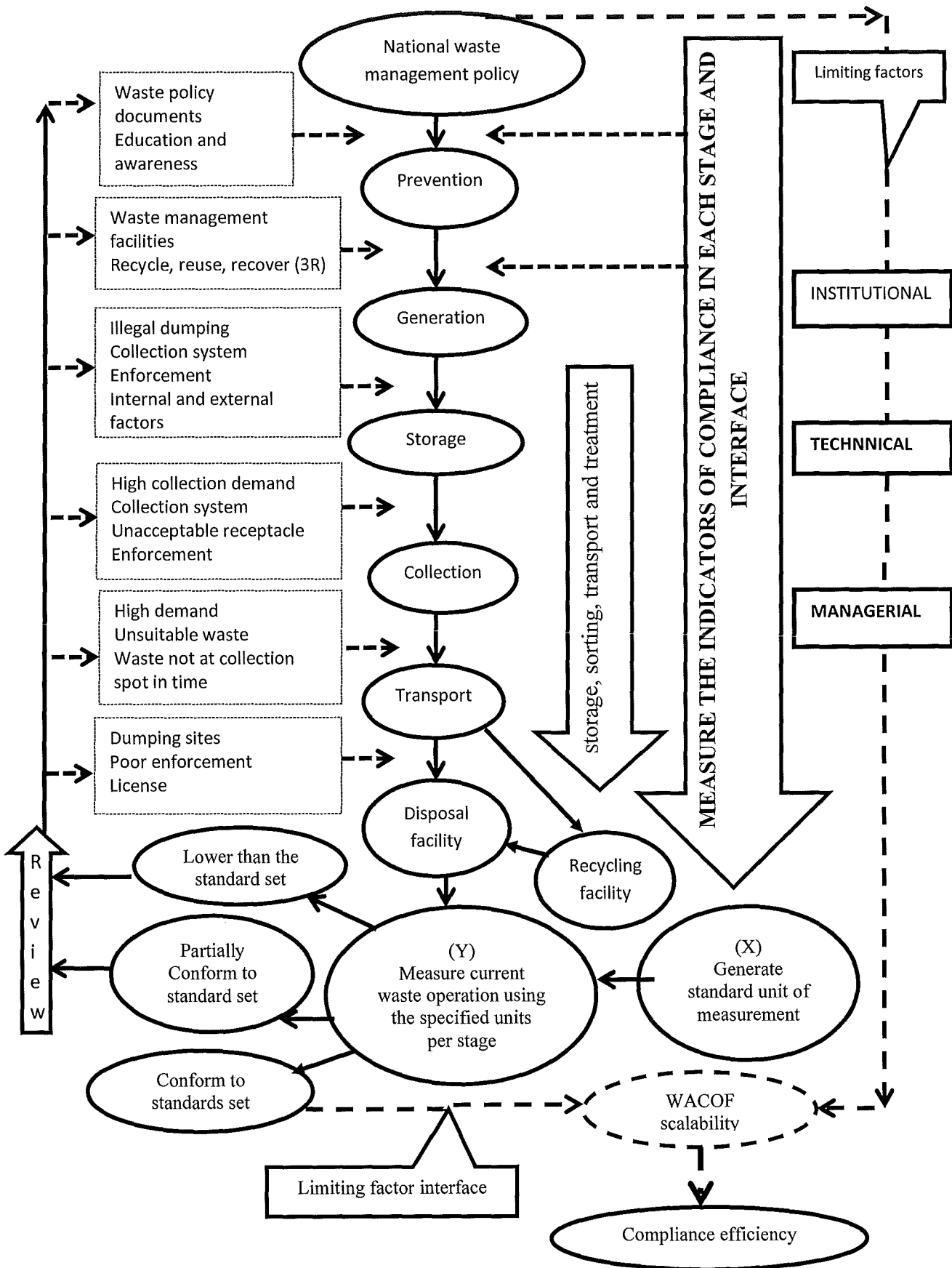


Figure 25: The Waste Compliance Framework (WACOF).
Source: Author.

The WACOF framework, therefore, looks beyond the physical components of the waste chain in the time-space-continuum to indicate what other interventions may be required for it to be delivered. Being both a physical and social model, the WACOF framework places emphasis on the need for planning, coordination, resource allocation and synchronization. The WACOF allows for developments towards technical and managerial efficiency in handling the waste stream and, in so doing contributes in narrowing the gaps between national minimum waste standards and the operations of municipalities.

The WACOF is different from existing waste frameworks in two critical structural aspects that differentiate it from the frameworks in use in respect of waste management systems at the municipal level. First, it is based on an understanding of the dynamics of the waste chain, which is a physical flow system. In this way, it addresses how waste can be moved along the chain at faster speeds, at lower costs, using fewer resources and ultimately achieving managerial and technical efficiencies which currently do not exist in the study area. Processes and the interfaces separating processes play a key role in understanding how the WACOF operates because an acceleration of movement across phases of the waste chain inevitably creates effects downstream. The waste system has to respond to these effects by increasing its demand on a strategic deployment of energy and resources; this makes it a responsive system. Second, the WACOF is not simply a physical framework. It is built within an institutional set up whose structure recognizes the need to facilitate information flows across the entire organization. This creates opportunities for learning new ways of delivering both high quality service and infrastructure through time. Such a structure becomes an example of a learning organization.

The framework addresses technical and managerial inefficiency in the stages of the waste hierarchy. It makes it possible for the municipality to identify stages where there is internal system design weakness and non-compliance. Compliance is measured according to the national standards for the collection of waste. This is done to advise the municipalities on how to achieve effectiveness by appropriately identifying areas of low or no compliance, and then be able to address them. Each success goal or requirement is measured and has a corresponding indicator and ability to explain the effectiveness of existing operational strategies, in terms of the extent to which actual outcomes are aligned with desired outcomes. Indicators are viable and provide a balanced picture of expected performances to achieve the goals. When the outcome is no compliance, it means there is a loop creating that unwanted

behaviour. Therefore, this framework is a system that can override the waste management inefficiency and allow municipalities to be effective.

The units of measurement in the framework are centred on commitment levels of the municipal waste management system to national standards for the collection of waste. A municipal performance outcome is the deviation value between the expected outcome and the current operations standards. A large deviation below the mean indicates non-compliance while a value above the mean indicates compliance. Attention must be given to the stages which are non-compliant (symbolised as - -) and the action should be to establish strategies to improve the operational performance. Municipalities will generate their standardised units of measurement relevant to their management and operational standard sets.

7.6 Input Elements for the Proposed Framework

The framework is built around inputs, processes and outputs all housed within an institutional structure (I) which controls both the managerial (M) and technical (T) components of the waste chain. These are treated as three inter-connected sub-systems of municipal management as is shown in Figure 26.

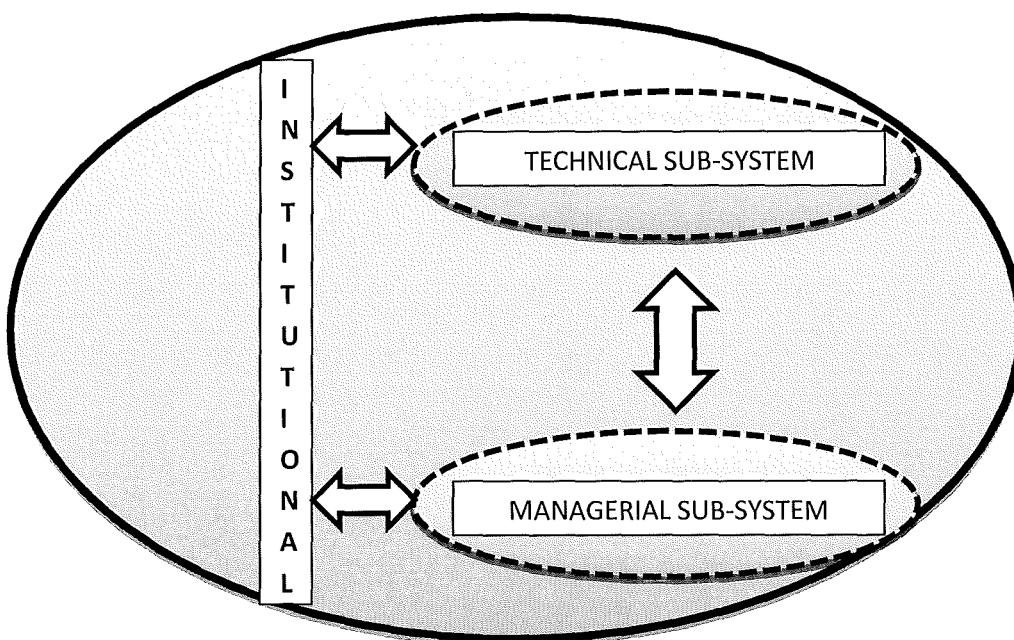


Figure 26: Initial Platform of the WACOF.
Source: Fieldwork.

Table 15: Inputs to the Waste Compliance Framework (WACOF).

Sub-system	Requirements	Description	
Institutional	Policy	Environmental and waste Policies	
	Planning	National & Municipal Plans	
	Strategies	Guidelines	
	Programmes	Specific to Municipality	
	Projects	Specific to Municipality	
	IDP	Sector Plans	
	Annual Budget	Allocation votes	
	Inland Revenue	Retained taxes	
	Organisation	Personnel	
		Capacity	
Sub-system	Requirements	Description	
Technical	Infrastructure	Temporary Collection Facility	
		High Capacity Waste Bins	
		Storage Facility	
		Gates	
		Sorting Facility	
		Treatment Plant	
		Municipal Landfill	
		Perimeter Fencing	
	Equipment	Front-end Loaders	
	Vehicles	Specialized Trucks	
	Operations	Time Scheduling	
		Weighbridge	
	Records	Data collection	
		Annual Reports	
Managerial	Enforcement	Municipal bye-laws	
	Permitting	Registration & Regulation	
	Monitoring	Performance Procedures	
	Evaluation	Performance Measurement	
	Operations	Time Scheduling	
	Coordination	Personnel, capacity and efficiency	

For each sub-system, it is necessary to specify the inputs and also, thereafter, to indicate constants, which are elements that apply irrespective of the sub-system and a particular process. Table 15 summarises the inputs of the WACOF framework. It indicates the sub-systems and specific requirements, and describes of each requirement.

The WACOF framework also addresses the compliance accuracy expected or hoped for when quantifying and measuring the management and implementation of the waste policy and other requirements. It is important to set specific, measurable targets which will indicate or confirm progress and compliance towards achieving the implementation of the waste hierarchy, waste management policy goals and objectives. Understanding and prioritizing environmental strategies and goals helps to achieve meaningful and effective environmental measurements. It is also crucial to understand the role of waste stakeholders involved in the system. In this regard the WACOF parameters are based on the application of principles of Integrated Waste Management Plan (IWMP). In an IWMP compliance requires the application of suitable techniques, technologies and management programs covering all types of solid wastes from source towards waste reduction, and effective management that is still produced after waste reduction.

7.7 Waste Management Compliance Parameters

Table 16 presents a scale for determining compliance level after a municipality has administered total scores based on the municipal solid waste management parameters in Table 17. The parameters for municipal solid waste management has been established to control generation, storage, collection, transfer and transport, processing, and disposal of solid waste in a way that is in harmony with the best principles of public health, economics, engineering, aesthetics, and other environmental considerations. The disposal site parameters will vary depending on the classification of the landfill.

Table 16: Waste Management Compliance Scale.

Levels			Percentage
Level 0	Non-existent	No existing attribute	0
Level 1	Low level of compliance		1-25
Level 2	Medium level of compliance		26 - 50
Level 3	High level of compliance		51-75
Level 4	Fully compliance	All the attributes in the standard	76-100

Table 17: Waste Management Compliance Parameters.

