Title	Developing integrated and sustainable municipal solid waste management systems in low-income contexts : Lessons from Maputo City, Mozambique
Author(s)	Dos Muchangos, Leticia Sarmento
Citation	大阪大学, 2017, 博士論文
Version Type	VoR
URL	https://doi.org/10.18910/61733
rights	
Note	

Doctoral Dissertation

Developing integrated and sustainable municipal solid waste management systems in low-income contexts: Lessons from Maputo City, Mozambique

Letícia Sarmento dos Muchangos

January 2017

Division of Sustainable Energy and Environmental Engineering
Graduate School of Engineering
Osaka University

Preface

The research work presented in this PhD thesis, titled "*Developing integrated and sustainable municipal solid waste management systems in low-income contexts: Lessons from Maputo City, Mozambique*", was performed at the Division of Sustainable Energy and Environmental Engineering at Osaka University, in Japan, from December 2013 to November 2016, under the supervision of Professor Akihiro Tokai, with collaboration with Ms Atsuko Hanashima from Osaka Sangyo University.

The overall work completed is included in six manuscripts prepared for scientific journals. The first manuscript, *dos Muchangos et al. (2015a)*, provide an outline of the municipal solid waste management policy in effect in Maputo City and identify the barriers hindering its performance. In the second manuscript, dos *Muchangos et al. (2015b)*, elucidate the hierarchical and cause-effect structures of those barriers and classify the influential and affected barriers to the waste management system. The third manuscript by *dos Muchangos et al. (unpublished)*, is concerning an introductory depiction of the stakeholders' outlook in the waste management system, comprising their identification, assessment of role, power, interest, knowledge and satisfaction, as well as, unveiling their degree of connectivity within the system.

Subsequently*, dos Muchangos et al. (2016a),* describe and quantify the main flows of municipal solid waste in Maputo City, in a past-to-present analysis, whilst in a short communication type of manuscript, *dos Muchangos et al. (2016b),* classify the input data uncertainty and calculate the uncertainty and the sensitivity of the results from the quantification of flows. Following-up the quantification of the main flows of waste, in the last manuscript, *dos Muchangos et al. (unpublished),* present an estimation of the greenhouse gases contribution and the costs associated with the current and alternative options for municipal solid waste treatment and final disposal methods in Maputo City.

January 2017

Letícia Sarmento dos Muchangos

Acknowledgements

My special and sincere gratitude to Professor Akihiro Tokai, my supervisor, who steadily guided and motivated me through the process of conducting this research. Since when I was merely an applicant for his supervision, Professor Tokai have been attentive and affirming of my potential, which is very humbling and reassuring. I am very thankful for the learning and professional growth opportunities that he provided.

A word of appreciation to Hanashima-sensei, who have been closely following and supporting my doctorate journey, and, at all times, actively and enthusiastically embraced my development. I would also like to acknowledge the role of my peers in providing helpful feedback to improve my research progress.

I must also recognise my former professors from the master's course, Professor Baizhan Li, Dr Yuanyuan Liu and Dr Meng Liu, from Chongqing University, for encouraging and backing up my efforts to proceed to a doctoral program.

To my first and forever teachers, my parents, Aniceto and Leontina, thank you for being a source of inspiration and for creating an environment that allows the freedom to pursue my aspirations and my self-development. To Esmeralda and Nicole, my sisters, your existence, understanding and unconditional friendship is fundamental for me, and I will continuously strive to absorb your most valuable principles. I am proud and privileged to be your daughter and sister.

To the family and friends that unwearyingly follow and support my endeavours, I deeply appreciate and thank each one of you.

I am grateful and hold singular admiration and affection to Mauro, who continues to believe and encourage me while displaying boundless companionship and love. I am extremely fortunate to witness your determination in facing and overcoming life obstacles, and so, undeniably learn and draw motivation from you.

Last, but not least, I dedicate this thesis to my niece Aliah, for being a miracle of life and always putting a smile on my face. She is a striking reminder of the importance to safeguard the wellbeing of the future generations.

Abstract

Municipal solid waste (MSW) has a significant degree of complexity and represents one of the major challenges of the 21st century in urban settings of all contexts. The challenge is particularly acute in the cities from the lowest-income countries, where poor waste management practices and related public health implications continue to be problematic, thus, municipal solid waste management (MSWM), being considered one of the most immediate and serious issues in these locations. Maputo City, the capital of Mozambique, represents an example on how low-income societies have been failing to create and maintain MSWM systems, despite the continuous efforts from the local authority. The challenges and problems within the MSWM system in Maputo City have been increasing, ranging from technical to non-technical problems, including weak institutional and management structure, lack or fragile relationships between stakeholders, low public awareness and participation, waste generation increase, limited waste collection coverage, financial unsustainability, inadequate infrastructure and equipment, and unsound waste treatment and final disposal schemes.

The aim of this thesis is to evaluate a MSWM system to propose improvement measures and pathways, as a contribution to the decision-making process towards integrated and sustainable systems from low-income contexts, in a case study of Maputo City, Mozambique. The study was conducted based on the Integrated Sustainable Waste Management (ISWM), a comprehensive approach that considers the practical and technical elements of the waste management system, its stakeholders, and the enabling aspects. Thus, several analytical decision-making tools and system analysis methods were applied to respond to each of the topics addressed.

Firstly, in Chapter Three, the policy and institutional aspects were accessed, through the identification and evaluation of the barriers to the current MSWM policy in Maputo City. The findings indicated the presence of 26 barriers distributed within six policy instruments - three for legislation and regulation; three for voluntary agreements; four for economic instruments; five for education and influence over behavioural change; four for monitoring, information and performance assessment; four for choice of technology; and three for community linkages. From the identified barriers, nine, which are mainly related to institutional weakness and lack of cooperation among stakeholders, are classified as influential/cause barriers, that is, barriers that contribute the most to the poor waste policy performance.

In Chapter Four, the main stakeholders in the MSWM system, their role, interest, power, and the overall access to information, knowledge and satisfaction with the structure and functioning of the system, were evaluated; and the interrelationships related to the

partnerships and collaborations and the sharing of information were also clarified. That resulted in the identification of 35 stakeholders, categorised among six key groups – the government, civil society, academia, service users, donors and cooperation agencies, and the private sector. All government institutions, a donor and cooperation agency, an academic and a private sector institution, and two organisations from civil society, featured as the most powerful and interested stakeholders. The stakeholders with interest in the system, but with little power, included the remaining stakeholders from academia, a civil society organisation, and three stakeholders from private sector. The remaining stakeholders presented much reduced power or interest in the system. Moreover, on the analysis on partnerships and collaborations and the sharing of information, at least one stakeholder from each group exhibited a prominent set of connections with other stakeholders, however, in general, stakeholders showed a significant lack of connectivity in both types of interrelationships.

The following Chapter Five dealt with the understanding of the physical elements of the waste management system in Maputo City and the estimation of MSW flows for the years 2007 and 2014. The findings demonstrated that after MSW generation, MSW follows five main routes, either reused and recycled at the source, sent to material recovery markets, sent to formal and informal sites, uncollected, or disposed of in illegal dumpsites. Between the studied periods, MSW generation increased from 397×10^3 tonnes to 437×10^3 tonnes, and material recovery increased from 3×10^3 tonnes and 7×10^3 tonnes, yet, far below the potential. Waste final disposal in open dumps and illegal dumpsites triplicated from 76×10^3 tonnes in 2007, to 253×10^3 tonnes in 2014, due to the significant increase of waste collection coverage. The study also demonstrated the existence of gaps in the data compilation and consistency, causing the results to vary in average, between 29% and 71%, in 2007, and between 41% and 96%, in 2014. In turn, the sensitivity analysis clarified the parameters that influence each flow of MSW the most, which include, the rate of waste reused and recycled at the source, waste processed for recycling, MSW in the inner city, MSW in the municipal districts 6 and 7, collection rate, and illegal dumping rate.

In Chapter Six, an assessment of the current and alternative waste treatment and final disposal schemes was completed, to estimate the greenhouse gas (GHG) emissions and the costs. The business-as-usual scenario, involves MSW being finally disposed of in open dumps, while in the alternative Scenario 2, MSW is disposed of in a sanitary landfill, and in the Scenario 3, MSW is recovered via recycling and biological treatment (3A - composting or 3B - anaerobic digestion), and the remaining MSW is disposed of in a sanitary landfill. The most environmentally impactful scenarios were Scenario 2, with GHG emissions values of 260,621 tonnes CO_2-eq per year, and the business-as-usual scenario with 201,112 tonnes CO_2-eq per year, while Scenario 3A and 3B showed negative net GHG emissions, -296,008 tonnes CO_2-

eq per year and -211,603 tonnes CO_2-eq per year, respectively. In the cost perspective, Scenario 2 followed by Scenario 3A, presented the least costly alternatives, less than US$ 1.0 million per year, and around US$ 3.5 million per year, respectively. On the other hand, the business-as-usual scenario displayed the highest total cost, US$ 27 million per year, due to the cost of inaction, and Scenario 3B the second highest, US$ 14.5 million per year, due to the costs associated with large-scale and centralised facilities and equipment. Adding to that, with the potential increase in per capita income in the future, and subsequent changes in waste composition, the GHG emissions increased in both the business-as-usual scenario and Scenario 2, and the opposite was verified for Scenarios 3A and 3B, coupled with a significant increment of recyclable material.

The work completed in this thesis represents a contribution to the knowledge on ISWM, as a valid concept for cities in low-income contexts, to guide the development of environmentally friendly, socially just and economically viable MSWM systems, within a systematic and comprehensive framework.

Table of Contents

Table of Tables

Table of Figures

Abbreviations

$	United States of America currency
3Rs	Reduce, Reuse and Recycle
ABRELPE	Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais
AMOR	Associação Moçambicana de Reciclagem
CBO	Community-Based Organization
CO2	Carbon Dioxide
CRF	Capital Recovery Factor
CTV	Centro Terra Viva
CWG	Collaborative Working Group
CYN	Chinese Yuan
DEMATEL	Decision Making Trial and Evaluation
DGIS	Division for International Cooperation from the Netherlands Ministry of Foreign Affairs
DOC	Degradable Organic Carbon
EUR	Currency of the Eurozone
FOD	First Order Decay
GHG	Greenhouse Gas
GIZ	German Development Agency
IGES	Institute for Global Environmental Strategies
INE	National Statistics Institute of Mozambique
IPCC	Intergovernmental Panel on Climate Change
ISM	Interpretive Structural Modelling
ISWA	International Solid Waste Association
ISWM	Integrated Sustainable Waste Management
JICA	Japanese International Cooperation Agency
Kuwuka JDA	Youth Development and Environmental Law
LCA	Life Cycle Analysis/Assessment
LVIA	Association of Italian Lay Volunteers
MBT	Mechanical Biological Treatment
MD	Municipal District
MFA	Material Flow Analysis
MICMAC	Impact Matrix Cross-Reference Multiplication Applied to a Classification
MICOA	Ministry for Coordination of Environmental Action
MRF	Material Recovery Facility

MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
NGO	Non-governmental organization
O&M	Operation and Maintenance
OECD	The Organisation for Economic Co-operation and Development
RM	Reachability matrix (RM)
SA	Stakeholder Analysis
SNA	Social Network Analysis
SPREP	Secretariat of the Pacific Regional Environment Programme
SSIM	Structural self-interaction matrix (SSIM
SWM	Solid Waste Management
UEM	Eduardo Mondlane University
UNEP	United Nations Environmental Programme
UN-HABITAT	United Nations Human Settlements Programme
UWEP	Urban Waste Expertise Programme
WIEGO	Women in Informal Employment: Globalizing and Organizing

1. Introduction

1.1. Background

With the advancement of societies, the problems with solid waste management (SWM) have been increasing and passing down to the coming generations. Solid waste impacts and pressure on the environment, are reaching alarming numbers on a global scale, endangering both the integrity of nature and human health. In a local context, problems such as flooding, air pollution, respiratory and communicable diseases, are associated with mismanagement of solid waste (Hoornweg & Bhada-Tata, 2012; Risti, 2005). As described by Wilson et al. (2015), “waste management is a basic human need and can also be regarded as a ‘basic human right’. Ensuring proper sanitation and SWM sit alongside the provision of potable water, shelter, food, energy, transport and communications as essential to society and to the economy as a whole”.