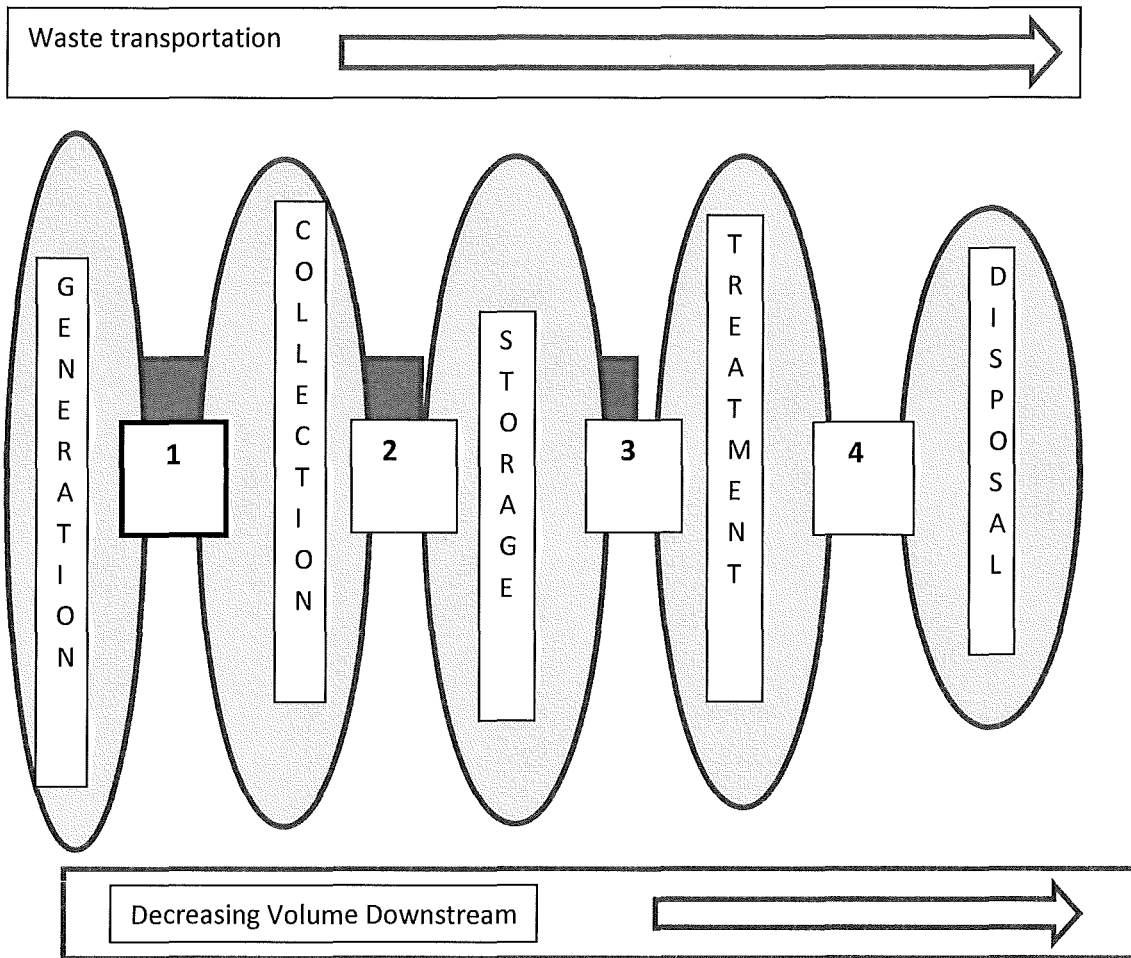
Compliance parameters	Compliance criteria	Points	Municipal score
Effective waste minimisation	Minimisation strategy/plan		
	Recycling centres		
	Composting facility		
	Buyback centre		
	Drop off centre		
	Coordination of recycling facilities		
Adequate resources	<ul style="list-style-type: none"> Human resource 		
	Waste manager		
	Waste officer		
	Education and awareness officer		
	Landfill operational manager		
	Compliance and enforcement officer		
	General workers supervisor		
	Service workers (drivers, litter pickers, door to door collector)		
	<ul style="list-style-type: none"> Finance 		
	Efficient annual capital budget		
Compliance	<ul style="list-style-type: none"> Equipment Legislature 		
	Integrated waste management plan		
	Waste by-laws		
	Enforcement procedure		
Information	Waste data in categories (monthly and annual)		
	Report to SAWIS		
	Complains records		
Service delivery	Map of serviced and un-serviced areas (including serviced primary, secondary roads)		
	Total number of households		
	Total number of serviced and un-serviced households		
	Service delivery backlog		
	Number of commercial establishments by type (restaurants, markets, liquor store, hotels and lodges etc.).		
	Number of government/institutional buildings by type (schools, hospitals, etc.)		
Education and awareness	Education and awareness programme		
	List of regular publications		
	Bill board/Dissemination and sharing of information		
Collection	National standards		
	By-laws		
	Collection monitoring report		
Separation	Awareness programmes for segregation of wastes to promote recycling or reuse of segregated materials.		

Table 17 (continued): Waste Management Compliance Parameters.

Compliance parameters	Compliance criteria	Points	
Storage	National standard		
	By-laws		
Transport	National standard		
	750 household per day		
Disposal	Licence /permit		
	Entrance information board		
	Documents related to the disposal facilities used (EIA report)		
	Operating records		
	Weighbridge		
	Borehole		
	Status quo of landfill airspace		
	Sanitation		
	Spotter		
	Protective clothes (workers)		
	Cell preparation		
	Immediate covering		
	Signage onsite		
	Recyclers registration (if available)		
	Incinerator		
	Any complaints related to emissions to the atmosphere or indoor environment		
	Any complaints related to noise		

7.8 Rationale and Specification of the Proposed Framework

There is justification for the alternative framework has been proposed here. A survey of current waste management frameworks in Section 7.4 indicated that they are complete packages that target the multiple nature of waste management as a physical and socio-economic activity, bringing on board personnel, skills, management, services, infrastructure and resources under changing conditions in time and space. But these frameworks do not serve the same purpose, making it difficult to compare them. While elements centred on time, cost, impact and problem solving are common in these models, there no universally dominant waste management framework. This is understandable because waste management itself straddles a broad field of study. The existing models look at waste management in its totality, making it difficult to tackle the sub-systems within. There is justification in re-configuring this organizational structure and in targeting particular components because their requirements for managerial, institutional and technical are diverse.



Where 1, 2, 3 and 4 are interfaces between the processes.

Figure 27: The waste chain within the WACOF.
Source: Fieldwork

The waste chain in Figure 27 captures the flow of waste from where it is generated, across time and space, to final landfill disposal. The chain is made up of stages which are essentially observable and measurable processes. It is also made up of interfaces which describe the separation between stages. Achieving efficiencies in this waste chain requires that waste flows smoothly in each stage without interruption and time spent at the interface is minimized. The more the system is able to get rid of flow constraints along the chain, the faster the waste will be delivered through the chain to the final destination, thereby freeing up time, labour and resources. Improvements in one stage, therefore, create a ripple effect that runs through the system, resulting in a response in all other stages. No framework in municipal waste management, to the best of the researcher's knowledge at the time of this

study, used this type of process dynamics in addressing issues of efficiency in delivery optimization in order to enhance compliance with pre-determined targets.

Each stage in the waste chain allows for waste recovery, waste accumulation, leakages, sorting and selection and, ultimately, a reduction in volume as the cargo of waste travels along the chain to the final destination (Denzer 2005). Built on a process mapping platform, the proposed framework uses the municipal waste chain as a starting point. The proposed framework requires that those engaged in operating the actual waste chain do understand these linkages if interventions are to create a cumulative effect on waste volumes moved, on waste sorted and treated, on waste recovered and resold and on the volume of waste disposed of finally. Such understanding should then inform the critical role of time-cost-efficiency in the delivery of the system.

7.9 Assumptions of the Proposed Framework

The assumptions of the proposed framework are presented against the background of the identified managerial, technical and institutional constraints pointed out in Chapter 4 and in Section 7.4. It is difficult, given the manner in which the framework has already been constrained as stated in Section 7.5, to include all the inputs appearing in Table 15. This would make it no more than already existing frameworks and would make the proposed framework fail to address the problem at hand. A deliberate selection of assumptions, therefore, applies; in so far as these create the space within which not only to build a framework but also to indicate possibilities for empirical testing. Therefore

a set of assumptions that directly address the process dynamics of the waste chain become the focus of the developed framework. The following are the assumptions of the proposed framework:

- i. That there already exists in each municipality a functioning management system within which the waste management directorate operates as a recognized sub-system with a clear set of mandates to deliver.
- ii. That within each municipal waste directorate a conversion of the national waste management minimum standards into quantitative measures has already been done allowing for waste to be reported in standard units of measurement.
- iii. That the waste chain is both a physical construct and a social organization with clear processes and interfaces capable of responding to internal material-energy inputs and the external environment.

- iv. That change can be initiated at any point of the waste chain by manipulating inputs of energy and materials to cause a ripple effect downstream in the form of a cascading system.
- v. That the delivery of an efficient waste management system will be driven by the targeting of process-interface-response dynamics of the waste chain through a synchronization of changing inputs, information flows within and beyond the sub-system and better planning.

Each of these assumptions is briefly explained in the context of the proposed framework and in the context of the key findings of this study as reported in Section 7.2. In assumption (i), the focus is the institutional structure in the form of the municipality- which is an organization entrusted with the key responsibility of delivering services and infrastructure to people, firms, business and other institutions falling within its area of jurisdiction. The waste management directorate is the division within the municipality that is responsible for handling and disposal of waste from diverse sources. In assumption (ii), in order to override the limitations that the national minimum waste standards impose onto measurement, each waste directorate should convert these into standard units of measurement. Ideally, such units should be aligned across local municipalities in the province to allow for comparison and to create similar conditions for the keeping of records.

In assumption (iii), what has already been expanded in section 7.8 is summarized. The waste chain is a responsive sub-system, meaning that it has an inherent capacity for adjusting to change, be it internally or externally initiated. This being the case, it follows that a planned intervention can be configured to produce desired outcomes within the overall waste system. It should be recalled that the minimization of deviations between current operations and the expectations as per national guidelines is a measure of compliance with the waste hierarchy policy requirements. For this to be achieved, it is necessary to envisage a form of intervention in the waste chain that amounts to a re-engineering of relations (Ruhiiga 2002).

In assumption (iv), the idea of “ripple effect” as in waves in physics is critical. Every intervention in a process/stage unleashes a wave effect that transmits energy and materials into the next stage. It is in this respect that the proposed framework mimics a cascading system- that translates materials and energy throughout the entire waste chain from generation to final disposal. In assumption (v), the key research problem of this study is

summed. Here, an efficient waste management system should contribute towards the minimization of deviations, thereby bridging the gap between national waste standards and the individual operations of the municipalities. Implied in the assumption is the role of planning- which extends across the institutional component (finance, budgeting, personnel), technical component (covering equipment, infrastructure, vehicles, tools) to the managerial (decision-making as to how best to delivery an efficient waste system). Understanding information flow calls for a grasp of the complexities of knowledge spill-overs through space and time (Ruihiga 2013). The waste directorate should be seen as a learning organization capable of knowledge and technology acquisition through which it is able to improve its performance.

7.10 Requirements for Compliance with the Waste Hierarchy

In the waste hierarchy, management and traceability are important because they enable the system to identify and trace the relationships between requirements at different points in the design. At any point in the design, it is essential to be able to identify the source of a particular requirement so that we can justify its existence (Van der Walt 2010). Similarly, there is little point in articulating a requirement unless we can look forward in the design to identify what requirements have flowed from it. Consequently, a design must have backward and forward traceability requirements (Van der Sluijs et al. 2005). A functional requirement is also a necessary action that must be accomplished, with a performance requirement being a description of how well a function is to be executed or achieved, or how well it is to be accomplished. A performance requirement is generally couched in terms of degree, rate, quantity, quality, timeliness; and so on. It can also describe the conditions under which the function is to be performed. Compliance can be achieved if clear, achievable and measurable requirements are stipulated (Phiri et al. 2012).

Systems operate under a certain limitation with suitable capacity. The scalability of the municipality is also a factor of a system showing the ability of the system to handle the increases in load without an impact on the performance of the system, or the ability to be readily enlarged. There are two methods for improving waste management system scalability: scaling vertically (scale up), and scaling horizontally (scale out). Scaling vertically requires adding more qualified human resources such as environmental auditors, air and water quality specialists to a single system.

7.11 Waste Collection Standards

Table 18 indicates the national domestic waste collection standards that should be followed by the municipal waste role players. Municipalities could set their own quantifiable achievable indicators of compliance. This information should be accompanied by education and awareness meetings to inform the relevant waste stakeholders within the municipality's area of jurisdiction.

7.12 Framework Interface Responsiveness

The operational responsiveness in the WACOF framework is the quality of the waste management chain, which indicates its ability to respond to the dynamic conditions of the environment and system resource input (Figure 28). When the municipalities establish the responsive elements (success indicators) within the waste chain, the responsive process interface reacts to the events as they transpire. The response of a well structured chain that has system diagnostic procedures enhances performance of the system by identifying the bottlenecks early and making adjustments to its operation. System resources such as institutional arrangement, capacity and waste data drive the significance of the consistency and standards of the municipal waste management division. Operational responsiveness requires significant changes in components linked together in an efficient system. Systematic and consistent assessment of the specific requirements of the stages of the waste chain is one of the objectives to be achieved by municipal waste management and operational systems. Operational responsive processes must directly provide feedback to support the processes by providing information to feed the operators and decision makers.

Through monitoring, each interface feedback must be communicated to the responsible person to protect the system against delay. Gaps can be identified and corrected quickly. However, the municipality should determine the acceptable response time for the task in each interface of the system. The stages in the waste chain respond to the stimuli of the management and operational status and the system should design a diagnostic tool to determine the deficiencies that need intervention, as is indicated in Figure 28.

7.13 Application Potential of the Proposed Framework

As noted in Section 7.5 that certain pre-conditions are needed for the proposed WACOF framework to be meaningfully implemented by a municipality.

Table 18: Waste Collection Standards and their Indicators of Compliance.

National waste collection standards		Indicators of compliance
Level of service	Equitable waste collection to all households within the jurisdiction	% increase of collection in underserved areas
	Onsite appropriate and regular supervised disposal (remote rural areas)	% decrease of illegal dumping
	Community transfer to central collection (medium density settlement)	% increase in number of people transferring waste
Collection	Sorting at source (secondary cities)	% increase of waste sorted at different stages.
	Clear guidelines regarding types of waste, sorting, appropriate containers, removal schedule for each type of waste	% increase of sorting at source
	Encourage recycling, by providing kerbside collection, drop off centres within easy reach. Cooperate with recycling sector	% increase in number of Kerbside and drop off centres
Receptacle	Easily distinguishable between non-reusable and non-recyclable	% of properly marked colour coded non-reusable and non-recyclable receptacles
	Maximum size of receptacles is 240L	% increase in number of acceptable receptacles per total number of household
	National waste collection standards	Indicators of compliance
	Fit for the safe storage of waste	% increase in number of acceptable receptacles per total number of household
	Rigid and durable to avoid spillage and leaking	% increase in number of acceptable receptacles per total number of household
	Intact and not corroded or worn out	% increase in number of acceptable receptacles per total number of household
	Receptacle covered	% increase in number of acceptable receptacles per total number of household
Communal collection points	Bulk (skip) for building rubble, garden waste (not appropriate for domestic waste that can be blown by wind)	% increase in number of acceptable receptacles per total number of household
	Receptacle covered	% increase in number of acceptable receptacles per total number of household
	User friendly for children and disabled people to dispose	% increase of people using communal points
	Easily accessible for collection vehicle	% increase of people using communal points
Frequency of collection	Encourage waste separation at source	% increase of recycling facilities
	Not encourage illegal dumping and nuisance	% decrease of illegal dumping spots
	Non-recyclable at least once per week	% decrease of illegal dumping spots
	Recyclables a least once after two weeks with coordination with the industries	% decrease of illegal dumping spots
	At communal collection point it should be within 24hours of receptacle being reported full or at regular intervals	% decrease of illegal dumping spots
Drop-off centres for recyclables	Bulk containers within 24 hours or reported full but not less than once per week	% decrease of illegal dumping spots
	Easily accessible to the public	% of waste to drop-off centres
	Conducive to recycling behaviour	% increase of proper policy and procedure for recyclers and those dropping waste
	Clean and user friendly	% increase in cleanliness

Table 18 (continued): Waste Collection Standards and their Indicators of Compliance.

National waste collection standards		Indicators of compliance
Collection vehicles	Be appropriate for the specific task and geographical terrain	% increase of appropriate vehicles
	Closed vehicles	% increase of appropriate vehicles
	Health issues (regular cleaning)	Vehicle wasted on a daily basis
	Maintenance schedule must be adhered to	Consistence vehicle maintenance
Health and safety	Collectors must receive regular medical check ups	% increase of consistence in medical fitness certificate (once per year)
	Appropriate personal protective equipment	% increase of appropriate protective equipment
	On-going training on health and safety issues	% increase of training outcome (certificate)
Communication, awareness creation and complaints	Waste management officer – general communication, awareness and complaints and resolve them within a set period:	% increase of implementation of communication and awareness plan
	Maximum of 24 hours	% increase of complaints resolved within 24 hours
	National waste collection standards	Indicators of compliance
	Complains must be dealt with	% increase of complaints resolved within 24 hours
	Efficient and effective register for complaints must be kept	% increase of complaints resolved within 24 hours and record keeping
Collection service standards for kerbside	Weekly collection according to the schedule	% decrease of illegal dumping and unacceptable waste to landfill
	When service is interrupted backlogs must be addressed	% increase of remedial measures
	When collection is missed collection waste must be removed not later than next collection schedule day	% increase of remedial measures and communication to the public
	Collection tem must return the same bin to the premises	% decrease of complaints about unreturned bins
	A charge will be set for replacement of waste bins if reported stolen or lost, vandalised or damaged	% increase in enforcement consistent
	During December holidays revised schedule must be publicised	% increase in communication strategies
	No charge if the receptacle is damaged by service provider and indigent households qualifying	% decrease of complaints about unreturned bins
	Stipulate time for receptacle to be out for collection	% decrease of illegal dumping % increase of number of household bins collected in an area
	Unacceptable waste stipulated in waste by-laws may not be collected	% decrease of unacceptable waste at collection point and % increase in enforcement
	All complaints addressed, promptly, appropriately, efficiently and effectively	% decrease of complaints about waste collection
General	All communication to household residents must be via the waste management officer	% increase in proper channel for communicating waste issues

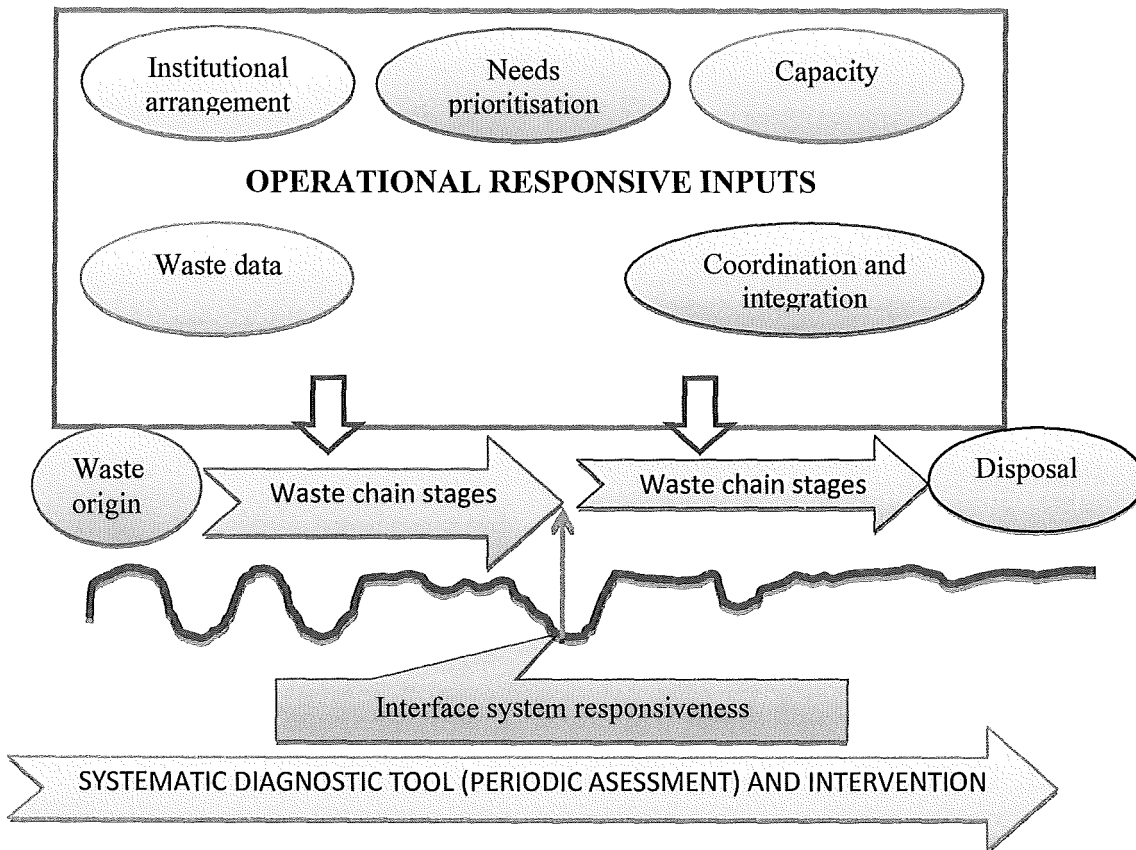


Figure 28: WACOF interface responsiveness.
Source: Author.

One critical pre-condition is the development of a waste measurement schedule on the basis of which municipalities could initiate a continuous process of recording performance. This empowers municipalities to build up and continually update data sets on the state of waste management through time. Analysis of such data sets would then inform these municipalities on the need for periodic reviews of policy, planning and practice as the waste system has to continually change with changing socio-economic conditions. The potential applications of the proposed WACOF framework are:

- The WACOF deals with a set of measurable elements reported through standard units. In so doing, it allows for the keeping of records on every stage of the waste chain. This forms the basis for measuring and comparing performance, firstly through time and, secondly, across different municipalities. Critical performance attributes should be measurable in order to find ways to deliver the necessary performance levels. This provides a clear target to work towards, as a precise criterion for judgment of failure or success. The WACOF creates space for inputs from the institutional component (I) and the managerial component (M) to be disseminated into the waste chain in a

manner that allows for the authorities (i.e. management) to measure the impact of its interventions on the waste management system.

- Because the WACOF is built on a schedule of numerical measurement units converted from national waste standards, policy requirements for waste management generated from the institutional layer (I) can be easily integrated into a learning organization. The complete system requires that the three components I, T and M are inter-dependent but are, ultimately, driven by the goal of achieving efficiencies in delivering services and infrastructure to the community under their control.
- The design of the WACOF reinforces and supplements all activities linked to the monitoring and evaluation (M&E) of the waste management system. Management and operational efficiencies vary by municipalities but generally include daily activities, time spent in each activity, cost of activities and the process within the waste hierarchy from start to finish. The effectiveness of the waste stakeholders will deal with efficiency; how stakeholders execute their respective roles and responsibilities.

Most of the municipal waste management systems measure their performance on the basis of waste collection schedule and cleanliness of the public places such as towns and streets. It is necessary to quantify requirement activities by selecting what to measure followed by an objective or “goal performance.” That is a part of the integrated system. However, focusing on the activity is not enough. In addition, management must have an honest dialogue with each waste stakeholder concerning how they can improve the requirements of the waste hierarchy. Without a direct authentic dialogue, it is difficult to improve, whereas an honest dialogue leads to better results and will close the loop of an integrated system that allows municipalities to measure and quantify performance. The municipality must consider the context of the waste hierarchy in waste management, as well as the operational environment, in order to determine functional requirements for the system design.

Process-interface-response dynamics have been built around the structure of the waste chain. The framework develops the pre-conditions for measurement and provides the platform to measure compliance indirectly. It shows how to achieve efficiency along the stages. It further creates allowance to understand the measuring process. The framework is an adaptive wave

response system wherein its elements adapt to the circumstances over time through the action of the flow. Levanen and Hukkinen (2013) support the WACOF issue of adaptive strategies for change development in applied to the existing policy. The focus of the framework is on the flow of waste through the chain looking, at success and failures and trying to understand the behaviour of the system over time. Figure 28 illustrates possible increase if an underperforming municipality improves in terms of the identified limiting factors. These limiting factors are internal factors such as institutional arrangement, capacity, coordination and integration and needs prioritisation. The framework also shows the significance in the municipality to consider the perspective of the other waste stakeholders such as the communities, institutions and business. Changes in inputs elements set the pace of the dynamics of the system. However WACOF stimulates the ability of the system to be flexible and adjustable in order to maintain scalability.

Adoption of process mapping generates the ability of the waste design to identify challenges as they emerge in each stage of the hierarchy, as a system. When one aspect of the chain is malfunctioning, the whole system is affected. The WACOF framework adopts the systems analysis approach that creates scalability, which is a conducive and continually moving platform where in management and operation design adapts to change.

The framework is a simplified systematic and organised way of measuring compliance performance by providing a platform to the municipalities to establish desired performance in specific measurable terms. It has the ability of identifying loops and an opportunity to review the process. WACOF has the possibility of comparison within, across and between different waste chains by providing the municipality a space to establish their own relevant standard units of performance measurement. It further links efficiency and compliance because when a municipality is striving to achieve framework output, to conform or be above the minimum standard expectations at the same time, they will be effective and efficient.

The WACOF framework has possibilities for generating mathematical notations, equations and empirical testing. This can be achieved by subtracting the value of the actual current waste operation from the generated standard unit of measurement specified per waste hierarchy stage. This provides a platform for the prediction of the performance level, as in Equation 2.

$$P = t(x - y) \quad (\text{Equation 2})$$

Where p = performance level

t = time/period

x = generated standard unit of measurement

y = Current waste operation using the specifies standard units of measurement

7.14 Limitations of the WACOF Framework

Given that a framework is a simplified representation of reality, every framework inevitably suffers from certain departures from this reality. In any case, every framework is built on a set of assumptions such that if they are in place, it should predict the behaviour of that reality that it represents. It should be pointed out that in the building of the proposed framework, not all the key findings have been included: it would be impossible to do this. Attempting to include all applicable elements would make it impossible to interpret or to relate to any particular aspect of the waste management system. Also the WACOF is built, first and foremost, on the waste chain platform, which provides a form of “bounded reality” that may depart in some respect from the true reality of waste management in the study area. No attempt has been made to build into the framework the three components identified in Section 7.2, that is- the institutional, the managerial and the technical. Only a selection of some of these elements from these holds.

The time constrained nature of this study means that no empirical testing of the proposed framework was carried out. Field testing would require testing at intervals of at least six months, spread over at least five years, keeping a time series data set for each interval and computing change-through-time to establish response and output scenarios towards a systematic reduction in non-compliance. One problem of the design of the waste management system is that it is not particularly aligned to the individual differences within municipalities. The WACOF does not address this problem of design because design is a national competency that goes beyond the powers of municipalities. The WACOF captures trends and responses to interventions using conventional numerical measures of distance, time, cost and volume but is unable to factor into its predictions the role of personnel in collectively working towards achieving an efficient waste delivery system. In this way, the framework does not address the related issues of capacity and competency at the level of the municipality. Being built on a waste chain platform, the WACOF framework does not address the issue of the low levels of environmental awareness in the public that was one of

the findings, because this partly feeds into the public's lack of interest in maintaining a healthy environment.