Among the several existing types, SWM in urban areas, i.e. municipal solid waste (MSW), has a significant degree of complexity and represents one of the major challenges of the 21st century in urban settings of all contexts (Risti, 2005; Scheinberg et al., 2010a). From the many aspects, linking the cities of the world, waste management might be the stronger one. It’s also a way to categorise the city’s overall governance in the public eye, on the basis that there is a correlation between being able to successfully manage the waste and managing the other complex services such as health, education, or transportation (Hoornweg & Bhada-Tata, 2012; Scheinberg et al., 2010a; Wilson et al., 2015). Furthermore, the amount of MSW generation is rising faster than the rate of urbanisation. For instance, in the early 2000s, there were 2.9 billion urban residents generating around 0.68 billion tonnes per year, a decade after, these amounts increased to about 3 billion residents generating 1.3 billion tonnes per year, and in addition, by 2025, urban residents will likely increase to 4.3 billion, generating about 2.2 billion tonnes per year. In addition, globally, SWM costs have been increasing from an annual $205.4 billion, in 2012, to about $375.5 billion in 2025 (Hoornweg & Bhada-Tata, 2012; Hyman et al. 2013; Wilson et al., 2015). Furthermore, as can be seen in **Figure 1**, the cities in the lowest income countries will likely double the size of its population and waste generation rates over the next 20 years, and by 2025, the management costs will display a significant increase of more than a 5-fold increase (Hoornweg & Bhada-Tata, 2012). Thus, is clear that waste is both a source of major challenges and promising opportunities, particularly in the case of the cities in low-and-middle-income countries, where, for a variety of reasons, poor waste management practices and related public health implications continue to be problematic (Hyman et al., 2013; Konteh, 2009; Marshall & Farahbakhsh, 2013).

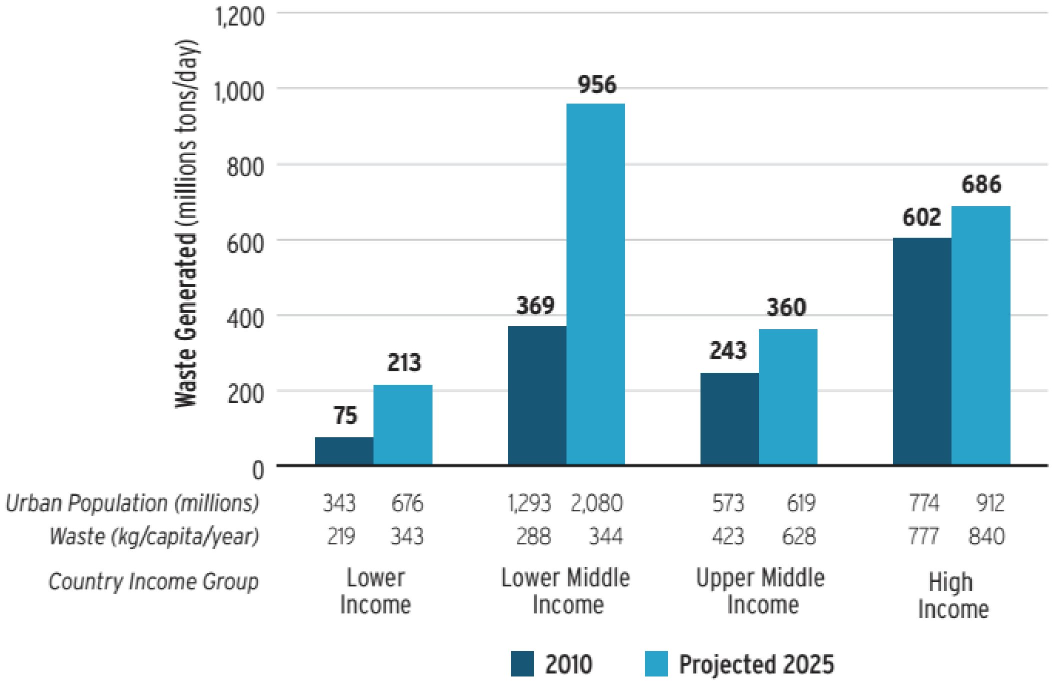


Figure 1 Urban Waste Generation by Income Level and Year.
Source: Hoornweg and Bhada-Tata, 2012

In the rapidly growing cities of the low-and-middle-income countries, the municipal solid waste management (MSWM) is currently regarded by the local authorities, as one of the immediate and serious issues (Sankoh & Yan, 2013). Municipal managers in those countries in the South, i.e. in Africa, Asia and Latin America, face a number of common problems about waste management, which Klundert and Anschütz (2001) summarised as follows:

- A lack of a wide-ranging policy framework for waste management and a lack of tools to evaluate and improve efficiency, effectiveness and sustainability.
- The under-functioning staff that also lacks motivation and staff that is difficult to find due to the low status and salaries and due to difficult working conditions.
- Difficulties in cooperation and communication with citizens.
- Misconduct of services users, such as illegal dumping, misuse or non-use of containers, damaging and stealing public storage containers, and opposition to service charges, leading the authorities to believe that the citizens are part of the problem, instead of important for the solution.
- The high probability that municipal managers will have problems with private enterprises, both formal and informal, due to inappropriate/illegal dumping of waste, market competition and corruption issues, and unpreparedness to coordinate and monitor their

activities.

- Discrepancies between profits and expenses due to increasing costs and inadequate revenues.
- Inefficient and sometimes overpriced waste treatment facilities, as well as high transportation and disposal costs.
- The equipment and spare parts that are inadequate for the local contexts, and are poorly maintained, out of date, or also not enough available.

To address the plethora of problems in those countries, the conventional approach for waste management, that is also called the ‘technical fix’, was often preferred. This approach has its focus on technical and financial-economic sustainability of waste management, while neglecting the socio-cultural, environmental, institutional and political aspects that influence the sustainability, the issues of stakeholder participation, the waste prevention and resource recovery, the interactions with other systems and also the integration of different habitat scales, such as city, neighbourhood and household (ABRELPE & ISWA, 2013; Klundert & Anschütz, 1999). Nevertheless, increasingly evidence emerged, showing that the conventional waste management assessment and plans in low-and-middle-income countries were cyclically produced and not implemented, resulting in failure (Anschütz et al., 2004). Consequently, in the 1990s, practitioners in waste management began working on a framework to describe, theorise and ultimately address the common problems with waste management assessment and planning in low-and-middle-income countries in the South and in countries in transition, and the concept – or framework, method or approach, depending on the focus of the user, Integrated Sustainable Waste Management (ISWM) was created. ISWM comprises solutions that are technically appropriate, economically viable and socially acceptable, caring for the protection of the environment. In addition, ISWM properly addresses the issue of context, by promoting the development of waste management system that best suits the society, economy and environment in a particular location, and has a particular commitment to making sure that the specific conditions of the countries in the South and in Eastern Europe, which are quite different from those in OECD countries in the North, are taken into account (Anschütz et al., 2004; Klundert & Anschütz, 1999; Wilson et al., 2013).

1.2. The Integrated Sustainable Waste Management concept

The Integrated Sustainable Waste Management (ISWM), is a concept firstly developed by the professionals from the WASTE organisation, and partners or organisations working in developing countries in the mid-1980s. Following, in the mid-1990s, the development of the concept was prepared by the Collaborative Working Group (CWG) on SWM (Guerrero et al., 2013). The core concept has been developed and enhanced, out of more than 15 years of experience on waste issues in lesser economically developed countries, and the realisation that instead of technical issues, the other aspects of waste management, are most likely to influence the success or failure of improvement measures for waste systems (Dulac, 2001; Klundert & Anschütz, 2001).

As opposed to the conventional approach, ISWM expands the way of thinking and addressing the waste management issue, from a technical standpoint to a more comprehensive approach that allows an understanding of the often neglected but important environmental, socio-cultural, institutional, political and legal aspects. In addition, the stakeholders of the system are equally considered and evaluated, together with the conventionally recognised elements of the waste management system, such as prevention, reuse and recycling, collection, street sweeping and disposal (Klundert & Anschütz, 2001).

The terms, *Sustainable* and *Integrated*, can be defined as follows. *Sustainable*, refers to a system that is suitable to the local conditions, operating from a technical, social, economic, financial, institutional, and environmental perspective and that is capable of upholding itself over time, without future resource constraints (Klundert & Anschütz, 2000). On the other hand, *Integrated* refers to a system that makes use of several inter-related waste activities and options, at different habitat scales, such as household, neighbourhood, and city, and considers all types of stakeholders for their involvement and cooperation with the system, and also, accounts for the interactions between the waste management system and the other urban systems (Klundert & Anschütz, 1999; 2000).

1.2.1. The dimensions of ISWM

ISWM concept distinguishes three dimensions in waste management: (1) the stakeholders involved in and affected by waste management; (2) the practical and technical elements of the waste management system; and (3) the sustainability or enabling aspects of the local context that must be accounted for when assessing and planning a waste management system (**Figure 2**) (Anschütz et al., 2004; Hoornweg & Bhada-Tata, 2012; Klundert & Anschütz, 2001).

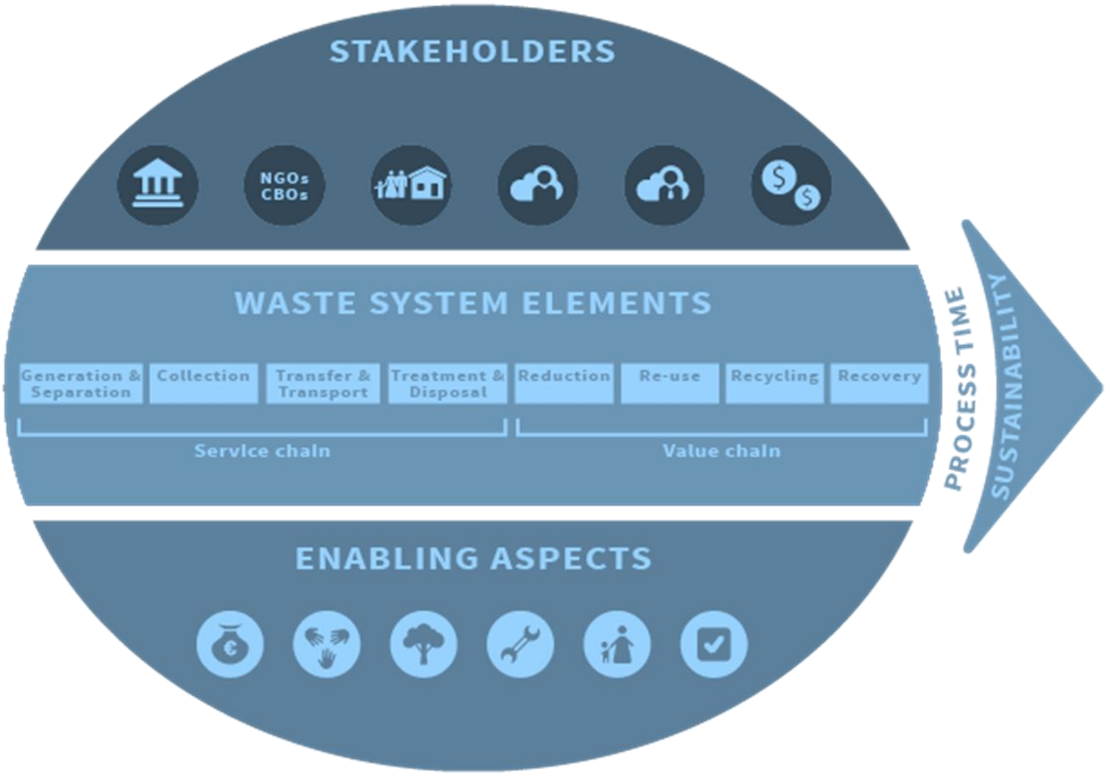


Figure 2 The ISWM concept.
Source: WASTE, 2015

The stakeholders' dimension is primarily related to the participation and involvement of stakeholders in developing the waste management system. Stakeholders such as municipality and the service users, such as citizens or households, are, for the most part, always present in the group of stakeholders of a waste management system; the remaining stakeholders differ according to each study area, thus they must be identified and categorised according to their group of interest. Since the roles and interests of each stakeholder differ, the main goal in an ISWM process is to ensure their engagement and cooperation towards the same objective, which is to improve the waste system. It is equally important to pay attention to the shared characteristics of stakeholders, be it social, geographic, or by other common systems in addition to solid waste. This is because stakeholders can influence each other's opinions and actions and/or can wield particular importance that can affect the direction and priority setting of the decision-making process. The stakeholders commonly part of the waste systems include local government authorities, NGOs/CBOs, service users, private informal sector, private formal sector and donor agencies

(Anschütz et al., 2004; Klundert & Anschütz, 2001).