In its current state, the WACOF remains essentially a conceptual framework. It is not at present possible to use primary data and run computations to test its predictive powers. Given time, two parallel developments from this framework should make this possible. The conversion of input elements into standard mathematical notations is possible as a first step towards generating applicable equations. Primary data from field trials could then be tested using such equations. National minimum standards for waste management are designed in a manner that fails to specify quantitative deliverables making it almost impossible to measure compliance at the level of local municipalities. In an earlier publication (Appendix 8) derived from this study, Mudau et al (2013) report a simplified schema for generating a flexible set of parameters that could be used in place of these national guidelines, and which provides a robust methodology for comparing compliance and efficiency. The flexibility this schema would not handicap the ability of municipal waste directorates to still gather and report performance statistics to SAWIS. The development of waste compliance parameters in Chapter 7 (section 7.7) complements WACOF in promoting performance measurement and efficiency. A successful waste management system is reliant on accurate information which helps the management authorities to know the state and level of the system's performance. Measurement of performance in this framework incorporates the idea of change occurring, and the ability to identify problems. Without measurement, the waste management directorate cannot precisely confirm failure or success of the system's operation. Without quantifiable measures of compliance performance, no value can be attached to translate the meaning of the waste management guidelines. Therefore, the municipal waste management directorate cannot properly allocate resources such as capital, infrastructure and human resources. Furthermore, measurement of compliant outcomes will not be rationalized.

Through public dissemination of the findings of this study in the form of a user friendly executive summary of the WACOF framework, it is hoped that the local municipalities in the study area can be convinced about the urgent need for such a system. Ideally, such an exercise should be undertaken in all local municipalities in each district municipality of the Limpopo Province. Thereafter, the district municipalities could compare notes and generate a provincial schedule of minimum standards that are expressed in standard measurable units. This would then act as a yardstick for all waste management directorates in the province.

7.15 Summary

This chapter has presented the basic structure of a proposed intervention framework. The aim of the framework is to add value to the existing waste hierarchy. In addition the framework fulfilled certain preconditions such as translating the guidelines of the waste standards into numeric units. Its strengths and limitations have been elaborated upon. In the next chapter, the conclusions and recommendations emerging from the study are presented.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This study was undertaken in order to apply process mapping within a system framework in investigating compliance in municipal solid waste management. A selection of municipalities in Limpopo Province, South Africa, was used. A set of objectives was advanced together with hypotheses to guide the project. A review of literature revealed knowledge gaps and a link between current literature and these gaps were made at the end of Chapter 2. Based on a descriptive research design, a specification of variables was presented, the population of interest described and sampling procedures were carried out. Instruments for data collection were then designed and tested through piloting to ensure validity and reliability. The study used questionnaires and observation in data collection and the primary data collected was subjected to descriptive statistics followed by hypothesis testing using Fisher's Exact Test.

The results, following data analysis, are presented in Chapters 4, 5 and 6. In general, it was established that municipalities were not complying with the national minimum standards for waste management. It was also noted that there were inherent institutional, managerial, policy and technical limitations within which the waste management directorates had to operate. The significance of these findings was then discussed to provide a platform for an intervention in the form of a framework. The design of an intervention followed conventional steps resulting in the WACOF framework. This study has shown that WACOF offers potentially exciting insights into the municipal waste management system. The contribution of this research is then discussed in the context of systems analysis and how municipalities could benefit.

From a systems analysis perspective, this study contributes to an understanding of the how process mapping approach can enhance waste management, and unpack the obstacles to service delivery. It provides a potential platform of municipal waste management service delivery with reference to the measurement of the efficiency of compliance with the waste. System analysis and model design potentially can make process mapping of the waste management system flexible enough to accommodate changes as they are inevitable in any system. This study will improve the ability of understanding process mapping components of the waste hierarchy, for an appropriate level and implementation of municipal waste service

delivery in order to meet waste management minimum legal and other requirements of waste management.

8.2 Conclusions

The key findings of the study were derived from analysis of data as in Chapters 4 to 6. It was noted that currently there are in-built problems of design in the municipalities. A profile of existing municipal waste management systems in the study area was presented indicating that the majority of the municipalities did not have appropriately trained personnel in positions related to environmental concerns. Needs prioritization by municipal management was not appropriate for efficient waste delivery systems. The internal institutional structures of municipal management need improvement. Both technical and individual managerial capacities to enhance the waste management directorates are insufficient. Process mapping on waste management systems was done and the results indicated that local municipalities in the study area do not comply with minimum national standards for waste management when implementing the waste hierarchy. The minimum national standards for waste management do not provide a quantification schedule of measurable elements for testing compliance. The poor state of waste data generation, storage and usage hamper the waste management system due to lack of actual data. Low levels of environmental awareness in the general population perpetuate a culture of lack of care for the environment, entrenched by lack of interest by the public to consider environmental education and awareness as a priority.

The internal and external system bottlenecks that interrupt the efficiency in the flow of waste from source to final destination were identified. To help address these, the WACOF framework was developed as a way of providing an understanding of the waste system by observing and measuring performance within the chain. By identifying the missing information or loops, the WACOF makes it easier for the waste directorate decision makers to make accurate decisions because they cannot respond accurately to the weaknesses without information or with inaccurate data; consequently they cannot respond in a timely way. The WACOF framework gives the municipalities some guidelines on how to design an operational schema for compliance minimization in waste management.

The contribution of the WACOF framework to the state of knowledge in waste hierarchy management is that it has revolving time and duration attributes to adapt to changes. Process-interface-response dynamics have been built around the structure of the waste chain.

WACOF develops the pre-conditions for measurement and provides the platform to measure compliance indirectly. It also shows how to achieve efficiency along the chain stages with the potential to facilitate understanding. The adoption of process mapping generates the ability of the waste design to identify challenges as they emerge in each stage of the waste hierarchy.

The framework also helps build a learning organisation that shows how to enhance the performance of the waste chain. It also has prospective links to efficiency and compliance. The WACOF framework has possibilities for generating mathematical equations and empirical testing. This can be achieved by subtracting the value of the actual current waste operation from the generated standard unit of measurement specified per waste hierarchy stage. These provide a platform for the prediction of the possible future compliance performance level. From a compliance point of view, the study has set a basis for further research in this field. This may lead to the development of a Waste Management Compliance Index (WMCI) with application potential localised to South Africa but potentially beyond its borders.

8.3 Contributions of the Study to the Body of Knowledge

8.3.1 Knowledge Gaps Identified

It is important to show which of the knowledge gaps the study successfully addresses and, in the process, extend the boundaries of existing knowledge with regard to compliance in municipal waste management systems. The gaps in knowledge are carried forward from section 2.9 of the literature review chapter. Five knowledge gaps were identified, and are specified as follows:

- Studies reporting *characterisation of waste streams* are limited
- The use of *process mapping and of systems analysis* in studying the interface along the waste chain remains an un-researched area.
- Quantification and *measurement of efficiency* at each stage of waste hierarchy is not articulated to ensure consistency during the assessment of progress by waste policy.
- *Performance measurements* and the generation of parametric measures of efficiency are handicapped by the lack of reliable data sets.
- The waste management system performance is reported consistently as a whole system, with little regard to the *dynamics of its components*.

8.3.2 Key Findings in Relation to Knowledge Gaps

- *Characterisation of waste streams*

Waste management as a critical component of the urban development process is not deemed a priority across all municipalities in the study area. The prioritization of needs by municipal waste management directorates, such as sorting of waste at source, is not appropriate for an efficient waste management system. There are low levels of environmental awareness in the general public with regard to waste management. Waste management directorates are handicapped by constrained resource allocations in the IDP-guided municipality budgets. This translates into inadequate personnel compliments, inadequate equipment, inadequate waste collection and low levels of performance monitoring. Consequently, problems of technical and managerial capacity are widespread. Low levels of environmental awareness and the need to subscribe to the basic principles of conservation, protection, etc., mean that the masses of the people are not participating actively in implementing a green environment strategy. This is partly due to the low level of political will shown across all the three tiers of government in the country when it comes to dealing with issues of non-compliance with waste management regulations. There is insufficient capacity, both technical and managerial, in individual municipal waste management directorates.

- *Process mapping and systems analysis*

The data sources consulted (journals, government publications and reports) on operation and management along the waste chain report fragmentation with regard to the waste hierarchy. The waste management policy is descriptive and qualitative in nature because it describes what the waste system must do without providing specific quantifiable numeric targets. It only explains what should be done and why. Inherently, there is no numeric values attached to the specific requirements of the waste management standards, although municipalities have differences in terms of structural and social conditions. No standard measurements provide targets for the performance of the system. No standard benchmark scores exist to encourage municipalities to commit themselves to achieve the expected goals. Municipalities are operating in an environment (capacity) which is not conducive for them to deliver what is required.

Municipal management is interested in maintaining visible day to day running of the waste management system, which is collection and disposal of waste. Lack of periodic

monitoring of stages in the waste chain makes non-compliant behaviour to persist. Policy designed at national level cascades to the province, district and then the local municipalities without clear measurable, traceable, testable and achievable requirements. This creates a delay in waste management project design and implementation by local municipalities. Periodic performance reports were non-existent, but the reports are important because they serve as an instrument for monitoring performance continuously. It is also difficult for the municipalities to benchmark because the targets have no quantifiable standards. It is, therefore, impossible to conduct a review of the operation of the system without using specific standard units of measurement.

The institutional structure of municipalities is not designed to facilitate the easy flow of information between its components, leading to persistent delays in translation of policy into plans, projects, implementation and outcomes. It remains an administrative outfit characterised by rigid guidelines and delivery protocols. While this may facilitate uniformity in service delivery, it may itself act as a handicap when municipalities have to respond decisively to urgent issues of service delivery. But at a deeper level, this represents distortions between the requirements of governance systems on one hand and efficiency considerations on the other hand. The legislative environment, compared to most developing countries, has seen a radical overhaul since 1995 but it is in the structures for implementation through permitting, enforcement, monitoring and control that serious problems arise.

- *Measurement of efficiency*

The minimum national standards for waste management do not provide a quantification schedule of measurable elements for testing compliance. The standard guidelines from the national level to the local municipal waste management system have a top down approach that goes from national, provincial, district and then to local government. This approach does not provide clear possibilities for adjusting the guidelines to specific municipalities.

- *Performance measurement*

The state of municipal waste data generation, storage and data usage systems is poor. This study has identified internal factors that lower the efficiency and effectiveness of the performance of the municipal waste management system. Differences in the contexts of each municipality did not handicap the accuracy of the results of the research because

there were large deviations from the expected standards in most of the municipalities studied. The regular keeping of statistics on the type and volume of waste generated, stored, transported, treated and finally disposed of remains problematic. This leads to a serious lack of data on the basis of which planning interventions can be affected. The use of a weighbridge at various sites in this study is of limited value because the methodology for capturing the waste delivered at the landfill sites remains inefficient. Weighbridge data is, therefore, of very little practical value because there is no separation of waste at source. Limitations imposed by a lack of record keeping creates a major challenge because municipalities cannot properly plan efficiently for waste management. The elements for measurement are not standardised by the national policy and, therefore, it is difficult for the municipalities to have a point of reference for measuring performance.

- *Dynamics of components*

The guidelines for waste management are not flexible enough to accommodate the physical, social and economic changes along the waste management chain. This is because the operational efficiency of the overall system depends on the dynamics of parameters along the waste management chain.

8.3.3 Knowledge Gaps Addressed by the Study

Using the WACOF (detailed in Chapter 7), this research study has indicated that breaking up the waste chain into its constituent components facilitates the identification of system bottlenecks. Each phase is characterised as a dynamic quantity exposed to both internal and external drivers but with linkages upstream and downstream. The underlying rationale is that it is not possible to treat the entire waste system as a whole, an approach consistent with much of the existing literature. Rather, appreciating the inherent differences between waste policy, generation, temporary storage, waste transportation, waste treatment facilities and disposal sites extends possibilities for intervention. Using a parametric set of measures, it becomes possible to report on performance of the waste chain at different scales and to compare them across municipalities.

Research of an analytical nature does benefit from this study through primary and secondary data sets captured across interval and ratio scales but falling within the parametric measures earlier referred to. The findings address three critical bottlenecks in the state of existing knowledge on waste management regulation compliance. A number of disciplines of study

can make use of the findings from this study, beyond environmental science. They include civil engineering (flow dynamics/technical efficiency), applied mathematics (modelling human-environment systems), systems engineering (re-engineering spatial behaviour), environmental management (integrated waste systems), and environmental economics (resource optimization/allocation). Therefore this work can be judged as truly extending our understanding of the dynamics of the waste management system.

8.4 Limitations to the Study

Several limitations of the study are acknowledged. These are presented with accompanying explanations. First, it was not possible in this study to get access to reliable datasets from municipalities with respect to waste streams. This would have allowed for the use of time series analysis to trace developments in performance across significant periods of time. Second, where weighbridge records were kept, these lacked consistency making it impossible to compare different landfill sites in terms of operations. Third, while recent legislation that has seen the establishment of a waste information system (SAWIS) is commendable, local municipalities did not show a full appreciation of the benefits of keeping accurate records on waste streams. The study did not enquire into the relationship between municipalities and SAWIS. Fourth, while this study has established limitations in the design of national waste guidelines, it was not possible to test the extent of understanding of these limitations at the level of local municipalities in the study area. Fifth, this study has identified internal organisational arrangements that may impact on performance. It was however not possible to pursue these in order to establish the understanding of municipal management as to the long effects on efficiency.