The elements of waste management system, also denoted as the technical components of waste management, are related to how solid waste is handled and where it ends up. Thus, most of them are also part of the life cycle of given materials. The life cycle or material flow starts with the extraction of natural resources until the disposal phase. Given that a waste management system combines all the stages in the management of the flow of materials, a waste management plan is part of an integrated materials management strategy, to allow the decision-making in regards to the proper materials flow within the city (Anschütz et al., 2004). There are eight main waste elements in ISWM that should be considered simultaneously, to guarantee efficiency and effectiveness of the system. Those are generation and separation, collection, transfer and transport, treatment and disposal, reduction, re-use, recycling, and recovery. Nevertheless, the history and characteristics of the study area have an influence on the definition of the system elements that already exist and the ones that should be developed. Because a comprehensive ISWM aims at improving the system being studied, the addition of elements such as waste prevention or minimisation, reuse and recycling to the existing mix is necessary. It is also important to acknowledge the role of stakeholders in affecting the waste elements (Klundert & Anschütz, 2001). Because this dimension also caters for waste disposal, there are significant environmental implications, and for this reason, a number of national environmental authorities, have taken the idea of a waste management hierarchy as an operational policy guideline. The waste hierarchy, is one of the foundations of the ISWM approach, and it indicates the order of preference that should be given, whenever possible and feasible, concerning waste management actions, that is from waste prevention, followed by reduction, recycling, recovery, up to disposal (ABRELPE & ISWA, 2013; Anschütz et al., 2004; United Nations Environment Programme [UNEP], 2005).

Lastly, the ISWM enabling/sustainability aspects dimension contains six aspects, each one of them allowing the assessment of the existing waste system and the planning for expansion or development of a new system. The sustainability aspects include political-legal, social-cultural, institutional-organisational, technical performance, environmental, health, and financial-economic. A simultaneous analysis of these aspects helps in predicting their effect in the sustainability of the whole system and in designing measures and identifying priorities (Anschütz et al., 2004).

1.2.2. ISWM as an assessment framework

In waste management, as well as in other urban services, there is often an inclination to look for answers quickly, without a detailed evaluation of the situation. Those answers are commonly associated with material and financial resources, including in cases in which those are not at the core of the problem. Thus, such resources are used indiscriminately and the actual problems remain, for the most part, unsolved. The application of ISWM is aimed at avoiding this situation, either in assessing and monitoring already established waste systems or in planning for new systems, including the technology selection and decisions related to required investments (Klundert & Anschütz, 2001).

In an assessment exercise, it is crucial to first identify the functionality of the system and the main constraints, and understand what can generate sustainable improvement, to identify the appropriate pathway from present to future and the required actions to achieve that. While conventional assessment only focuses on efficiency and effectiveness, ISWM has three additional principles – equity, fairness and sustainability (Anschütz et al., 2004; Klundert & Anschütz, 2001).

Efficiency has to do with managing the waste by capitalising on the benefits, reducing the costs and optimising the use of resources, and *effectiveness* deals with the service coverage and quality of such services. In addition, e*quity* means that the system is designed to serve all, regardless of the social or economic status; however, not everyone is served or participates in the same way. instead, the system responds to everyone more or less wants and needs. *Fairness* means that the costs of the system are distributed considering the ability of the stakeholders to pay for it. It often results in cross-subsidies, where payments from wealthy households are used to cover the cost of serving slum areas. And, s*ustainability* means that the system can operate at a steady level without mismanaging the present resources and without the risk of stopping the operations in the future, due to resource lacking, also means that the system is set up according to the technical, environmental, social, economic, financial, institutional and political contexts (Anschütz et al., 2004; Klundert & Anschütz, 2001).

Even though ISWM is not supposed to be taken as a blueprint in itself, it can provide a framework and the basis for sustainability assessment of existing systems and for policy change and technology selection towards the development of sustainable waste management systems (Klundert & Anschütz, 1999; 2000). As reported by Klundert and Anschütz (1999), "the concept has already been used as a framework for the analysis of the SWM systems in different studies - Lardinois and van de Klundert in 1995, Hemelaar and Maksum in 1996, Moreno et al. in 1999, Coffey in 1996, Schuebeler et al. in 1996 and van Beukering et al. in 1999". During the course of the 2000s, the concept of ISWM was further developed and refined and increasingly has become the standard when discussing SWM issues in low-and-middle income countries. Within the implementation of the eight-year Urban Waste Expertise Programme (UWEP), a programme supported by the Netherlands Ministry of Foreign Affairs, Division for International Cooperation (DGIS) the ISWM was further established. The programme aimed at improving the waste management, livelihoods and urban governance in Bangalore in India, La Ceiba in Honduras, Tingloy in the Philippines, Bamako in Mali, Varna and Blagoevgrad in Bulgaria, San Andres in Peru, Quseir in Egypt, and San Isidro de Heredia in Costa Rica, cities in countries which are classified as ‘poor,’ ‘in-development’ or ‘non-industrialised’ (Anschütz et al., 2004). In more recent studies, Guerrero et al. (2013), adapted the ISWM framework in their study on the SWM challenges in developing countries and Marshall and Farahbakhsh (2013), recognise ISWM as the current paradigm concerning the need for a systematic approach to SWM in developing countries.

1.2.3. Simplified ISWM concept

Scheinberg et al. (2010) adapted the three-dimensional ISWM framework, for the purposes of a systematic comparison between 20 cities, in the work *Solid Waste Management in the World’s Cities* for United Nations Human Settlements Programme [UN-HABITAT]. As a result, the ISWM was simplified into two overlapping *triangle*s - the physical elements (hardware) and governance aspects (software), as shown in **Figure 3**.

The first triangle contains the three key physical elements that a city needs to address if it aims for a successful, functioning and sustainable ISWM system. Those are described below, according to the works of Scheinberg et al., (2010); Wilson and Scheinberg (2010); Wilson et al. (2013).

1. Public health: maintenance of the urban health condition, with a focus on waste collection services.
2. Environment: environmental protection throughout the waste flow, with a focus on waste treatment and final disposal.
3. Resource management: resource recovery by returning both materials and nutrients to valuable use, with a focus on the 3Rs.

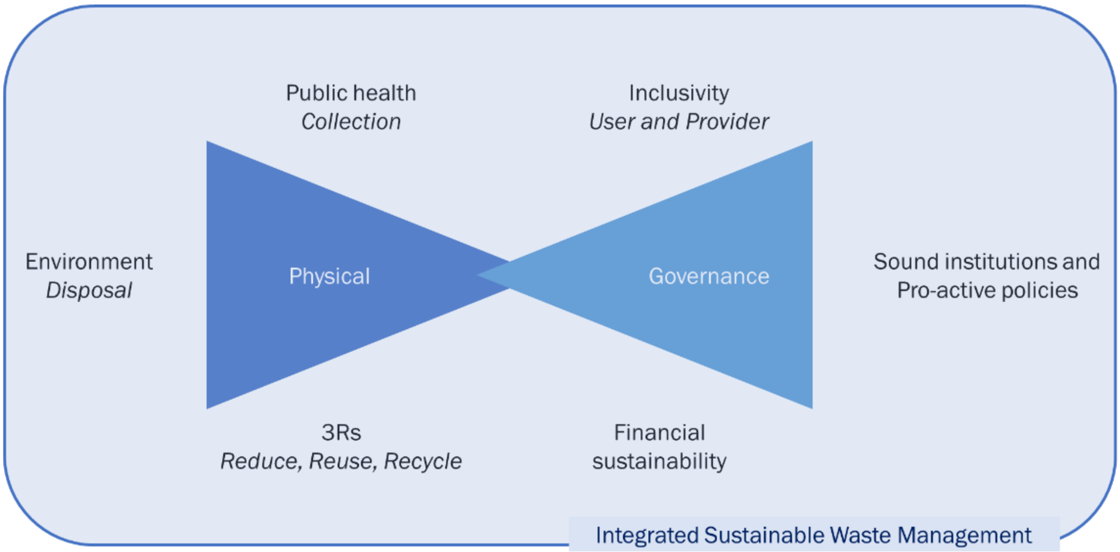


Figure 3 Two triangles representation of ISWM framework.
Source: Hyman et al., 2013

Because the physical elements are not sufficient to provide a sustainable and well-functioning ISWM system, the second triangle focuses on the governance strategies that include:

4. Inclusivity: the creation of an adequate environment to allow all stakeholders (users, providers and enablers) to contribute.
5. Financial sustainability: provision of cost-effective and affordable services.
6. Sound institutions and proactive policies: a system based on such kind of policies.

Wilson et al. (2013) also used the simplified framework to document the existing realities in developing countries and to explore a number of challenges and opportunities for solutions. Moreover, Wilson et al. (2015) added to the discussion by introducing benchmark indicators based on this simplified ISWM. The same framework was also used as the primary analytical framework in the 2015 Global Waste Management Outlook (Wilson et al., 2015).

1.3. Research scope

1.3.1. Maputo City as a case study

In Mozambique, governmental authorities have acknowledged the environmental matters since the early 1990s, when the National Policy for the Environment (1995) and the Environmental Law (1997) were established. Since then, the government have been developing and implementing sectoral policies, including waste management policies, such as the Regulation on Bio-Medical Waste Management (2003), the Regulation on

Environmental Quality Standards and Effluent Emissions (2004), the Regulation on Waste Management (2006), the Integrated Urban Solid Waste Management Strategy for Mozambique (2012), and the Regulation on management and control of plastic bag (2015). Adding to national regulations, Mozambique also ratified to the Bamako and Basel Conventions (Mozambican Ministry for Coordination of Environmental Action [MICOA], 2008). Waste management responsibilities are divided according to different jurisdiction levels, the national, the municipal and the district levels. Even though, the municipalities in Mozambique are responsible for SWM in the urban areas, they have been proven unable to solve or mitigate the impacts of waste and the other urban environmental challenges, as well as, have been failing to create and maintain inclusive, sustainable, and self-financing MSWM systems. A prime case illustrating the struggles the Mozambican municipalities currently face, is Maputo City, the capital city (Cabinet of ministers, 2006; Maputo Municipal Council, 2008b; Stretz, 2012a). For instance, the majority of Maputo City population does not have access to the basic urban services, and the municipal budget is as low as of U$ 5.0 per capita, which corresponds to a third of the average value in Sub-Saharan Africa and fifty cents of the average in Asia and South America (UN-HABITAT, 2007). Adding to that, is the increasing population growth, caused by rural exodus and resulting in a growth rate of 3.5% per year (1.5% higher than the national rate), which means that in the suburban[1] neighbourhoods, the population density will reach 3,200 inhabitants per km^2, without an appropriate expansion of the required infrastructure (UN-HABITAT, 2010). Moreover, apart from the high disease incidence, Maputo City is at greater risk for rapid disease spread, due to the high population density. For example, malaria affects 11% of the city's population, and HIV/AIDS has a higher prevalence in the city than the rest of the country, accounting for 39% of mortality in the city (Hedrick-Wong & Angelopulo, 2011). UN-HABITAT (2010), further reports that sanitation issues such as lack of drainage, poor collection and disposal of solid waste, have been the cause of diarrhoeal diseases, including cholera, and (prevalence of) malaria, resulting in loss of life and reduced productivity. As an example of how serious this situation has been, from the cases of cholera recorded between 1997 and 2000, an average of 250 deaths occurred per year, and between 1996 and 2000, around 1,500 inhabitants perished from malaria (UN-HABITAT, 2010). More recently, in 2014, more than 44,000 cases of malaria were registered that resulted in the death of at least 53 people, while in 2015, 429 cases of acute diarrheal diseases, with a higher incidence in children, where registered, within a matter of 2 weeks (Newspaper Opaís, 2014; 2015a).

---

[1] The term "suburban" differs from the North European or American definition of "suburban"; rather, it means a "sub-urban" area surrounding the formal "urban" area (Jenkins, 2000).

On the MSWM in Maputo City, it can be seen in the following **Table 1** that similar to what commonly occurs in other low-and-middle-income countries, there are several existing problems. Besides, even though there are previous studies addressing Maputo City's MSWM issues, those are in a limited number, most focus on physical aspects and qualitative descriptions, there are no consideration of causality relationship between the identified issues, and, few address the issues of environmental impacts, costs and the stakeholders of the system. The reviewed studies include Allen and Jossias (2011) that assessed the policy context surrounding waste scavengers. Buque (2013) that looked at the contribution, challenges and perspectives of the selective collection of waste in Maputo. Chingotuane (2008), who considered the effect of civic education on plastic waste recycling. Daud (2002), with his contribution to the management of solid waste and persistent toxic substances, focusing on Maputo and Matola cities. Ferrão (2006), who evaluated the removal and final disposal of solid waste in Maputo City. Macuácua (2002), who looked at the relationship between the municipal authority and private companies in waste removal and final disposal processes. Mertanen et al., (2013) that studied the scavengers and their work in Maputo City. Tas and Belon (2014) that described the MSWM system in Maputo City, as part of a review of the waste sector in Mozambique. Nhacolo (1999), who studied sanitation problems, including SWM, in one of the most problematic neighbourhoods of Maputo City. Segala et al., (2008) that within their evaluation of MSWM in the Mozambique, selected Maputo City as one of the case studies. Stretz (2012a), who analysed the economic instruments in Maputo City MSWM and Stretz (2012b) that then looked into the management model adopted in Maputo City.

Table 1 Summary of the problems in Maputo City MSWM system

Type	Reported problems
Technical	– Increasing waste generation: 0.3 kg capita^{-1} day^{-1} 1995 to 0.5 kg capita^{-1} day^{-1} in 2009. – MSW collection coverage is 90% in the urban area and 60% in the peri-urban area. – Only 65% of the population has access to regular waste management services. – Waste reuse activities are limited and are mostly undertaken low-income household settings. – Cost recovery from the MSW services is about 62%. – Limited waste recovery and treatment schemes, which in its majority is undertaken by private initiatives and scavengers. – Obsolete infrastructure and equipment. – Open dumping as a method for MSW final disposal.
Non-technical	– Unqualified personnel and low levels of motivation. – Lack of trust between the local government authority and the private sector. – Illegal dumping. – Insubstantial relationship with waste scavengers. – Public litter and misconduct. – Low levels of public awareness and participation

Sources: Allen & Jossias, 2011; Buque, 2013; dos Muchangos, 2012; Ferrão, 2006; Maputo Municipal Council, 2008b; MICOA, 2012; Mozambique National Cleaner Production Centre, 2007; Segala et al., 2008; Stretz, 2012a

1.3.2. Objectives

In this doctoral thesis, the aim is to present a comprehensive evaluation of an MSWM system from a low-income context, based on the ISWM concept, in a case study of Maputo City. This work is an effort to combine the discussion on the different aspects of MSWM systems, to address the complexities particular to low-income contexts, and as such, draw lessons and pathways to develop integrated and sustainable systems. To accomplish the main objective, the following specific objectives were considered relevant:

- **I.** Analyse the barriers affecting the performance of the MSWM policy.
- **II.** Identify the key stakeholders, their role, characteristics, and interactions in the MSWM system.

III. Investigate the past and current flows of MSW in Maputo City, and

IV. Discuss the environmental impacts and cost requirements of the current and alternative MSW treatment and final disposal schemes.

The contribution is aimed at policy and decision-makers with a focus on government and local authorities, but also inclusive to waste management practitioners from the private sector, civil society, academia and development agencies.

1.3.3. Research framework and questions

The research framework is based on the ISWM concept, described in section 1.2, which integrates the three dimensions of ISWM and the physical and the governance aspects of the MSWM systems. It aims to provide a transferable and scientific-based roadmap, to support problem identification, to give a structure to those problems, and to elucidate which are the priorities. Following, according to the four specific objectives, four research topics were selected.

In relation to need for a MSWM system with sound institutions and pro-active policies, *Topic I*, focuses on answering **Why is the MSWM policy underperforming, and what can trigger its improvement?,** through the combined application of a group problem-solving technique – Delphi method, and the two structural modelling methods – Interpretive Structural Modelling (ISM) and Decision Making Trial and Evaluation Laboratory (DEMATEL). As for the need to ensure stakeholders' inclusivity and committed contribution, *Topic II* seeks to answer **How to ensure that the decision-making process for waste management, is inclusive and transparent?,** by combining the application of the Stakeholder Analysis (SA) and the Social Network Analysis (SNA) methods. In regards to the importance of understanding the elements and flows of the MSWM, *Topic III,* specifically answers to **Where the MSW ends up, how it flows in the city, and, where are the bottlenecks and flows with potential that require priority intervention?,** by carrying out a Material Flow Analysis (MFA), including the consideration of input data uncertainties, with the application of the Hedbrant and Sörme model and the sensitivity analysis. As an extension of the previous topic with emphasis on environment and economic sustainability, the last *Topic IV*, answers to the question, **With the knowledge of the system's flows, what are the environmental impacts and cost requirements for the current and improved alternatives of MSW treatment and final disposal?,** with the application of a life-cycle thinking approach.

1.3.4. Outline of the thesis

The subjects of each chapter are briefly described next. Chapter One presents an introduction to the issue of MSWM and its particular urgency in low-and-middle income countries and the development and relevance of the ISWM concept to tackle that issue. In addition, the ISWM concept and its features are also explained, followed by the clarification of the aspects pertaining to the background of the research, the objectives and construction of the research framework. The summary description of the case study area and the overview of the MSWM system, are presented in the Chapter Two. Chapter Three presents the analysis of the barriers to MSWM policy and of the extent of their influence to the success of the policy. In the following Chapter Four, an assessment of the stakeholders of the system and their interrelationships is completed. Chapter Five presents the past-to-present material flow analysis of the MSW in Maputo City, and Chapter Six follows up with an environmental and cost assessment of the present and alternative future scenarios for waste treatment and final disposal. Lastly, in Chapter Seven, the summary of the main findings, the contribution of the thesis, and proposal for future studies, are presented.

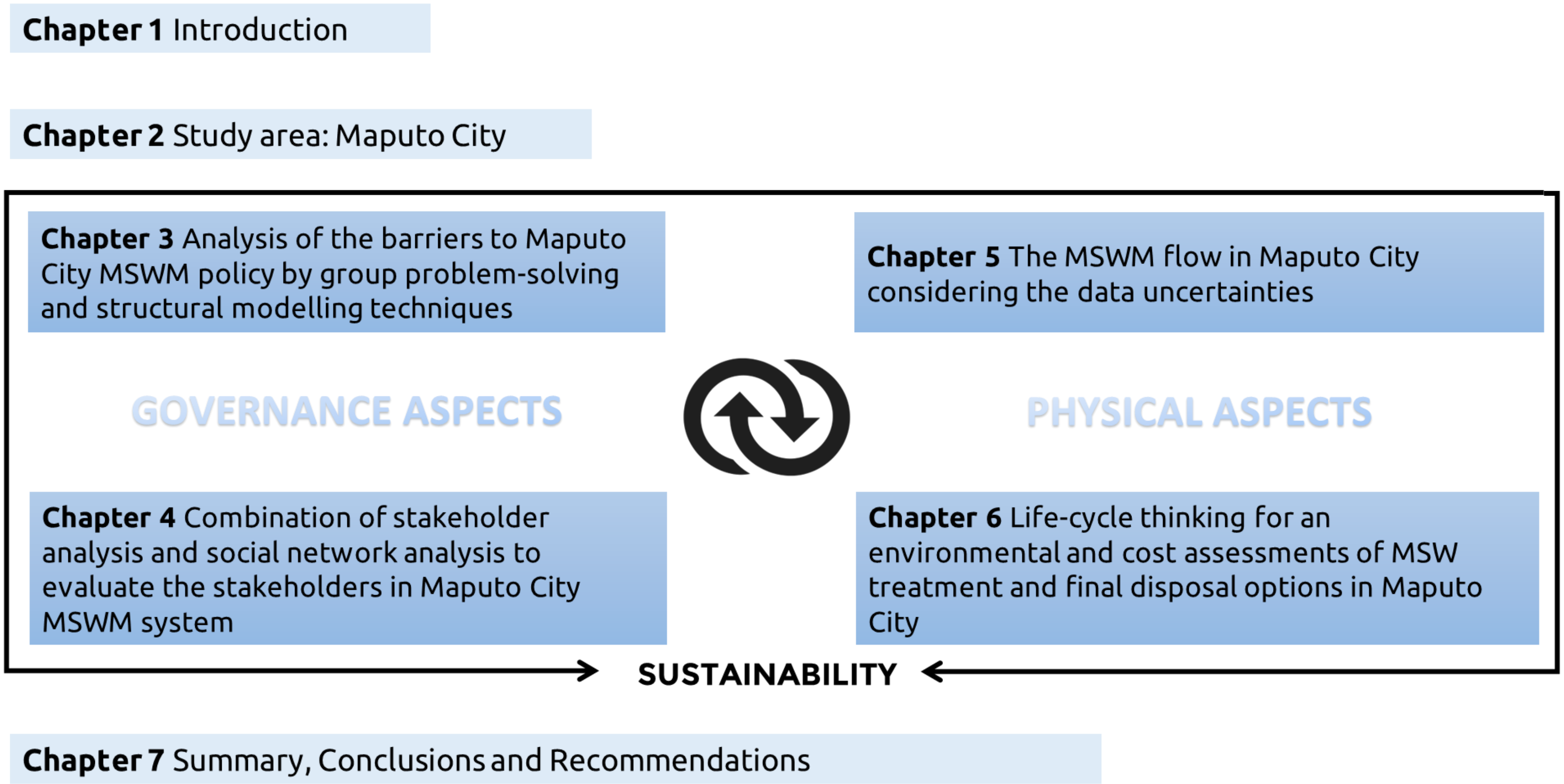


Figure 4 Outline of the research

2. Case study: Maputo City

Maputo City, also known as the Municipality of Maputo, is the capital of the Republic of Mozambique and the centre of the metropolitan area of Maputo Province. Traditionally the largest urban concentration in Mozambique, Maputo also holds an importance within the Southern Africa context (Maputo Municipal Council, 2008a).

It is located in the extreme south of the country in an area of about 308 km^2, with three main distinct areas separated by a common bay: the inner city, with five municipal districts (MD) - MD1 to MD5, occupying around 54% of the total city area, KaTembe - MD6, occupying 31%, and the island of Inhaca (KaNyaka) - MD7, occupying 15% of the total city area (**Figure 5 and Table 2**). The estimated population is around 1.2 million, however, along with the neighbouring capital of Maputo Province, Matola City, it forms what is termed *Great Maputo* area, with over 2 million inhabitants (Maputo Municipal Council, 2008a;2008b; National Statistics Institute [INE] of Mozambique, 2015; Stretz, 2012a; UN-HABITAT, 2010).