8.5 Areas of Further Research Study

This study has highlighted certain pertinent issues that still require research attention in order to extend insights on the current state of knowledge on compliance in municipal waste management systems. These are presented in note form.

- Design and standardisation of variables in the measurement of waste streams
- Evaluation of SAWIS in relation to its interface with municipal waste directorates
- Organisational structure and efficiencies in service delivery
- Long term planning towards zero-waste
- Assessment of technical efficiency (TE) of the waste chain

8.6 Recommendations

A set of recommendations are made based on the findings from Chapters 4-6. These recommendations include further research avenues, to improve the quality of municipal waste management. An agenda of municipal waste management would be incomplete without considering the relationships within the structure of the institutional arrangement. Neutrality of the municipal internal leadership plays a major role in setting effectiveness in a municipality. This can be done by balancing politics and science in order to enhance the intersection of politics, science and policy. Waste management will then be given adequate attention by the municipal authorities. Ultimately, this will result in a healthy enabling environment for the waste system directorate to be more efficient. Specific recommendations are as follows:

- In an effort to end non-compliance and unbalanced municipal needs prioritization, municipalities would do well to consider waste management accomplishments as one of their top priorities. The realization of a balanced needs prioritization management would help to achieve a high level of success while remaining purposeful to the core business of the municipality. Prioritization helps to cope with the complex decision making challenges in priority management, by balancing responses to municipal roles and responsibilities.
- To enhance some basic waste policy initiatives and implementation, standardized units of measurement for compliance performance outcomes should be established. This also entails municipalities supporting the proposed WACOF framework for application on the ground. The measured requirements provide a clear guideline on the state of the observed performance versus expected temporal and spatial scope, scale and resolution. This includes providing appropriate measurable policies, procedures and expectations.
- Municipalities should initiate a “waste sorting at source principle” by using colour coded bins in their premises. This can be extended to other waste stakeholders such as households, schools, business outlets and public places. Buying the colour coded waste bins can be made compulsory for all residential, industrial, commercial and

government buildings. This could be enhanced through the setting up of recycling facilities.

- To achieve the optimal implementation of waste management compliance municipalities should facilitate collaboration between programmes in the IDP. In addition, municipal awareness and education programmes can be integrated with provincial and national programmes to avoid duplication of activities and to save money and time.
- One of the tools for achieving environmental compliance is effective and consistent control and regulation through enforcement of the by-laws. The future strategy to promote effective enforcement by local municipalities may involve strengthening their institutional capacities to manage and enforce waste by-laws, improving the legal and regulatory environmental frameworks and increasing public awareness and participation.
- In order to develop and improve the state of waste data generation, storage and usage system, municipalities should adopt the culture of record keeping. This provides an opportunity for success because information generated informs decision makers about what is happening on the ground. The waste data would also provide a baseline for planning, tracking and measurement of improvement.
- The establishment of municipal waste hierarchy operational procedures is one strategy that could improve high priority level to waste conveyance belt management, operation implementation and monitoring. Municipal waste hierarchy operational procedures provide clear guidelines about the requirements of each stage of the waste chain.
- The creation of periodic system monitoring of the waste conveyance belt will be of significance. It can be achieved if there are enforceable rules that contain sufficient requirements to ensure compliance with each stage of the waste chain. Monitoring creates the ability to notice the direction and magnitude of the deviation and breakdown of implementation of the requirement guidelines and standards.

- Through capacity building and mentoring, the municipal waste management directorate will be encouraged to comply with waste management policies. This could be achieved by empowering waste employees on how to read, understand and adapt to the policy requirements.
- Municipalities should initiate and provide platforms for environmental education to conscientize the communities on aspects regarding their obligation in waste separation at source, as well as environmental health aspects. These will empower waste stakeholders to understand, contribute and adopt proactive action concerning environmental issues. Integration and coordination of municipal community outreach programs and campaigns could be of help in waste management awareness and education. These reduce cost and time and as well overlapping duties such as disseminating information to the relevant stakeholders.
- The establishment of nurturing and support programmes aimed at establishing the municipality's abilities to manage waste effectively would allow growth and development in the implementation of waste management policy. Its ultimate goal is to assist the local government to respond effectively and equitably to the requirements of waste management policy, irrespective of their local municipality category or financial status. nurturing and support can be approached more proactively and seen as a way to strengthen and grow existing competence, rather than only responding to lack of competence in implementation of the waste regulations, because often approached from a point of deficiency. The main purpose of waste management system design nurturing and support is to effectively deploy the operational human resource for the management of waste. Nurturing is more than simply the relationship between policy developer and the end user. It requires purposeful processes and interactions that enable efficient progression of the waste policy end user, which are local municipalities and other waste management stakeholders. In addition, physical activities in each stage should be analysed in order to identify aspects relevant to conditions that are expected in management practice.

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APPENDIX 1

QUESTIONNAIRE FOR WASTE MANAGERS

This questionnaire is designed to facilitate the analysis of the current situation and issues of municipal waste management, in particular compliance with legal requirements and other requirements. Your responses will be treated with confidentiality. Please answer each question honestly.

Inquiries: Mudau N.V. Cell : 0722158401 Tel: 015 962 8591 E-mail : virginia.mudau@univen.ac.za
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PUT AN X OR WRITE YOUR ANSWER WHERE APPLICABLE

District municipality

Capricorn	Mopani	Vhembe
-----------	--------	--------

Local municipality _____

1. What is your highest level of education?

Matric	1
Other tertiary qualification	2
Tertiary qualification in Environmental Health	3
Tertiary qualification in Environmental Science	4
Other (specify) _____	5

2. How many years of service do you have in the waste management section?

Less one year	1
1 – 4 years	2
5 – 8 years	3
9 years and above	4
Other (specify) _____	5

3. KEY REFERENCE DOCUMENTS:

In the table below indicate which documents are available in your municipality:

Documents	1	2
Environmental management plan (EMP)	Yes	No
Waste management by-laws	Yes	No
Enforcement compliance guide	Yes	No
Waste hierarchy guide	Yes	No
Landfill licence	Yes	No
Landfill operational plan	Yes	No

4. How satisfied are you with implementation of the Waste Management Policy of 2008?

Very satisfied	1
Slightly satisfied	2
Not satisfied	3

5. If your answer to Question 4 is 2 or 3, what is the reason for your not being very satisfied?

Workload	1
Lack of integration and coordination	2
Lack of resources	3

6. Is the municipality waste collection service adequate?

Adequate	1
Slightly adequate	2
Not at all adequate	3

7. Is the rate of urbanization outstripping the capacity of the waste service in your municipality?

Not, it is not	1
Yes it is slightly	2
It is a serious problem	3

8. Is waste prevention and minimisation given a priority in your municipality?

Not a priority	1
It is regarded equally among other issues	2
A top priority	3

9. Do you have buyback centres in your municipality?

Yes	1
No	2

10. Do you have waste management projects or programmes that are not funded by the municipality?

Yes	1
No	2

THANK YOU FOR YOUR COOPERATION

APPENDIX 2

QUESTIONNAIRE FOR WASTE MANAGEMENT SUPERVISORS

This questionnaire is designed to facilitate the analysis of the current situation and issues of municipal waste management, in particular compliance with legal requirements and other requirements. Your responses will be treated with confidentiality. Please answer each question honestly.

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PUT AN X OR WRITE YOUR ANSWER WHERE APPLICABLE

District municipality

Capricorn	Mopani	Vhembe
-----------	--------	--------

Local municipality _____

1. What is your highest level of education?

Matric	1
Other tertiary qualification	2
Tertiary qualification in Environmental Health	3
Tertiary qualification in Environmental Science	4
Other (specify) _____	5

2. Indicate the level of compliance with the national waste management policy in your municipality.

Not compliant	1
Compliant with parts of it	2
Compliant with all of it	3

3. Give a reason or reasons for the compliance level you chose in Question 2.

Poor national policy interpretation at local level	1
Lack of compliance and penalty information to public	2
Lack of monitoring and policy implementation timeframe	3
Other (specify):	4

4. Based on your experience is waste management by-law enforcement consistent in your municipality?

Not consistent	1
Slightly consistent	2
Very consistent	3

5. If the answer in question 4 is “not consistent or slightly consistent” which of the following apply as the reason (select as many as applicable)?

Lack of enforcement policy and procedures	1
Lack of local enforcement structure	2
Lack of penalty information and dissemination	3
None of the above	4

6. Score the following municipal internal factors influencing waste management system status quo according to strength:

	1	2	3
	Not influential factor	Slightly influential factor	Influential factor
Integration and coordination			
Institutional arrangement			
Municipal needs prioritisation			
Lack of information and communication			
Insufficient budget			

7. Score each of the following external factors influencing waste management system status quo according to strength:

	1	2	3
	Not influential	Slightly influential factor	Influential factor
Lack of public interest and participation			
Public ignorance			
Social factors			
Economic factors			
Cultural factors			

8. Between internal (Question 6) and external factors (Question 7) which category has more negative influence on the municipal waste management system?

Internal factors	1
External factors	2

9. How often do you compile waste performance reports?

Monthly	1
Quarterly	2
Per semester	3
Annually	4
Never	5

10. How do you disseminate waste management information to the public?

	1	2	3
	Never use	Sometimes use	Always use
Electronic media			
Printed media			
Awareness campaign			
Other (specify) _____			
Never disseminate			

11. How often do you communicate waste management information with the public?

According to awareness programmes	1
On national environmental events days	2
By invitation from different stakeholders	3
Other (specify)_____	4
Never communicate	5

12. Which national environmental event do you always celebrate each year?

None	1
Water week	2
Arbour day	3
Cleaning day	4
Other (specify)_____	5

13. What is your household waste disposal chain of activity after collection?

Source point to disposal facility	1
Source point to temporary storage to disposal facility	2
Source point to temporary storage then to re-claimers and disposal facility	3

14. What is your business waste disposal chain after collection?

Source point to disposal facility	1
Source point to temporary storage to disposal facility	2
Source point to temporary storage then to re-claimers and disposal facility	3

15. Do you record waste data?

No	1
Yes, some.	2
Yes, all.	3

16. If the answer to Question 15 is “Yes, all”, is the available data actual or estimated?

Neither	1
Estimated	2
Actual	3

17. How is the public or waste stakeholders response to waste minimization programmes such as sorting at source?

Negative	1
Positive	2

18. Complete the table below by providing information of resources:

Number of litter pickers	Number of Door to door waste collectors	Number of vehicles / compactors	Number of drivers

THANK YOU FOR YOUR COOPERATION

APPENDIX 3
QUESTIONNAIRE FOR GENERAL WORKERS

This questionnaire is designed to facilitate the analysis of the current situation and issues of municipal waste management, in particular compliance with legal requirements and other requirements. Your responses will be treated with confidentiality. Please answer each question honestly.

Inquiries : Mudau N.V.
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 Tel: 015 962 8591
 E-mail : virginia.mudau@univen.ac.za

PUT AN X OR WRITE YOUR ANSWER WHERE APPLICABLE

District municipality

Capricorn	Mopani	Vhembe
-----------	--------	--------

Local municipality _____

1. Your work type:

Litter picking	1
Door to door waste collector	2

2. Your age:

19 years and below	1
20-49	2
50 and above	3

3. Your gender:

Male	1
Female	2

4. Which training related to waste management have you attended in the past five years?

Waste characterisation	1
Waste handling	2
None	3
Other (specify) _____	4

5. If, in Question 4, you indicated that you have attended waste related training, how many working days per week have you attended the training?

Seven days (Monday to Sunday)	1
Six days (Monday to Saturday)	2
Five days (Monday to Friday)	3
Saturday, Sunday and holidays by arrangement	4
Other (specify) _____	5

6. How many working hours per day do you work in the waste management section?

8 hours per day	1
6 hours in shift groups	2
Other (specify) _____	

7. If a waste container is not intact during collection day what do you do?

Do not collect and impose fine	1
Collect everything without imposing fine	2
Collect everything and impose fine	3
Other (specify) _____	4

8. If there is waste which is not supposed to be collected by the municipality in the collection point what do you do?

Do not collect	1
Collect	2
Do not collect and leave a note informing the owner of the waste where to dump	3
Other (specify) _____	4

9. Which of the following waste containers do you prefer at household waste collection points?

Bin (metal or plastic)	1
Refuse plastic bag	2

10. How serious is illegal dumping of waste in your municipality?

Very Serious	1
Serious to some extent	2
Not at all serious	3

11. What is the most common problem that you encounter during litter picking?

Sharp objects	1
Dead animals and snakes	2
Community negative attitude	3
Other (specify) _____	

12. What is the most common problem that you encounter during waste collection?

Torn respectable	1
Medical waste	2
Waste not at assembling point in time	3
In town stealing of wheels of the waste bin	4
Other (specify) _____	5

13. What is the most common problem when transporting waste?

Liquid leaking	1
No transport available	2
Other (specify) _____	3

14. What is the most common problem that you encounter when disposing of waste in a disposal facility?

No spotter	1
Lack of proper place to dispose	2
Exposure to health hazard (pollution)	3
Other (specify) _____	4

THANK YOU FOR YOUR COOPERATION

APPENDIX 4

QUESTIONNAIRE FOR HOUSEHOLDS

This questionnaire is designed to facilitate the analysis of the current situation and issues of municipal waste management, in particular compliance with legal requirements and other requirements. Your responses will be treated with confidentiality. Please answer each question honestly.