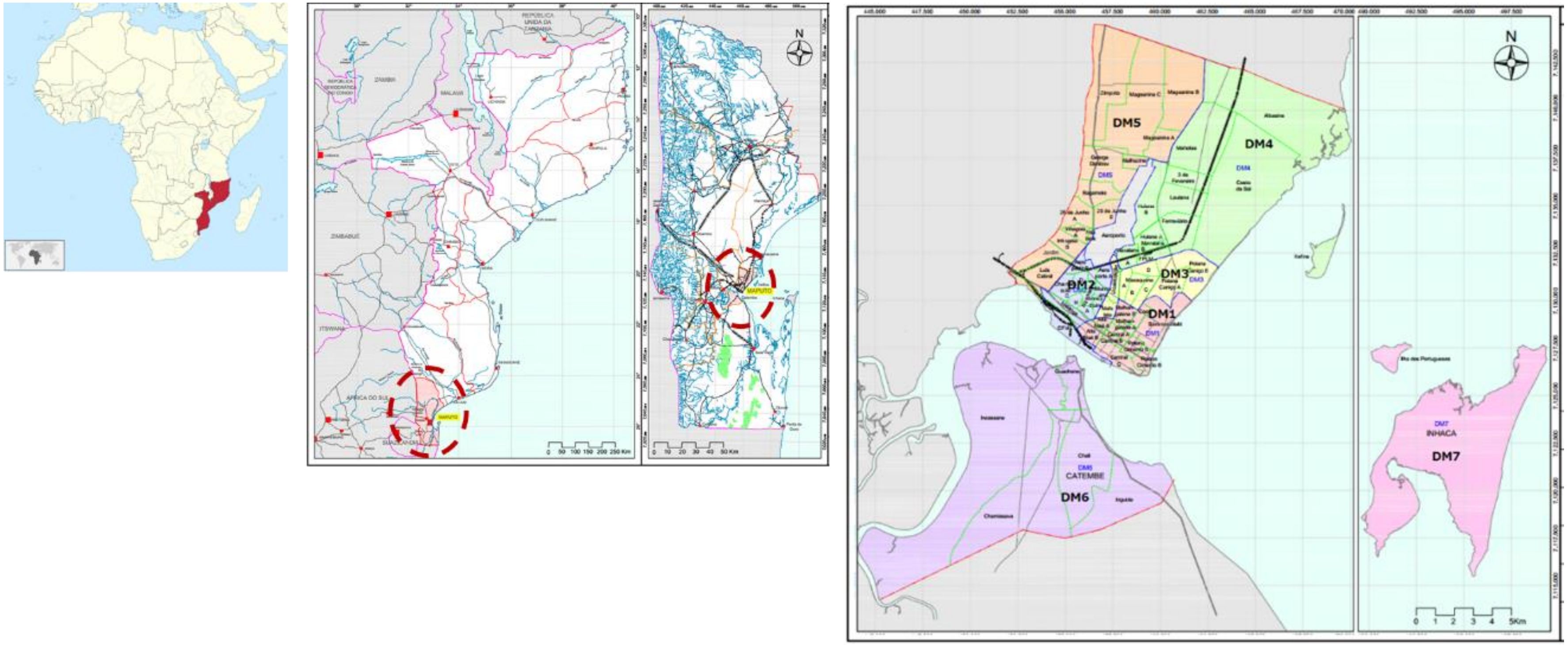


Figure 5 Map of Mozambique; Location of Maputo Province and City; Municipal districts of Maputo City.

Sources: Wikimedia Commons, 2015; Maputo Municipal Council, 2008a

The Indian Ocean employs significant influence on the overall climate in Maputo City, that is tropical humid. There are two seasons, the wet and humid from October to March, and the dry season from April to September; the average annual maximum temperature is 31°C and the minimum is 13°C, though, in the humid season, temperatures can rise above 40°C. In addition, the average annual rainfall and the average relative humidity in 2007, was about 805 mm and 76%, respectively (Maputo Municipal Council, 2008a).

Table 2 Population and characteristics of the municipal districts of Maputo City

Municipal district (MD)	Population^{2016}	Characteristics	
KaMpfumo (MD1)	111,854	Urban	Medium to high living standard Residential area with low-rise detached houses - low density Residential and commercial areas with high-rise buildings – high density
KaNlhamankulu (MD2)	160,465	Suburban	Medium to low living standard Older suburban neighbourhoods with high density and areas with restricted access roads
KaMxakeni (MD3)	233,004		
KaMavota (MD4)	353,414	Semi-urban	Medium to low living standard Detached houses, low density and spacious roads City periphery
KaMubukwani (MD5)	370,658		
KaTembe (MD6)	22,423	Rural	Low living standard Detached houses and very low density
KaNyaka (MD7)	5,634		
Total	1,257,453		

Sources: INE, 2015; Maputo Municipal Council, 2008b; Stretz, 2012b

As the largest port in the country, the economy of Maputo City has its focus around the harbour. The main exporting products are coal, cotton, sugar, chromite, sisal, copra, and hardwood and the secondary products comprise the cement, pottery, furniture, shoes, and rubber. Industry manufacture and tourism are part of the economic foundations of the city as well. The industries present in the city comprise food, beverages, chemicals, petroleum products, textiles, cement, glass, asbestos and tobacco; Maputo also significantly collects benefits from activity in the rest of the country's economy, as it remains the main business, political and transit centre of the country. However, there are still several challenges, such as the unemployment rate that is around 20%, the illiteracy rate that is about 6.4% among men and 19.2% among women, and more than half the city's population live below the poverty line (Hedrick-Wong & Angelopulo, 2011; UN-HABITAT, 2010).

2.1. The MSWM system in Maputo City

The statute, *Positions for municipal solid waste cleaning in Maputo* (2008), defines MSW as "any substance or object with predominantly solid consistency (non-hazardous), which the holder discards or intends or is required to discard." In turn, there are five basic principles that the MSWM system in Maputo City is guided by the Principle of broad participation; the Polluter Pays Principle, the 3R's Principle; the Producer Responsibility Principle; and the Principle of Improvement at Source (Maputo City Municipal Assembly, 2008). Furthermore, MSW is classified as follows (Maputo City Municipal Assembly, 2008; Maputo Municipal Council, 2008b):

- Household solid waste (or similar): generated in households or similar settings.
- Commercial solid waste: from shops, offices, restaurants, and other similar establishments, deposited in containers under conditions similar to household waste.
- Large household waste: household waste that cannot be removed by normal means because of its volume, shape, or dimensions, whose deposition in existing containers is considered inconvenient by the municipality.
- Waste from gardens and private spaces: wastes from the maintenance of private gardens, such as trimmings, branches, stems, or leaves.
- Waste from public gardens, parks, roads, cemeteries, and other public spaces.
- Non-hazardous industrial solid wastes: with similar characteristics as household and commercial solid wastes.
- Medical solid waste: non-contaminated waste from medical institutions; comparable to household waste.
- Waste from dead animals and waste produced by animals.
- Inert waste - sand, ash and other waste with similar characteristics;
- Debris: waste from construction and/or demolition of buildings or public or private infrastructure, including limestone, rocks, debris, land and other with similar characteristics.

2.1.1. Institutional and policy aspects

The Municipal Council of Maputo City, through its Directorate of Health and Salubrity, is the local authority responsible for managing MSW. The waste managing tasks can be performed by the directorate itself, in combination with, or attributed to private entities or CBOs. Those tasks include sweeping, placement, collection, transport, storage, transfer, treatment and final disposal of MSW. In addition, the directorate is responsible for managing cemeteries, and developing activities for disease prevention and health promotion in the city (Maputo City Municipal Assembly, 2008; Maputo Municipal Council, 2008b). **Figure 6** shows the organisational structure for MSW in the local authority and **Table 3**, presents a summary of the main legislative and regulatory instruments governing MSWM in Maputo City.

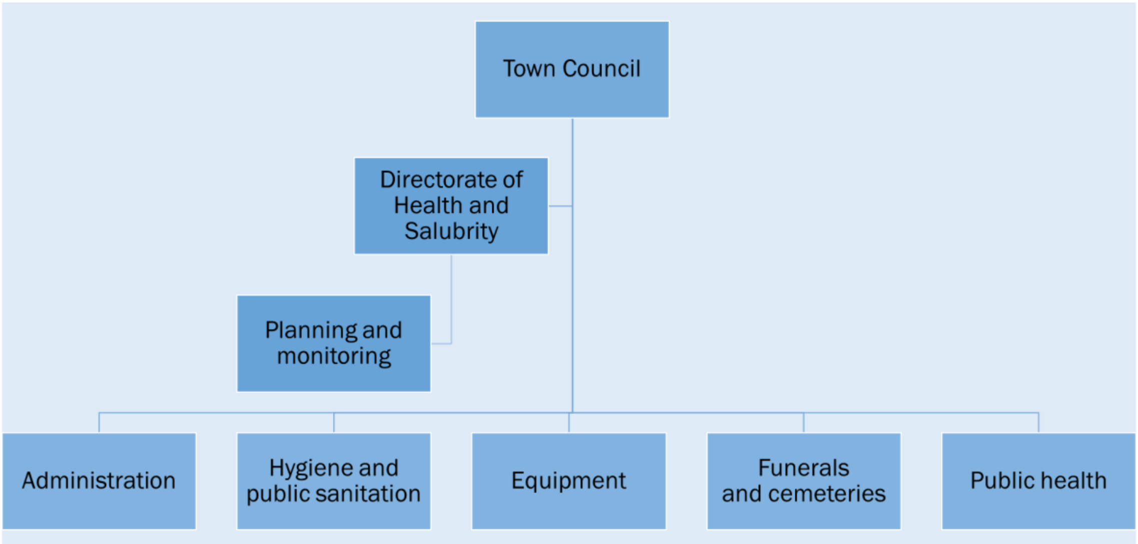


Figure 6 MSWM structure in Maputo City.
Source: Adapted from Maputo Municipal Council, 2008b

Additionally, several economic instruments are in place with the objective of revenue generation, comprising the household waste fee, the proof of service, revenues from commercial services provided by the local authority, disposal fee for current and future waste final disposal sites, and other fees and fines (Maputo Municipal Council, 2008b; Stretz, 2012a).

Table 3 Key legal instruments regulating the MSWM in Maputo City

Level	Instrument
National	– Environmental Policy (Resolution 5/95 of 3 August) – Environmental Law (20/97 of 1 October) – Regulation on Waste Management (2006) – Integrated Urban Solid Waste Management Strategy for Mozambique (2012) – Regulation on management and control of plastic bag (2015)
Local	– Law of Local Governments (2/97 of February 18) – Law of Finance and Patrimony of Municipalities (11/97 of 31 May) – Master Plan for the Management of Municipal Solid Waste in the City of Maputo (2007/8) – Positions for Municipal Solid Waste Cleaning in Maputo City (86/AM/2008) Regulation on inspection of cleaning activities in Maputo City (87/AM/2008) – Regulation on private sector participation in the cleaning process of Maputo City (88/AM/2008) – Regulation of the cleaning components of Maputo City (89/AM/2008)
(planned)	– *Regulation on MSW treatment and recovery* – *Regulation for sanitary landfill, treatment and transfer station operations and closure of open dumps* – *Regulation on information, education, and awareness of citizens of Maputo Municipality cleanliness*

Sources: Buque, 2013; Cabinet of ministers, 2015; Maputo Municipal Council, 2008b

2.1.2. Generation, handling and storage at source

The MSW generation per capita and density values are distinct according to the city areas and the associated socioeconomic characteristics. In addition, the values for waste density are directly influenced by the quantity of sand present in the waste mixture. As shown in **Table 4**, the waste generation per capita within the municipal districts in 2007, varied from 0.20 to 1.15 kg day^{-1}, and waste density, varied from 240 to 490 kg m^{-3}, respectively. As a result, the estimated MSW generation accounted for around 1053 tonnes day^{-1}, divided among seven categories: household waste; commercial and industrial waste; waste from wet markets and fairs; construction and demolition waste; green waste; waste from sweeping; and large household waste (Maputo City Municipal Council, 2008; Stretz, 2012b). The daily average generation for each category and the MSW composition values for the urban and suburban areas in Maputo City can be seen in **Figure 7**.

Table 4 MSW in Maputo City (values for 2007)

Areas (municipal districts)	**Generation per capita (kg capita day^{-1})**	**Waste density (kg m^{-3})**
MD1	1.15	240
MD2 and MD3	0.49	490
MD4 and MD5	0.25	350
MD6 and MD7	0.20	350

Source: Adapted from Maputo Municipal Council, 2008b

After generation, MSW generators handle and store the waste according to the different adopted waste collection and transportation schemes. Within the neighbourhoods from the urban area, with low population density, generators store the MSW in plastic bags and place it in front of the buildings, while in high-density neighbourhoods, waste is stored in available public containers. In the suburban and semi-urban areas, generators keep the waste stored until a primary collection is carried out from door-to-door, usually twice a week. In areas not covered by collection services, particularly in the rural areas, waste is usually buried with or without being burned first (Maputo Municipal Council, 2008b; Tas & Belon, 2014).

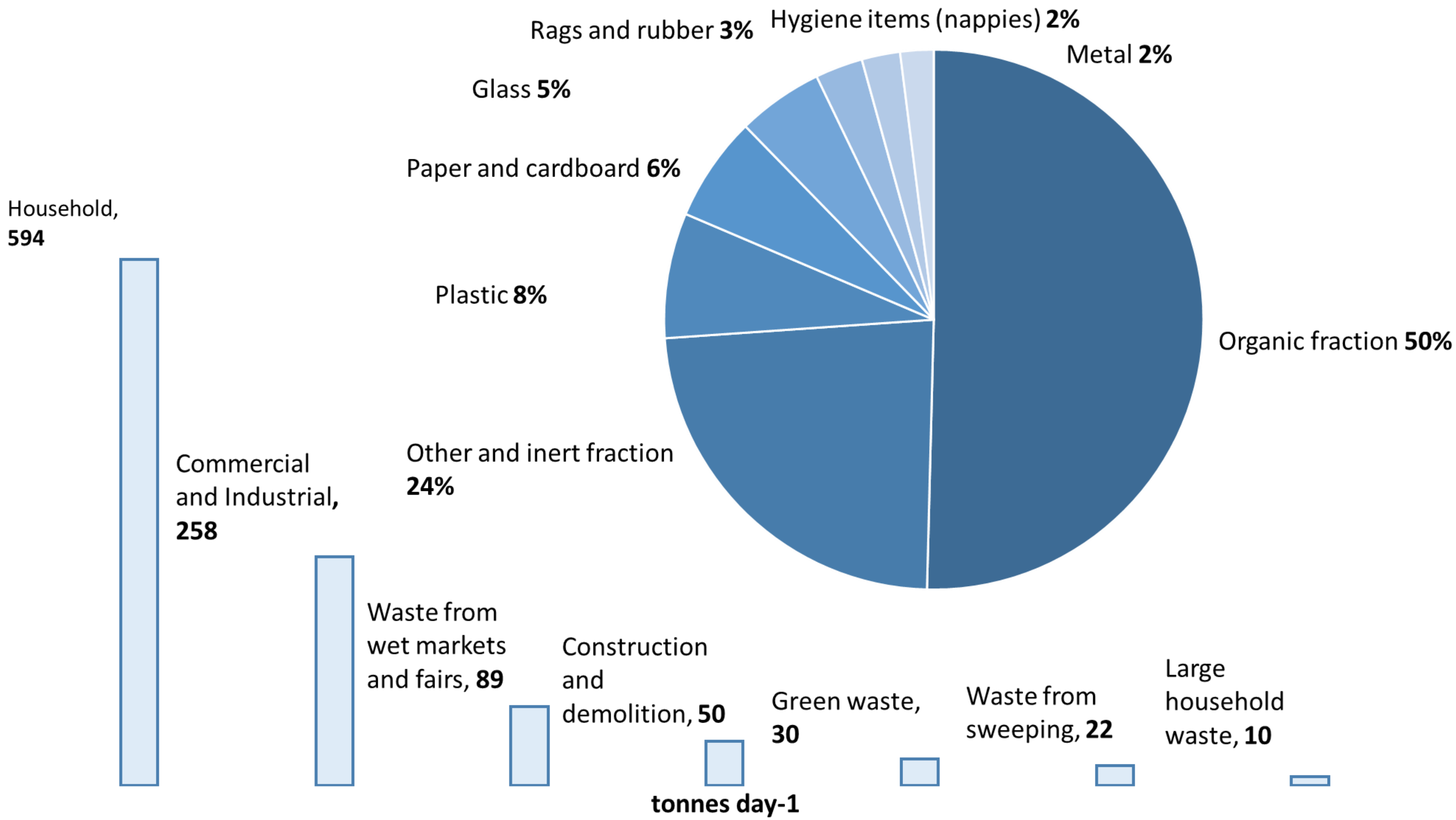


Figure 7 MSW generation and composition in Maputo City.

Sources: Adapted from Maputo Municipal Council, 2008b; Stretz, 2012b

MSW generated in the formal and informal wet markets and fairs, waste from sweeping, and green wastes, are also stored in available public containers. Large non-household MSW generators, with daily generation exceeding 25 kg or 50 litres, are required by law to ensure that the waste is handled and collected by licensed companies or by the municipal authority, under a service contract (Maputo Municipal Council 2008b).

2.1.3. Collection and transport

In the urban area, MSW is collected from door-to-door and from the public containers and then, transported directly to final disposal, every day or every other day. This is usually done by private companies contracted by the local authority or by the local authority itself. Conversely, in the suburban and semi-urban areas, collection and transport are carried out first through the primary collection by small-scale enterprises contracted by the authority, and then through the secondary collection by the authority and contracted private companies. In the municipal districts, MD6 and MD7, waste collection services are irregular, unstructured and quite rudimentary. For instance, waste collection in MD6 is organised by the district administration with little staff and minimal equipment; waste from several waste drop-off points is piled into a trailer pulled by a tractor, and the service does not cover some areas (dos Muchangos et al., 2014; Ferrão, 2006; Maputo Municipal Council, 2008b; Tas and Belon, 2014).

Even though Stretz (2012a) reported that over 90% of the population had access to waste collection services since 2012, compared to less than 40% before 2007, the service coverage significantly differs between the urban and the remaining areas, which is around 90% and 60%, respectively (Segala et al., 2008).

Table 5 Progress of MSW collection coverage in Maputo City

Population with access to regular collection service	2007	2010	2012	2014
Service coverage	<40%	65%	75%	>90%

Sources: Stretz, 2012a; 2012b

2.1.4. Final disposal

After collection in the inner city, the MSW is transported and finally disposed of in the municipal open dump, *Hulene dumpsite*. The dumpsite is located in a swamp, bounded to the west by the Hulene River, and occupying approximately 17 hectares with an average waste height of 15 meters (Ferrão, 2006; Stretz, 2012b). Activities in the dumpsite began around the late 1970s and permanent closure, with replacement by a sanitary landfill, is expected by the end of 2017 (Ferrão, 2006; Maputo Municipal Council, 2008b; Newspaper Opaís, 2015b). The Hulene dumpsite is open 24 hours a day and seven days a week and waste is deposited with minimal control and compaction, and it is rarely covered. In 2007, it received between 280 and 360 tonnes of waste per day, and this quantity raised to 700 tonnes per day in 2013. Much of the deposited waste is burned by scavengers searching for recyclables, and the piles of waste frequently self-ignite. As for the municipal districts MD6 and MD7, the common practice is to final dispose the collected MSW in dumpsites (dos Muchangos et al., 2014; Ferrão, 2006; Maputo Municipal Council, 2008b; Mertanen et al., 2013; Segala et al., 2008; Stretz, 2012b; Tas & Belon, 2014).

(a)

(b)

Figure 8 (a) Aerial photography of Hulene dumpsite; (b) Interior photography of Hulene dumpsite.

Sources: Google earth, 2016; Deutsche Welle, 2016

Illegal dumping in Maputo City consists of depositing the formally collected waste from the inner city and within areas not covered by waste collection services, particularly rural areas and new settlements, into vacant lots, ravines, and ditches. Allegedly, some private companies practice illegal dumping to evade the disposal fees at the Hulene dumpsite. Moreover, waste generators with no access to waste collection services usually recur to illegal dumping (Ferrão, 2006; Maputo Municipal Council, 2008b; Segala et al., 2008).

2.1.5. Waste reduction, reuse and recycling (3Rs)

Concerning waste reduction, few initiatives are in place. The most recent is the *Regulation on management and control of plastic bag* that prohibits: the usage of plastic bags that have less than 30 microns; the distribution of plastic bags for free in business centres; and the sale or distribution of plastic bags with more than 40% of recycled material in places that sell food products (Cabinet of ministers, 2015).

Reuse of MSW is a common practice, particularly in households that subsist on low incomes. Examples include glass and plastic bottles that are reused within the household or otherwise quickly removed from the waste stream, and large household waste such as old furniture and electrical appliances, which are reused wherever possible even when barely functioning, mostly in the informal market (Allen & Jossias, 2011; Buque, 2013; Maputo Municipal Council, 2008b). In addition, waste from construction and demolition activities is commonly reused in other types of construction, including road maintenance work (Maputo Municipal Council, 2008b).

From the total MSW generated per day, more than 30% does not reach the Hulene dumpsite. Instead, some of this waste is collected, processed for recycling and/or recycled by enterprises, licensed by the local authority. The remaining waste is collected and sold in the local market, or consumed as foodstuff, usually by people without work and homeless - the scavengers, also known as "catadores". The total number of catadores working in Maputo is unknown, but the majority, which is more than 500, is concentrated at the Hulene dumpsite and, in addition to that, there are more than 150 scavengers, collecting waste from the public containers in the municipal district MD1 (Allen & Jossias, 2011; Mertanen et al., 2013). The materials that are commonly recycled include paper, cardboard, plastic, glass, metal, cooking oil and electronic waste. After collection, those materials are processed, and most are forwarded to overseas recycling markets, and another portion is absorbed by the local recycling market (Tas & Belon, 2014). Waste generators and workers from waste processing for recycling enterprises; also contribute to the collection and assembly of recyclables. Hotels, restaurants, supermarkets and public and private institutions also provide recyclables to the system, by forwarding them to the enterprises. It is also common practice, in households with domestic animals, to use a portion of the organic waste to feed the animals (Allen & Jossias, 2011; Associação Moçambicana de Reciclagem [AMOR], 2013; Association of Italian Lay Volunteers [LVIA] & Caritas, 2009; Buque, 2013; Pagalata, 2008). Regarding waste composting, in the past, the local authority collaborated with a local cooperative, to produce compost from the organic waste from the wet markets and then sold it to local buyers, primarily in the agricultural sector. However, the activities were interrupted for almost a year in 2011, and resumed within 2012 with the intent of recycling 600 tonnes of organic waste per year (Allen & Jossias, 2011; Buque, 2013; LVIA & Caritas, 2009), yet, the operations were interrupted once more, up to the present time (COMSOL, February 02, 2016). **Table 6** summarises the available data concerning the material recovery activities in Maputo City, where recyclables are processed before being directed to recycling, by three main enterprises - RECICLA, AMOR, and Pagalata, and composting carried out by Fertiliza.