Inquiries : Mudau N.V.
 Cell : 0722158401
 Tel: 015 962 8591
 E-mail : virginia.mudau@univen.ac.za

PUT AN X OR WRITE YOUR ANSWER WHERE APPLICABLE

District municipality

Capricorn	Mopani	Vhembe
-----------	--------	--------

Local municipality _____

1. If your waste container is not collected on collection day what do you do to your waste?

Keep until next collection day	1
Dump at the nearest open space	2
Take the waste to the communal dumping site	3
Take waste to the municipal dumping site	4
Burn it	5
Other (specify) _____	6

2. Which of the following do you think is the cause of illegal dumping of waste within your area (you may select as many as applicable)?

Waste not collected on collection day	1
Public ignorance	2
People's none appreciation of the natural environment	3
Human upbringing environment	4

3. Who do you think is responsible for the education of the public about waste?

Teachers at school	1
Parents at home	2
Municipality	3

4. Have you ever attended an environmental awareness meeting or campaign in the past five years?

Yes	1
No	2

5. If your answer to Question 4 is No, give your reason for not attending environmental awareness events.

Never heard about it	1
Not important to me	2
Busy with something else	3

6. Are you willing to separate your household waste if there is a waste receptacle with different compartments?

Not at all	1
Sometimes	2
Definitely yes, always	3

7. Do you have eco clubs / schools in your area?

Yes	1
No	2

8. Which information about waste management do you often hear about or see every day?

Do not litter/ littering is prohibited	1
Prevent and minimise	2
Recycle	3
None	4

9. Where do you often get waste management information?

Non-municipal electronic media	1
Non-municipal printed media	2
Family and friends	3
Municipal media and campaign	4
Other (specify) _____	5

10. What is your opinion on municipal waste operational standards?

Satisfactory	1
Not Satisfactory	2

11. Give reason for the answer you stated in Question 10 if not satisfactory (you may select as many as applicable).

Lack of capacity	1
Poor communication strategy	2
Poor management	3
Collection inconsistency	4
Lack of public cooperation	5
Service by private company	6

THANK YOU FOR YOUR COOPERATION

APPENDIX 5

FIELD OBSERVATION CHECKLIST

OBSERVATION (disposal facilities, streets and town)	SCORES		
	1	2	3
1. Classification	1 = CGW	2 = SGB ⁻	3 = SGB ⁺
2. Waste permit	1 = In possession of permit	2 = Applied for permit	3 = No permit
3. Waster site ownership	1 = Local municipality	2 = Private company	
4. Site Operator	1 = Local municipality	2 = Contracted company	
5. Operation no. of days	1 = Monday to Sunday	2 = Monday to Saturday	3 = Monday to Friday
6. Operation time	1 = 7H00- 17H00	2 = 07H00- 18H00	3 = 24H00
7. Site notice board information	1 = Sufficient	2 = To some extent	3 = Not sufficient
8. Distance from residential areas	1 = less than 1km	2 = 1km to 3km	3 = 4km and above
9. Distance from source of water	1 = less than 1km	2 = 1km to 3km	3 = 4km and above
10. Status	1 = Controlled dump	2 = Partially controlled dump	3 = Not controlled dump
11. Fencing	1 = Well fenced	2 = Fenced but damaged	3 = No fence
12. Signposting	1 = Enough and directive	2 = Not enough	3 = No sign
13. Water and sanitation	1 = Available	2 = Not available	
14. Waste acceptance procedure	1 = Weighbridge	2 = Use of security guard	3 = No weighbridge
15. Control of vehicle access	1 = Well controlled	2 = To some extent	3 = No control at all
16. Spotter	1 = Available everyday	2 = Sometimes visit	3 = None
17. Equipment at plant	1 = Enough, in good condition	2 = Not enough and not in good condition	3 = None
18. Immediate covering of putrescibles	1 = Yes	2 = Sometimes	3 = No
19. Protective clothes for workers	1 = Well dressed	2 = At least one is not dressed	3 = Not at all
20. Final cover	1 = Done rehabilitated	2 = Partially done	3 = Not done
21. Prohibition of uncontrolled waste salvaging	1 = Prohibited	2 = Partially prohibited	3 = Not prohibited
22. Drainage of water away from the waste	1 = Well done	2 = Partially done	3 = Not done at all
23. General site maintenance	1 = Definitely	2 = To some extent	3 = Not at all
24. Burning of waste	1 = Do burn	2 = Do not burn	
25. Animals	1 = present	2 = Not present	
26. Waste type in the main streets	1 = Building materials (rubble)	2 = plastic and paper	3 = bottles and tins
27. Dumping in open space at residence edge (former black township)	1 = Very serious	2 = serious	3 = not so serious
28. Dumping in open space at residence edge (newly established residences)	1 = Very serious	2 = serious	3 = not so serious
29. Dumping in open space at residence edge (integrated or gentrified residences)	1 = Very serious	2 = serious	3 = not so serious
30. Littering in public places in town	1 = Very serious	2 = serious	3 = not so serious

APPENDIX 6
ETHICS CLEARANCE CERTIFICATE



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2013/10/30

ETHICS APPROVAL OF PROJECT

This is to certify that the next project was approved by the NWU Ethics Committee:

Project title: A process mapping appraisal of municipal waste management system compliance in Limpopo province, South Africa

Project leader: Prof Ruhiga Student: NV Mudau

NWU Ethics approval no: NWU-00123-13-A9

The Ethics Committee would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the Ethics Committee for any further enquiries or requests for assistance

Yours sincerely

A handwritten signature in black ink, appearing to read 'Marietjie Halgryn'.

Me. Marietjie Halgryn
NWU Ethics Secretariate

APPENDIX 7
COMPUTATIONS FOR FISHER'S EXACT TEST

Fisher's Exact Test for Compliance and IWMP

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	9.644 ^a	1	.002		
Continuity Correction ^b	7.160	1	.007		
Likelihood Ratio	12.390	1	.000		
Fisher's Exact Test				.002	.002
Linear-by-Linear Association	9.333	1	.002		
No. of Valid Cases	31				

^a 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.39.

^b Computed only for a 2x2 table.

Fisher's Exact Test for Operational Plan and Waste System Efficiency

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	27.231 ^a	1	.000		
Continuity Correction ^b	23.593	1	.000		
Likelihood Ratio	35.336	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	26.353	1	.000		
No. of Valid Cases	31				

^a 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.77.

^b Computed only for a 2x2 table

Appendix 7 (Continued) COMPUTATIONS FOR FISHER'S EXACT TEST

Fisher's Exact Test for Compliance and Recycling Facilities

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
	Value	df			
Pearson Chi-Square	4.973 ^a	1	.026		
Continuity Correction ^b	3.172	1	.075		
Likelihood Ratio	7.220	1	.007		
Fisher's Exact Test				.033	.029
Linear-by-Linear Association	4.813	1	.028		
No. of Valid Cases	31				

^a 2 cells (50.0%) have expected count less than 5. The minimum expected count is 2.48.

^b Computed only for a 2x2 table.

Fisher's Exact Test for Compliance with Weighbridge Availability onsite

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	13.459 ^a	1	.000	.000	.000
Continuity Correction ^b	10.644	1	.001		
Likelihood Ratio	14.240	1	.000	.000	.000
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	13.025 ^c	1	.000	.000	.000
No. of Valid Cases	31				

^a 1 cell (25.0%) have expected count less than 5. The minimum expected count is 3.48.

^b Computed only for a 2x2 table

^c The standardized statistic is 3.609.

Appendix 7 (Continued) COMPUTATIONS FOR FISHER'S EXACT TEST

Fisher's Exact Test for Limiting Factors and Waste System Efficiency

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.642 ^a	1	.200		
Continuity Correction ^b	.847	1	.357		
Likelihood Ratio	1.659	1	.198		
Fisher's Exact Test				.285	.179
No. of Valid Cases	31				

^a 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.77.

^b Computed only for a 2x2 table.

Fisher's Exact Test for Compliance and IWMP

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	9.644 ^a	1	.002		
Continuity Correction ^b	7.160	1	.007		
Likelihood Ratio	12.390	1	.000		
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Linear-by-Linear Association	4.813	1	.028		
N of Valid Cases	31				

^a 2 cells (50.0%) have expected count less than 5. The minimum expected count is 2.48.

^b Computed only for a 2x2 table.

Appendix 7 (Continued) COMPUTATIONS FOR FISHER'S EXACT TEST

Fisher's Exact Test for Compliance with Weighbridge Availability onsite

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	13.459 ^a	1	.000	.000	.000
Continuity Correction ^b	10.644	1	.001		
Likelihood Ratio	14.240	1	.000	.000	.000
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	13.025 ^c	1	.000	.000	.000
N of Valid Cases	31				

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Fisher's Exact Test for Limiting Factors and Waste System Efficiency

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
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Continuity Correction ^b	.847	1	.357		
Likelihood Ratio	1.659	1	.198		
Fisher's Exact Test				.285	.179
N of Valid Cases	31				

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APPENDIX 8

PUBLISHED PAPER

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A review of efficiency measures in South Africa's municipal solid waste management

N.V. MUDAU¹, T.M. RUHIIGA^{1*} and P.W. MALAN²

This paper reports the results of a survey of contemporary literature on waste management systems in order to assess the state of the use of efficiency measures in South Africa's municipal solid waste management. The methodology involved a classification of urban centres into three clusters and the choice of at least two cities in each of these clusters. A ground survey of waste facilities was carried out and results recorded on a structured observation schedule. Informal interviews were then conducted with officials of the waste directorate in each of these selected sites. A survey of literature followed in which the features of efficiency measurement approaches were extracted. A documentary analysis of local South African official sources on the measurement of MSW were then used to extract additional data. The data so collected were analysed using frequency distribution. The results indicated problems in the measurement of efficiency, an absence of a standard system of waste characterization, classification and reporting. These findings were then used as inputs into the design of an alternative scheme that integrates both process mapping and systems analysis. The limitations in the potential applications of the proposed scheme are acknowledged and implications thereof discussed.

Keywords: solid waste measurement, waste classification, process mapping, waste hierarchy, system analysis, technical efficiency, waste information system, South Africa

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INTRODUCTION

This paper presents an overview of the state of contemporary literature on efficiency measures of municipal solid waste management systems to provide a platform for analyzing municipal waste management in South Africa. The measurement of performance using specific indicators of the MSW tend to report results as per the entire system in spite of identifying a waste management hierarchy. There are limitations in the quantification of efficiency measures in municipal waste management where little attention is paid to the components of the system itself. Quantification of efficiency can be at different scales using different indicators, to reflect the degree to which current performance departs from expected levels. Ultimately, the desired outcome of efficiency measures is to use them to evaluate the overall performance of the MSW at different scales. To our knowledge, studies that investigate the measurement of efficiency in MSW at the municipal level, while well reported for developed countries hardly appear in the case of South Africa. Similarly we are not aware so far of any local studies where a combination of process mapping is imbedded within a systems approach to locate system discontinuities along the waste hierarchy chain. Analysis of existing municipal waste management systems (MSW) and actual operational performance (Karani & Jewasiekiewitz 2005) is important for testing the potential of process mapping. Eventually, the design of a methodology for quantifying efficiencies in waste management could be founded on an expanded theoretical base that integrates process mapping with systems analysis. This is significant in order to build assurance of the approach as well as tie it to existing knowledge and competences.

The main purpose the paper is to identify knowledge gaps in the waste management hierarchy and to outline the possibility of process mapping approaches in measuring performance. The key research question is: Is the management schema of municipal waste sufficiently configured to deliver an efficient system? In line with this, three prepositions to underpin the study are advanced: (i) global approaches in waste management are diverse showing a range of technological inputs; (ii) that the performance of waste systems across urban areas of different size and standards of living require designs that are adaptive to existing local conditions and capacity constraints; (iii) that integrating process mapping with systems analysis offers opportunities that have not so far been exploited locally in municipal waste management and (iv) that efficiency measures are critical in tracking performance at the level of individual municipalities. In line with these, the following objectives need to be addressed: (i) survey contemporary literature in order to identify knowledge gaps; (ii) briefly characterize the MSW system in South Africa; (iii) identify common measures of MSW at the municipal scale; (iv) apply process mapping imbedded within systems analysis to the assessment of efficiency in MSW and (v) design an alternative schema for measurement of efficiency.