Table 6 Waste processed per year by the current main enterprises in material recovery

Enterprises	2006	2007	2008	2009	2010	2011	2012	2013	2014
RECICLA (since 2006)	100[a]	100[a]	100[a]	100[a]	N/A	168[c]	N/A	180[c]	250[b]
AMOR	-	-	-	720[c]	720[c]	1440[c]	1440[c]	1440[c]	N/A
PagaLata (since 2006)	N/A	3000[d]	1343[c]	N/A	N/A	N/A	N/A	N/A	6000[b]
Fertiliza	-	-	N/A	N/A	N/A	36[c]	0[b,c]	240[c]	600[b]

N/A = unavailable data; - = before operation. Sources: [a]LVIA & Caritas, 2009; [b]Tas & Belon, 2014; [c]Buque, 2013; [d]PagaLata, 2008

3. Analysis of the barriers to Maputo City MSWM policy by group problem-solving and structural modelling techniques

3.1. Introduction

The need for a good waste management plan backed by a comprehensive waste management policy is indispensable because a waste management policy reflects the main principles and goals of such plan (Hyman et al., 2013). Within planning for waste management, three main phases can be recognised: the development, the implementation, and the review and update. Development and implementation, are very important, nonetheless, because failures will occur when implementing a plan, the review and update phase is a necessary response to the challenge of recognising failures, rethinking actions and turning these failures into opportunities for individual and institutional learning across the waste management. Thus, to successfully review and update a waste management plan, it is necessary to assess the progress of the existing waste management policy, including the identification of barriers to success (ABRELPE & ISWA, 2013; Hyman et al., 2013; Konteh, 2009).

Maputo City although has an array of municipal by-laws and regulations, to establish and implement its MSWM system, the gap between the existing policy instruments and its implementation is evident and little information exists on the status of, the performance of, and barriers to such instruments. Granting, there are several studies addressing Maputo City's MSWM issues, none focuses on the causality relationship between the existing barriers and there is no answer to how much each one of those barriers negatively affects the policy performance.

Barriers in a group context are often interrelated and a barrier may alleviate, augment, reinforce, or trigger another. Understanding these interactions is essential to arrive at reasonable measures to solve them. However, it is not always possible or logical to eliminate all barriers in a system, due to constraints in resources, time, and capability; thus, finding the core of the system has a real cost-saving benefit (Raeesi et al., 2013). Besides, these interactions among barriers add complexity to the analysis and make it difficult to complete the task if the barriers are not clearly structured. Therefore, it is essential to identify appropriate methods that can aid in this task.

Interpretive Structural Modelling (ISM) and the Decision-Making Trial and Evaluation Laboratory (DEMATEL) seem to be such methods. The advantage of combining DEMATEL and ISM is significant because both are powerful and effective methods to assist the decision-making process, as they can complement each other. ISM is macro-oriented – it can only fill binary options among the variables, such as 0 and 1, that are representative of a causal relationship between elements. In addition, ISM clarifies the interrelationships among the elements in an ordered and directional framework – the hierarchy structure, yet without consideration of each element strength/weight. In comparison, DEMATEL is micro-oriented – it has more options to classify the cause and effect interrelationships, such as 0, 1, 2, and 3, though this feature makes DEMATEL singularly unable to obtain a hierarchical structure as ISM does. DEMATEL is used to visualise the causal structure and determine the strength of the elements' relationships (Chuang et al., 2013; Falatoonitoosi et al., 2014; Yin et al., 2012). Therefore, combining these two methodologies appears to be an effective way to overcome these short-comes and systematically elucidate the barrier's structure being analysed. To date, published studies on ISM and DEMATEL combination are still few, particularly on the subject of policy analysis for waste management. Nevertheless, there are other worthy examples to account for. Chuang et al. (2013) applied a hybrid expert-based ISM and DEMATEL model, based on multi-criteria decision-making tools to investigate the complex multidimensional and dynamic nature of member engagement. Fukushi and Narita (2002) analysed the function and failure of the snow-melting machine and expressed directional graphs of the model using ISM and DEMATEL. Hou and Zhou (2011) studied the influence factors of distributed energy system based on DEMATEL and ISM. Li et al. (2012) presented a new system structure analysis arithmetic with reachable effect factor. Wu et al. (2010) used ISM and DEMATEL to identify safety factors on expressway work zone. Zhou and Zhang (2008) established hierarchy structure in complex systems based on the integration of DEMATEL and ISM.

Prior to the application of ISM and DEMATEL, a set of elements that describe the system or issue must be known, based on given relationships. The definition of the elements of the system and the subsequent construction of the full list of such elements are key parts of the structural modelling process. In order to stimulate, extract, and/or represent the ideas/ knowledge from the mind of an individual or a group, so that a representative list of elements of the issue can be structured, generating tools are required. Two key assumptions exist concerning generating tools, the first is that some sort of experience-based and intuitive knowledge or understanding of a given problem context exists in minds of certain individuals; and the other is that an effort is being made to elicit this knowledge or understanding and to represent it in a useful way. Furthermore, since a single individual or professional does not hold all the knowledge on ill-structured sociotechnical issues, it is always advisable to use a knowledgeable group in evaluation situations (Sharma et al., 1995); thus, the selection of the Delphi method, prior to the application of ISM and DEMATEL. Delphi method is a technique to arrive at a collective view regarding a certain issue, by a group of individuals whose opinions or judgments are of interest (Tseng & Lin, 2011).

In this chapter, the main objective is to assess the barriers to the waste policy in Maputo

City and investigate the causality relationship between them and the extent each one of those barriers negatively affects the policy performance. The specific objectives are:

(1) To identify the main barriers to the MSWM policy, through the application of Delphi method.
(2) To clarify the hierarchical and the cause-effects structures between the barriers, through the combined application of ISM and DEMATEL.
(3) Identify the barriers that hinder the most the policy - the most influential barriers.

3.2. Materials and methods

Initially, a literature survey to identify the waste policy instruments essential to a standard policy was conducted. Next, Delphi method was applied with seven experts on Maputo City sanitation issues, to reach a consensus on the identification of barriers according to each waste policy instrument. Lastly, with the application of ISM and DEMATEL, the hierarchic and cause–effect structure diagrams of barriers were developed, which allowed the analysis of results and discussion on the practical implications to improve the waste policy performance in Maputo City.

3.2.1. Waste policy and policy instruments

Because distinct governments use policy instruments to achieve the objectives set out in a policy, the content and quality of existing waste policies vary widely (UNEP, 2002). As noted by Vedung, in Kautto and Melanen, work (2004), "no uniform and generally accepted classification of policy instruments is found in the literature of public policy." However, despite the vast variety of policy instruments and initiatives that have been applied, some are fundamentally important (Hyman et al., 2013). Those are presented below.

1. Legislation and regulation: force society and firms to do what the public authorities decide; when mandated via legislation, they motivate the target entities to achieve certain tasks or refrain from doing certain things in accordance with what is demanded in the legislation (Kautto & Melanen, 2004; Tojo et al., 2006).
2. Voluntary agreements: rather than requiring entities to fulfil certain tasks laid down in legislation, they can be allowed to establish their own goals and strive to achieve them via voluntary initiatives. Voluntary approaches fall into three broad categories: industries acting independently without any engagement from public authorities, negotiated agreements between public authorities and industry, and public voluntary programs designed by public authorities. Those agreements can also lead to the development of legislation (Seadon, 2006; Tojo et al., 2006).
3. Economic instruments: involve the remuneration or deprivation of material resources;

they generally provide monetary incentives (e.g. subsidies and refunds), when the addressees carry out tasks the instrument wishes to stimulate; or disincentives (such as taxes), when the addressees do not fulfil the required actions. They are also used to make the system more efficient, and to internalise the costs of waste management (Hyman et al., 2013; Tojo et al., 2006).

4. Education and influence to behavioural change: involves guiding and influencing people and alter community norms through the transfer of knowledge, argumentation, or persuasion (Kautto & Melanen, 2004; Lura Consulting, 2004)
5. Monitoring, information, and performance assessment: deals with collection and exchange of information, and is a central part of the process of policy choice, development, and subsequent implementation. Besides, it allows progress to be monitored and performance to be assessed in relation to the set goals and objectives (Hyman et al., 2013).
6. Choice of technology: involves research on and the development of new or improved solutions and technology transfer to enable conscious and careful choices among available options (Hyman et al., 2013).
7. Community linkages: strategies or specific programs that connect solid waste solutions with other beneficial community goals and objectives, such as integrating SWM with socio-economic development programs (Lura Consulting, 2004).

3.2.2. Delphi method

Delphi is a qualitative method developed in the 1950s by Norman Dalkey of the RAND Corporation for a United States-sponsored military project (Skulmoski et al., 2007). The purpose of Delphi is to allow a discussion, in a given field or about a certain topic, which produces an extensive range of responses amongst selected experts (Wakefield & Watson, 2014). In addition, as cited by Wakefield and Watson (2014), Kennedy explained, “The Delphi method provides an opportunity for experts (panellists) to communicate their opinions and knowledge anonymously about a complex problem, to see how their evaluation of the issue aligns with others, and to change their opinions, if desired, after reconsideration of the findings of the group's work”.

The method is characterised by four key features: anonymity, iteration, controlled feedback, and statistical aggregation (Skulmoski et al., 2007). It often begins with loosely structured, open-end questions or propositions, and moves towards more quantifiable data or identifiable patterns through the combined input of the participants, however, that can be flexible as well. It is common to have questions to be answered, being proposed and selected by group members themselves before the first answering round. The aim is to move through the process up to the point where discussion displays consensus or it becomes clear that no consensus can be reached (Kauko & Palmroos, 2014; Wakefield & Watson, 2014). Respondents are asked to reply to the questions in writing, and in most cases, those are numeric estimates, ratings on a given scale, or yes/no answers. In most cases, the respondents have the opportunity to write comments on issues highlighted in the questionnaire. According to the number of respondents, statistics on their answers and comments are calculated; nevertheless, the information should remain anonymous to the respondents. The possibility to modify the answers and to add more comments is open to each respondent. After a few rounds, owing to the group opinion-building process, typically, some convergence in answers can be observed, which leads to less variance in the answers and more agreement within the panel. Moreover, the number of rounds can both be predetermined or dependent on criteria such as the purpose of research, consensus and stability. The number of respondents in Delphi panels greatly varies, from three to 98, depending on factors such as heterogeneity of the sample, verification and manageability trade-off. Even though it is ideal that the respondents will all be experts in the same field, to some extent they should have different backgrounds. The results are then defined as the mean or median of the individual answers (Kauko & Palmroos, 2014; Skulmoski et al., 2007). According to Kauko and Palmroos (2014), the Delphi method has been reported to work better than simple one-round surveys and forecasting accuracy of the discussion group tends to improve over rounds.

3.2.3. Interpretive Structural Modelling method

ISM is a computer-assisted method that assists individuals or groups to develop a map of the complex relationships among many elements involved in a complex decision situation. It was first suggested in 1973, by Warfield to examine several complex socio-economic systems. Its basis is on the user's practical experience and knowledge to take apart a complicated system into several subsystems or elements, and then construct a hierarchic, directional, and ordered multi-level structural model (Chen, 2012). ISM method has many capabilities that caused its broad application, those include, being understandable to a variety of users belonging to interdisciplinary groups, provides a way to integrate different perceptions, can handle a large number of components and relationships typical of complex systems, is empirical in terms of assessing the adequacy of model formulation, and leads to the understanding of system behaviour. Furthermore, it is easy to use and allows accessible sharing of the results to large audiences (Attri et al., 2013). Some examples of ISM broad application are a study by Chandramowli et al. (2011) that looked at the barriers to development in landfill communities. Liao and Chui’s (2011) evaluation of municipal solid waste management problems using hierarchical framework. A study of Mahajan et al. (2013) to identify and rank the challenging issues in Just-In-Time supply chain. Raeesi et al. (2013) that used ISM to understand the interactions among the barriers to entrepreneurship;

ISM was also applied by: Ravi and Shankar (2005) in an analysis of interactions among the barriers of reverse logistics; Sharma et al. (1995) who studied the objectives for the future of India's waste management; by Singh and Kant (2008) to develop the relationships among knowledge management barriers; and by Wang et al. (2008), who performed an analysis of interactions among the barriers to energy saving in China.