In 2011, South Africa produced 59 million metric tonnages of general waste (GW) while an estimated 5.9 million was recycled translating to about 10% with a balance of 53.5 million tons land-filled (DEA 2012). Municipal (GW01), commercial and industrial waste (GW10), generated within municipalities represent roughly 20.16 million tons when the recyclables are included. Few studies on waste

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characterisation in South Africa have been undertaken to date, save for GDACE (2008) for Gauteng Province and Gibb (2008) for Cape Town. According to the department (DEA 2006b), MSW quantities are increasing faster than economic growth, giving an example of Cape Town which registered a 5% growth per annum. The voluntary reporting of waste operations to the waste information system (SAWIS) means that the lack of accurate waste data remains a serious challenge in South Africa (DEA 2012) though the recent promulgation of the SAWIS regulations (RSA 2012a) should provide a framework for reporting waste data to SAWIS. Godfrey (2008) on waste collection reports that in 2005, only 68% of the municipalities was collecting some form of waste data. Sixty two percent of those municipalities collecting data believed that they were collecting unreliable data. It was further reported that 74.6% of municipalities collecting waste data were collecting data on landfills and 46.5% data on waste generators (not waste generation). Only 33.8% collected data on waste transportation, 14.1% on recyclers and 4.2% on waste treatment (Godfrey 2008). Since the municipalities collecting waste data often do so at landfills, only waste disposed of at municipal landfills are accounted for. While the larger well established municipalities may have since then improved their operations, this picture has not changed much for the majority of municipalities. Funding for municipal waste management has not been seen as a priority leading to persistent cases of under-funding across the country and low levels of collection efficiency. A series of municipal landfills dot the countryside though specialized facilities for medical and toxic waste remain far apart raising transportation costs. Overall, efficiency issues are linked to general problems of urban management (Nhlapo *et al.* 2011, Ruhiiga 2012) characteristic of provincial and municipal governments in the country. Waste recycling has remained under private operators and NGO's which focus mainly on glass, metal and paper.

With reference to approaches in waste management, Manaf *et al* (2009) reports that environmental issues are increasingly well publicized and they have wide-ranging implications for industry. Decision-making in many countries has undergone significant change (Sufian & Bala 2007) and although considerable efforts have been made by many governments in tackling waste-related problems, there are still major gaps to be filled in this area. Literature reveals a diversity of waste management systems tracing back to environmental protection concerns that came to the forefront in the 1970s, with an initial focus on eliminating uncontrolled disposal, followed by the systematic upgrading of technical standards (Kolikkathara *et al* 2011). The models developed during early 1980 extended the system boundaries by including municipal solid waste management (MSW) at the system level (MacDonald 1996).

During the 1990s, the concepts of sustainable waste management, integrated waste management, and recycle-reuse-resale were included in most models (Weng & Fujiwara 2011). Models of waste management systems (Morrissey & Browne 2004) may be put in three categories: those based on cost-benefit-analysis, those based on life cycle assessment (LCA) and those based on multicriteria decision making. But these models are concerned with refinements of weight allocations rather than the decision making process itself. But most models are not addressing the three critical

components simultaneously: environmental, economic and social. With reference to construction and demolition waste (C&D), Yuan *et al.* (2012) propose a model as a platform for simulating effects of various management strategies on C&D waste reduction. Using a systems dynamics methodology (SDM), they build into the model imbedded social, managerial and economic components. Assamoi and Lawryshyn (2012) compare land-filling and incineration options in MSW and report that the waste diversion initiatives were more effective in reducing the organic portion of the waste but that land-filling remained a better financial option in the short term. Consoni and Gigano (2012) compare waste gasification against conventional waste-to-energy (WTE) technologies currently in use and conclude that the former shows potential benefits with respect to material recovery and operation/emission control. Merrild *et al.* (2012) compare waste recycling against incineration and find that there are environmental benefits in recycling glass, steel, paper and aluminium instead of incinerating it.

Most solid waste management systems report in terms of solid waste generation, its characteristics, collection, transportation, disposal sites and administration (Kamperis *et al.* 2012, Lee *et al.* 2012, Laner *et al.* 2012). The systems approach is used when an organization sets environmental objectives and targets to be guided by standard requirements (Morrissey & Browne 2004). Planning for sustainable waste management needs to address several interconnected components in order to understand the dynamic nature of their interactions (Seadon 2010). It is this requirement that modeling of individual components of the MSW in current literature often fails to meet. Systematic techniques have been applied to handle municipal solid streams through a range of integrative methodologies in recent years. A sustainable waste management system should incorporate system feedback loops that harmonize the system operation (Seadon 2010, Pires *et al.* 2011). Issues of compliance elicit responses that centre on law enforcement with limited focus on the extent of compliance in the physical and managerial components of MWS. There is a significant body of literature developed in the United States (EPA 2007) on environmental compliance and enforcement (Stonier *et al.* 2008). INECE (2008) developed a guide on performance measurement for compliance and enforcement practitioners. Performance indicators for compliance and enforcement programs describe a level of activity or commitment made by government, and a set of results which contribute to an important social goal such as reducing environmental pollution (Stahl 2003). Markowitz and Michalak (2004) state that to ensure compliance programs achieve the intended results; program managers should periodically assess their performance measures to ensure that they are reliable, relevant, feasible, and comparable with others' efforts. Stonier *et al.* (2008) reports on measures needed for success suggests that effective management of environmental compliance and enforcement programs depends on the ability to communicate program success and progress. Gray and Shimshack (2009) reported that OECA and other environmental agencies are increasingly called upon to measure and evaluate the effectiveness of their enforcement activities.

Efficiency measures in solid waste management

Waste systems performance activities are meant to prevent avoidable waste from households and should be identified as issues which management practice should address to minimize waste (Shmelev & Powell 2006). Evaluation provides information on strategy to assess if the right action has been done, effectiveness in achieving expected outcomes, efficiency in optimizing resources, client satisfaction and lessons learned (Kusek & Rist 2004). The waste management hierarchy (WMH) is a recognized model for conceptualizing waste reduction and it has been adopted by most industrialized nations. The rational philosophy of WMH advocates waste avoidance, minimization, recycling, recovering, treatment and disposal (Shaw & Blundel 2010). The fundamental purpose of establishing hierarchical system measures is to improve efficiency in performance because work that is not measured cannot be managed since there is no objective information to determine its value (Hatry & Wholey 1999). Performance reporting and variance analyses need to be carried out frequently because reporting enables timely corrective actions needed for effective management control (Butler & Fekete 2009). The focus of strategic performance is to measure and monitor the implementation and effectiveness of an organization's work (Behn 2003). The MSW performance depends directly on its design capability (Rhoma *et al.* 2011). The impact in waste management can be measured using indicators to provide ultimate tests for the success of waste management programmes (Misra 2004, Wilson 2007).

Wherever source reduction is not feasible, recycling should be encouraged. Where it is not feasible to reduce or recycle hazardous waste, the waste should be treated in an environmentally safe manner prior to disposal. This minimizes the present and future threat to public health and the environment (ISO 2006, RSA 2008, Van der Walt 2010). Source reduction takes its place at the pinnacle of the waste minimization hierarchy because recycling and treatment options are likely to pose the lowest environmental risk. Both Ngoc and Schnitzer (2009) and Asase *et al.* (2009) assert that approaches for source reduction involve operational practices that include inventory control. Bodart *et al.* (2011) indicate that the prevention principle which reduces generation of waste at source is an important primary objective and hence places it at the top of the waste hierarchy.

Certain guiding questions are paramount in understanding the role of efficiency measures. These centre on issues of relevance, targets, priorities, indicators, optimization of inputs and impact of intervention on public health. The weights attached to these issues vary with particular waste directorates and the scale capacity across time and location. Targets which vary in time and space may be referred to as quantified performance levels which are to be reached over time and which are measured by indicators. The minimum requirement for the formulation of quantified targets appears to be essential to any good waste prevention programme. As the European Environment Agency itself has noted (Gray & Shimshack 2009) a waste policy which employs a hierarchy without any quantitative benchmarks is very ineffective. Shaw and Blundell (2010) have developed a model in which system boundaries are defined together with the internal and external environment. They indicate the role of analysis and actions that eventually lead to specific system deliverables. It is noted that the use of such an approach demands the examination

of each phase in the “life” of the product, process or service under investigation (Clearly 2009; Pires *et al.* 2011). A common approach to this end is the use of life cycle assessment.

MATERIALS AND METHODS

A quantitative research design applies built around a ground spot survey and observation of six sites spread to be representative of large cities, secondary cities and small towns; informal interviews with municipal officials specifically in the waste management directorate, documentary analysis of South African official sources on waste management, and literature review. The unit of analysis was the waste directorate of each municipality- irrespective of size and location: no sampling was carried out but sites for observation represented a random sample of six sites following the demarcation of urban clusters. A systematic ground survey of several municipal waste facilities across the country was conducted and salient features captured for a selection of cities and an observation schedule. The survey provided information on the general characterisation of the MSW in the country. This was followed by documentary analysis of official publications of the Department of Environmental Affairs (DEA) and other related government departments with overlapping interests in waste management. This survey generated numeric information about performance measurement with respect to the MSW and challenges around waste management. Data analysis involved the use of frequency distribution from the primary data or from existing official secondary data from the DEA reinforced by annual reports of various municipalities. A survey of literature was based on the use of internet search engines with the following terms: municipal solid waste, South Africa, waste management and, efficiency measures. This generated information on the existence of knowledge gaps on MSW. We identify knowledge gaps at this level. Thereafter, we develop a set of measures that could be mobilized into a schema for testing efficiency. We then present the appropriate schema and discuss its characteristics.

RESULTS

Knowledge gaps. The literature review in section 2 of this paper highlighted several gaps especially with reference to MSW in South Africa. The classification of waste in the form of standardized codes remains unresolved. Research reporting characterisation of waste streams is almost non-existent. The use of process mapping and of systems analysis in studying the interface along the waste hierarchy remains an un-researched area. The absence of a centralised system, until recently of reporting data has meant that typical analytical studies widespread in developed countries hardly apply in the case of South Africa. The result is that there still exist spaces in our understanding of the state of MSW at different scales. The measurement of performance, where this occurs and is reported, deals with the entire MSW system: we still do not know much about the actual dynamics of this and the changing trends affecting its efficiency in different areas.

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Measuring MSW efficiency. For municipalities, the following with regard to waste generation-collection and disposal are commonly reported: the amount of waste by mass (metric tons) generated, recycled, treated, land-filled and the recycled as a percentage of the total waste. This applies to both general waste (GW) and hazardous waste (HW).

Table 1. Percentage municipal waste generation by province, 2011.

Province	Kg/capita/annum	Waste generated as % of total waste
Western Cape	675	20
Eastern Cape	113	4
Northern Cape	547	3
Free State	199	3
KwaZulu-Natal	158	9
North West	68	1
Limpopo	103	3
Mpumalanga	518	10
Gauteng	761	45

Source: DEA (2012)

Table 1 shows the distribution of waste generation by province as of 2011. It will be noted that Gauteng and the Western Cape top the list accounting for 65% of the total. These two happen to score the highest GDP and the corresponding per capita income. Note that in column 2 showing per capita generation per annum, Northern Cape, in spite of having a population of less than 2 million as of 2011 (StatSA 2012), scores 4th overall position. In Table 2, the categorization of hazardous waste has recently changed from SANS 10228 to a new system reported in (RSA 2011, RSA 2012b) such that many organisations still report data as per the old categories (DEA 2012). Note that, electronic and electrical waste appears in categories, GW18 and HW 18 meaning that the actual apportionment would require the carrying out of tests to establish the existence or otherwise of toxic compounds in such waste first.

At the individual municipal level, empirical evidence shows that there is no standardised system for measuring efficiencies in MSW. The actual practice varies across these municipalities but generally, the municipalities that house the largest urban centres perform better. But even here, the absence of a standardised performance system means that MSW is reported in a manner that makes it difficult to compare municipalities or even individual cities.

Table 2. Classification schedule for waste management.

Level 1	Level 2	Level 3	Level 4
General waste	GW01 Municipal waste	Hazardous waste	HW01 Gaseous waste
	GW01 Municipal waste		HW02 Mercury containing waste
	GW10 Commercial and industrial waste		HW03 Batteries
	GW13 Brine		HW04 POP Waste
	GW14 Fly ash and dust from miscellaneous filter sources		HW05 Inorganic waste
	GW15 Bottom ash		HW06 Asbestos containing waste
	GW16 Slag		HW07 Waste Oils
	GW17 Mineral waste		HW08 Organic halogenated and / or sulphur containing solvents
	GW18 Waste of Electric and Electronic Equipment (WEEE)		HW09 Organic halogenated and/ or sulphur containing waste
	GW20 Organic waste		HW10 Organic solvents without halogens and sulphur
	GW21 Sewage sludge		HW11 Other organic waste without halogen or sulphur
	GW30 Construction and demolition waste		HW12 Tarry and Bituminous waste
	GW50 Paper		HW13 Brine
	GW51 Plastic		HW14 Fly ash and dust from miscellaneous filter sources
	GW52 Glass		HW15 Bottom ash
	GW53 Metals		HW16 Slag
	GW54 Tyres		HW17 Mineral waste
	GW99 Other		HW18 Waste of Electric and Electronic Equipment (WEEE)
	HW19 Health Care Risk Waste		
	HW20 Sewage sludge		
	HW99 Miscellaneous		

Source: DEA 2012.

Some municipalities provide efficiency measures biased towards the human capital component of waste management directorates. Others emphasise budgetary allocations and returns on investment. Yet others focus on the technical deployment of equipment and tools in the waste hierarchy. Overall however, the ability of municipalities to provide an efficient and modern MSW system is constrained by inadequate financing both at the provincial and at the municipal levels. This is made worse by a record of poor service delivery since 2001 and the corresponding

Efficiency measures in solid waste management

labor disputes between sections of organised labor and municipal management. There is also a low level of political will in supporting and enforcing high levels of compliance with environmental regulations and guidelines. This is a position raised by Karani and Jewasikewitz (2006).

Application of systems analysis. The systems approach is appropriate when analyzing the obstacles to service delivery. Systems are created to show internal networks and how processes lead to change. In MWS, we deal with open systems characterized by a linear structure of inputs-process-output-outcomes as shown in Figure 1. Each of these elements operates-often as a sub-system feeding into the next stage. It follows that the separation between the elements provides an interface whose time space behaviour is often not appreciated.

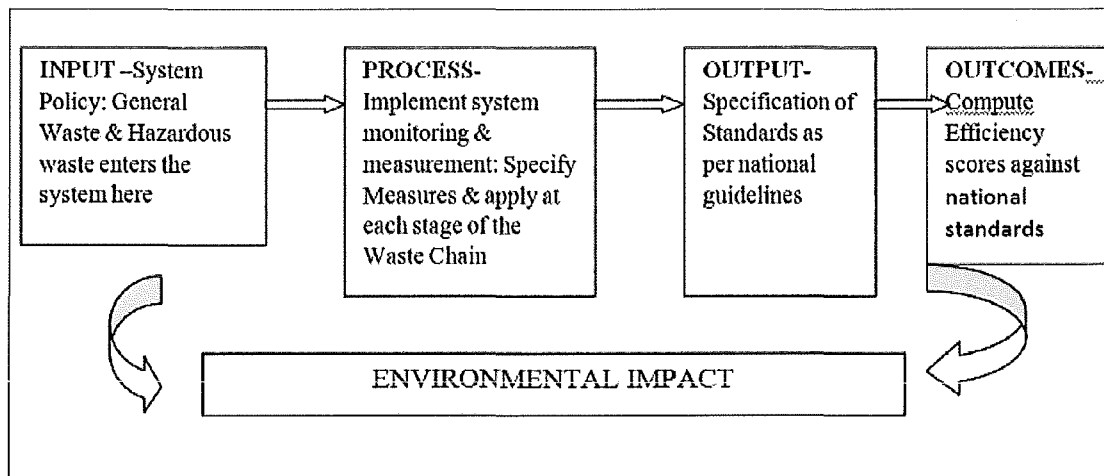


Figure 1. Waste systems analysis. (Source: Authors)

Systems analysis involves the components of the MSW and how they interact with the internal and external environment (Ming *et al.* 2006; Meadows 2009). Systems analysis techniques have been applied to MSW streams in many countries through a range of integrative methodologies in the last few decades. But there is limited literature reported on the waste management challenges that face municipalities in developing countries (Godfrey 2008, ADB 2002; ECA 2009). Process mapping (PM) tracks and analyzes the steps in a process by looking at the sequence of steps (See figure 1), the time-activity configuration at each node (interface) and the behavior of individual flows that link these nodes. The approach makes it possible to eliminate those segments of flows and or nodes not needed for better efficiency (George 2010).

In Figure 2, process mapping is integrated into the systems approach to indicate the responses of the waste chain in time and space. Depending on the size and sophistication of the waste directorate, the organizational tasks around waste management involve a set of protocols for control at each stage. There is a need to observe and to measure the time interval along the waste chain as waste moves from one stage to another. This literally amounts to some form of simplified network analysis aimed at testing whether each flow in the system is delivering its expected capacity. It is necessary to quantify the physical and financial resources deployed

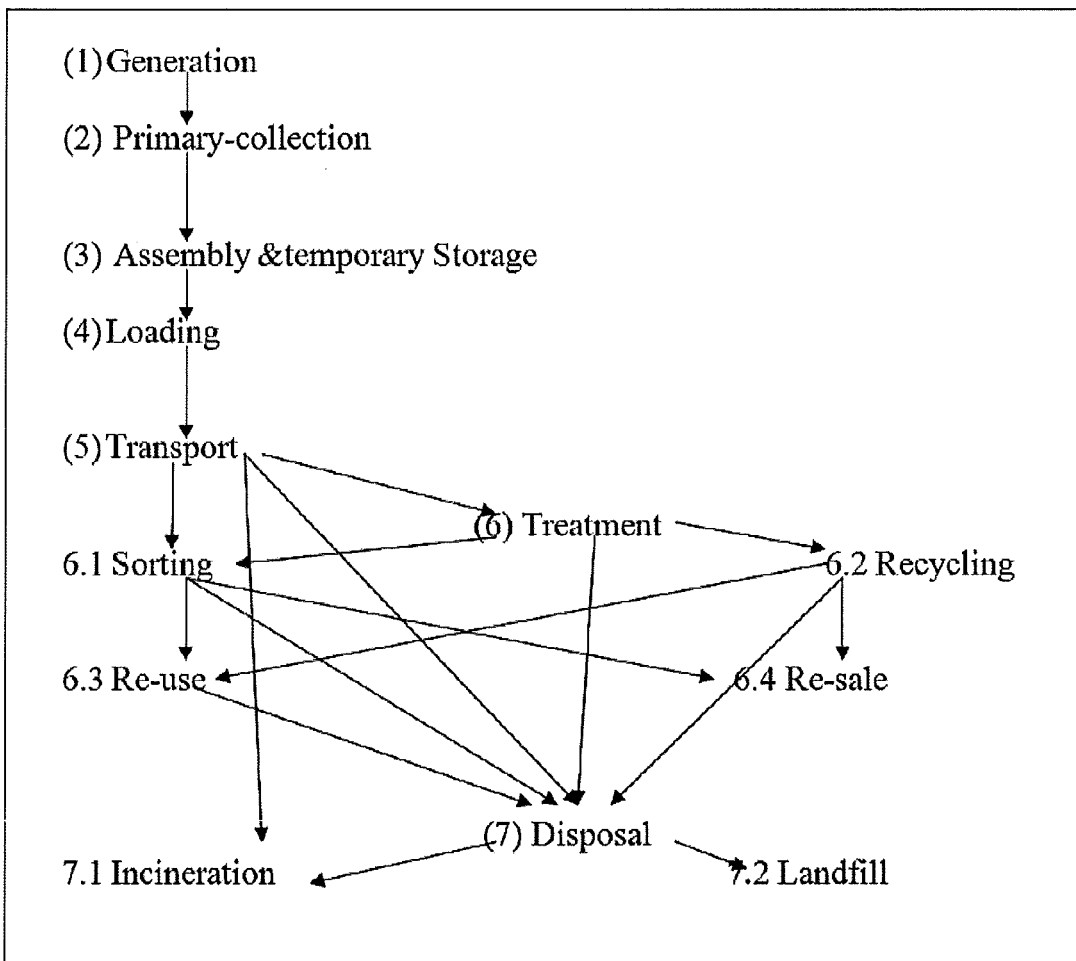


Figure 2. Incorporating processing mapping into the waste chain. (Source: Authors)

in delivering each stage and, to specify standard operational procedures. This presupposes the design of criteria for assessing performance. Combining process mapping this way into systems analysis provides a mechanism for identifying design weaknesses in the overall waste chain and points to areas where corrective interventions can be initiated. Current approaches in South Africa through which the efficiency of the MSW is reported do not adequately build these elements in their measurement procedures.

DISCUSSION

We now integrate both the original proposition advanced in the introduction with the objectives of the study before advancing an alternative schema. Key knowledge gaps picked up in the literature review highlighted issues around the characterisation of waste streams, the use of process mapping and of systems analysis in analyzing the interface along the waste hierarchy, a centralised system of waste reporting, and until recently-the reporting of waste on the basis of which typical analytical studies are not possible. The MSW in South Africa has been briefly shown to be negatively impacted by inadequate funding, problems of

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management capacity, the lack of adequate political will to enforce regulations and guidelines, the absence until recently of a centralised waste reporting structure and, diversity in the way efficiency is measured and reported. These conditions provide the rationale for suggesting an alternative approach aimed at overriding some of these constraints.

One consistent characteristic of the literature surveyed is the fact that different measurement approaches apply to different forms of waste and the levels of sophistication in waste management vary across South Africa. Efficiency measures are reported in current literature based on either cost or benefit approaches, the use of ISO standards, multi-criteria decision modeling and life cycle assessments. A combination of qualitative and quantitative evaluations applies.

The development of numerical measures of efficiency in MSW systems is essential to allow for comparisons across municipalities in one country and in terms of country studies. Such a quantitative dimension seeks to reduce the negative impact of waste and to minimize the quantity of waste generated. Consequently, whilst the European wording may not be particularly clear in this instance, the incorporation of quantified targets into waste prevention programmes should be considered as appropriate, and therefore as a requirement. To this end, we present a schema in Table 1 for managing efficiency measures at different urban scales in South Africa. From the onset, the schema assumes that in each municipality, systems for capturing data on waste generated, stored, treated, re-used, recycled, recovered and disposed are already in place. Clearly, such an assumption limits the potential number of municipalities that can put the schema in practice at present.

Efficiency measures for waste management are housed within the context of constraints of capabilities, budget, human resources, policy and environmental management systems in place. Efficiency measures when seen in the context of systems analysis with an in-built process mapping component vary between stages of the waste hierarchy. In Table 3, these are classified in three categories; technical, economic and managerial and for each stage, a possible set of measures is indicated. This classification remains tentative and is not exhaustive, just as the allocation of measures to specific categories can be varied. But the scheme indicates a possible way of bringing to the fore the critical need to approach efficiency at the point of individual stages of the waste hierarchy (Clearly 2009, Pires *et al.* 2011). Through this approach, it becomes possible for any waste management directorate to trace and isolate those stages of the hierarchy where the most serious system flaws exist and to target these. It also makes it possible to work out operational costs apportioned to each of these stages thereby providing a simple technique for estimating operational costs for the entire system and how efficiently, the system is working to deliver a service to the urban population. The sophistication of the scheme in Table 1 will depend on technology and management levels already in place and the structure of current funding. This varies between countries, cities, and waste management directorates and in time. Underlying the scheme is an inbuilt flexibility making it possible for a selective isolation of which measures to employ in measuring performance efficiency.

Table 1: A tentative scheme for efficiency measures.

Process stage	Technical	Economic	Managerial
1. Generation	*% of waste generation at base (household, commercial and institutions) *% of waste reduction at base	*Savings by value * Extent of household sorting by volume * Per capita waste generation in kg per annum	*Extent of environmental awareness in % *% increase of staff competency (education and training)
2. Assembly, Storage & Loading	* Time lag between delivery and removal * Mean volume of stored waste	* Mean time to load one vehicle * Number of vehicles deployed per trip * Vehicle capacity in metric tones * mean number of work hours per site per trip	* Extent of trip scheduling * Deviation lag between scheduled time allocation and actual time used per trip
3. Collection	*% of proper waste storage containers *% of number of bins in suitable collection point in time *Time spent for loading *Number of workers per vehicle	*% decrease in time wasters activities *% decrease in operational cost	*% reduction on collection schedule complaints *% reduction on collection frequency *% increase in number of days/weeks waiting for the next collection *% increase in public perception *% reduction in volume of waste collected
4. Transport	*Vehicle/ households ratio *Fleet Capacity *% of value for equipment	*% increase in asset value	*% decrease in vehicle breakdown
5. Treatment	* Generation-recovery ratio *% of waste that is recycled *% of resale waste recovered * Incineration * Biochemical treatment	*% of profit margins *% of product output	*Extent of environmental awareness in % *% increase of staff competency (education and training)
6. Disposal	*Landfill size *Life span of the landfill in years*Landfill capacity *% reduction of volume of waste to landfill	*Reduction in value of liability fines	*Extent of consistency and validity of weighbridge and material data sheet in % *% decrease of budget allocated for progressive rehabilitation *% reduction in landfill environmental impact

Source: Authors

CONCLUSION

This paper has presented a broad review of the state of contemporary research on municipal solid waste management. The findings indicate a significant volume of research literature across the full breadth of waste management. Where systems analysis has been used as a technique, the inclusion of process mapping remains limited. A parallel volume of research work consistently reports efficiency measures from the point of view of the entire waste system. The use of process mapping within the context of systems analysis remains poorly represented in current literature. Municipal solid waste management is beset by constraints of inadequate funding, expertise and management capacity. A tentative schema developed in this paper that combines process mapping and systems analysis and identifies possible measures at

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each stage of the waste hierarchy could offer an alternative technique for targeting efficiency measurement at the different stages of the waste management hierarchy. Further work in this direction is justified. While expected to adhere to national waste management guidelines, individual municipalities should adapt these to suit their local circumstances. Waste classification, characterization and reporting should be in line with the requirements of SAWIS to facilitate a system of waste reporting by all municipalities across the country. In this regard, municipalities-through their waste management directorates - should adopt a measurement system that has adequate inbuilt safeguards that allow for comparison of performance across the entire country. Fourth, it is necessary that municipalities appreciate the link between the increasing volume of solid waste generated and urbanisation and, initiate appropriate long-term planning measures for waste management.

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