3.2.4. Decision-Making Trial and Evaluation Laboratory method

DEMATEL method is a mathematical procedure created in the Geneva Research Centre of the Battelle Memorial Institute, to examine important societal matters. It is a comprehensive tool based on matrices representing the contextual relation and strength of influence of the target system elements, to build and analyse a structural model involving causal relationships between those complex elements. Moreover, it can convert the cause–effect relationship amongst elements into visible structural models, and as a result, allowing for an evaluation of the elements' strength of influence within the system (Chuang et al., 2013; Falatoonitoosi et al., 2014; Hsu et al., 2013; Wang et al., 2008). DEMATEL method has been considered one of the most valuable tool to sort out the importance and causal relationships among the evaluation criteria (Hsu et al., 2013). Unlike the traditional multi-criteria decision-making techniques, DEMATEL can confirm interdependence among considered elements and can derive a direct graph showing the interrelationships among those (Shieh et al., 2010). DEMATEL was previously applied in several studies: to develop a carbon management model of supplier selection (Hsu et al., 2013); to identify key success factors of hospital service quality (Shieh et al., 2010); to help improve the performance in a matrix organization (Wang et al., 2012); and to study sustainable management of low-carbon tourism for cultural heritage conservation (Wu et al., 2013).

3.3. Results and discussion

3.3.1. Barriers to the MSWM policy in Maputo City

Five rounds of questionnaires to collect the opinions of seven experts on sanitation and SWM issues in Maputo City were conducted. The number of participants were quite limited, mainly due to limited availability of experts, nevertheless, because Delphi method is centred on qualitative data collection and processing from expert sources and since the number of participants in this study falls within the range of the rules for Delphi application (3 to 98 participants), the obtained results are relevant for a depiction of the main barriers to the waste policy in Maputo City. The group of participants included prominent professionals from academia (01), public sector (02), non-governmental organisations (01), and international institutions (03) - the demographic characteristics of the participant experts are provided in **Table 7.**

Before beginning the Delphi rounds, a set of explanatory documents on the study objectives and the Delphi method as well as literature on waste management policy's instruments were provided to each participant. The process began in April 2014 and ended in July 2014.

Table 7 Demographic variables of Delphi method participants

Characteristics	Number (N = 7)
Gender	
Female	2
Male	5
Age	
31-40	3
41-50	3
50+	1
Education level	
Bachelor	2
Master	5
Experience in Maputo City MSWM	
< 5 years	2
5-10	3
11-15	1
>20 years	1

In the first round, in April 2014, the participants were asked to propose a maximum of three barriers for each of the seven waste policy instruments, resulting in 38 barriers initially proposed. For the second round, the barriers were summarised and sent back to the experts, soliciting their agreement or disagreement and comments. Upon receiving the experts' feedback from the second round, the barriers were listed according to the consensus status. These fell into three groups: agreed-upon barriers with/without proposed modifications, added new barriers, and non-agreed-upon barriers. In the third round, the experts were expected to reconsider their decisions and give their opinions on the non-agreed-upon barriers and the newly added barriers and to voice their final agreement on the proposed modifications to previously agreed-upon barriers. After receiving the third round of feedback in May 2014, a list of 28 consensual barriers was prepared for final evaluation and comments by the experts. Following that, in an attempt to further trim the list of barriers, a fifth round was performed in July 2014 with three of the seven experts, for them to carefully review the 28 barriers and propose improvements, causing some barriers to be eliminated and others to be enhanced. As a result, a final list was produced comprising the 26 barriers, identified in this process (**Table 8**).

Following, the results from Delphi method will be discussed for each waste management policy's instrument obtained, by supplementing the experts' input with relevant literature on low-income countries.

Table 8 Barriers to MSWM policy instruments in Maputo City

Policy Instrument	Related barriers
Legislation & Regulation	B1 Lack of control over legal content by those responsible for its implementation B2 Reduced law enforcement B3 Excessive subordination of legislative power to political power
Voluntary agreements	B4 Weak framework for promoting dialogue among stakeholders B5 General perception that the government is solely responsible for MSWM B6 Reduced spirit of volunteerism and excessive greed for easy profits
Economic instruments	B7 Charged waste fees fail to ensure the financial sustainability of the sector and fail to reflect principles of social justice B8 Improper budgeting and ineffective control over the costs of waste management services B9 Lack of financial incentives to reduce waste production at the source (domestic producers), such as recycling, reuse and other forms of exploitation B10 Lack of knowledge about green procurement
Education and influence to behavioural change	B11 Weak political will B12 Ineffective education programs and dissemination of good MSWM practices B13 Education programs lack enforcement, supervision and monitoring activities B14 No appreciation of citizen compliance (to serve as an example) B15 Too much dependence on imported products, sometimes without

	certification of quality
Monitoring, information & performance assessment	B16 Lack of planning, monitoring, and performance evaluation activities B17 Unreliable information systems and databases B18 Conflicts of interest and corruption B19 Absence of official recognition for MSWM workers and MSW handlers
Choice of technology	B20 Limited directives on the objectives, capabilities, and conditions (financial, technical) of the municipal authority B21 Lack of knowledge about existing alternatives and their feasibility B22 Dependence on donors' influence and decisions B23 Insufficient maintenance of existing equipment
Community linkages	B24 Reduced sense of ownership and willingness to participate within the community B25 Lack of municipal programs to create and strengthen links with the community B26 Ineffective representation of communities in decision-making bodies

3.3.1.1. *Legislation and Regulation*

In Maputo City, the process for establishing the MSWM regulatory framework is simultaneously in its development and implementation phases. The experts noted a gap in the effectiveness of the application and enforcement of laws and regulations caused by a lack of understanding among waste managers and law inspectors of their content and the limited resources available for enforcement activities. In addition, the experts also recognised excessive interference with legislative bodies by political bodies. These findings confirm what was previously documented by authorities in Maputo, who cited weak institutional capacity and a lack of qualified personnel as reasons for its poor MSWM performance (Maputo Municipal Council, 2007). Furthermore, these results are consistent with the findings of Marshall and Farahbakhsh (2013) that reported weak institutions as being a major issue in emerging and developing countries, which means that, institutional reinforcement and capacity building is a crucial requirement, and that the enforcement of laws governing regular MSWM activities and new project implementation is often poor, resulting in improperly functioning MSWM systems. Regarding personnel skills, Marshall and Farahbakhsh (2013) cited Schübeler who stated, "large discrepancies often exist between the job requirements and the actual qualification of the staff at the managerial and operational levels". Moreover, Chung and Lo (2008) suggested that waste management literacy among waste administrators in developing world cities, such as those in mainland China, is alarmingly inadequate. A similar situation also occurs in Mexico, as Buenrostro and Bocco (2003) reported that another consequence of poor administrative planning of public sanitation systems is that the majority of these services are directed by personnel with a low educational level and no SWM and/or technical training. As for the issue of political interference, Manga et al. (2008), described a representative case in Cameroon, where political interference limits efficient delivery and enforcement despite the existence of enforceable statutory instruments.

3.3.1.2. *Voluntary Agreements*

Voluntary agreements, which are often seen as a form of self-regulation, are flexible, and they foster a close dialogue among those involved (usually with wider interests, such as industry, consumer groups, NGOs, and the community). Entering into a voluntary agreement with one or more parties to introduce particular measures, is often an attractive policy option for governments. A successful example of a company's voluntary commitment is found in a case involving the well known company 3M, which cumulatively prevented the release of 1 metric tonne of pollutants and saved US$1 billion over 30 years. This agreement was implemented under the management of Dr Joseph Ling, the pioneer of the Pollution Prevention Pays (PPP) program in 1975 (Hyman et al., 2013; Seadon, 2006).

In the case of Maputo City, experts understand that voluntary agreements are affected not only by the authority failing to provide an environment to foster dialogue between itself and other stakeholders, particularly the industry sector, but also by the general perception that stakeholders are exempt from active participation in waste management matters. This has led to low levels of volunteerism. The experts also referred to the stakeholders as being driven by easy profit, thus disregarding the adoption of waste management sound schemes (which is a fallacy, as demonstrated by the case of 3M). In regards to stakeholders' lacking involvement, Guerrero et al. (2013) work on waste management in developing countries, reported that waste management is generally regarded as the sole duty and responsibility of local authorities and that the public is not expected to contribute. In addition, Shekdar (2009) confirmed that societal and management apathy is among the factors responsible for poor performance in developing economies and that the operational efficiency of SWM depends on active participation by both municipal agencies and citizens.

3.3.1.3. *Economic Instruments*

After examining the economic instruments applied in Maputo City, the experts identified barriers that include improper budgeting processes, insufficiencies and deficiencies in the social justice of the waste fee charged to waste generators, and the absence of economic incentives to promote the 3Rs and waste hierarchy concepts. In addition, experts also agreed that authorities and managers are not familiar with, and hence do not employ green procurement. The lack of financial resources is an already recognised and pressing matter in Maputo City. Local authorities' projections of combined revenues for 2012, which were based on all economic instruments of the solid waste sector, only covered 69% of the costs (Stretz, 2012a). To circumstantiate some of those findings, Stretz (2012a) also pointed out the issue of all households connected to the public electricity grid, being obliged to pay a waste fee, regardless of their access to municipal services (if any), type of service, and frequency. Analogous conclusions can also be found in other several studies, including Al-Khatib et al. (2010), Asase et al. (2009), Marshall and Farahbakhsh (2013), Sankoh and Yan (2013) and, Wilson et al. (2006).

3.3.1.4. *Education and Influence over Behavioural Change*

The majority of identified barriers to successful education and behavioural change in Maputo City are related to badly chosen actions and a lack of political will by the authorities. Experts believe that actions to encourage waste management awareness and participation, from domestic, small generators to industrial, large generators, are lacking; those that are currently in place need to be reformulated. Experts also have noted that product import activities and internal consumption are not yet regulated to consider waste management issues. These findings align with a past assessment from Maputo's authorities, who planned to develop a public education strategy to address the recognised gap in information and communication with the public (Maputo Municipal Council, 2007). Shekdar (2009) referring to factors responsible for poor performance in developing economies, argued that because the social status of SWM is low, it is treated with general apathy; and that the operational efficiency of SWM depends on active participation of the municipal agency and of citizens. In addition, the AMCOW et al. (2006) recognised that emerging success stories on sanitation and hygiene promotion clearly show that progress relies on political will.

3.3.1.5. *Monitoring, Information, and Performance Assessment*

In terms of planning and monitoring MSWM activities in Maputo City, the experts acknowledged several issues and evaluated the current system as fostering a "pretend to work, so I pretend to pay you" environment. A lack of systematic planning and monitoring, as well as corruption and conflicts of interests, are combined with weak data availability, reliability, and information-sharing structures. The experts also believe that the authority undervalues the personnel engaged in waste removal, which is reflected in poor working conditions and the limited or non-existent capacity-building activities. This was confirmed by Guerrero et al. (2013), who examined two aspects of this matter. First, in developing countries, scant information is available in the public domain, and even this information is extremely limited, incomplete, or scattered among various agencies, making it exceptionally difficult to gain insight into MSW management. Second, waste workers suffer from low social status, which leads to low motivation. On the other hand, Marshall and Farahbakhsh (2013) noted that in low-income countries, political jostling for power means that local authorities base decision-making on the interests of their parties; thus, it is common for government bodies to maintain inflated workforces for political reasons; this consumes much-needed funds. Moreover, they stressed that petty and high profile corruption remains a pervasive and infrequently confronted challenge for public institutions in developing countries.

3.3.1.6. *Choice of Technology*

The expert participants agreed that technology choice is constrained by the extremely limited technical capacity to carry out studies locally and to implement solutions and technologies that respond effectively to Maputo City's specific needs. Furthermore, donations and donor requirements are more often than not incompatible with the city's socio-economic situation, existing infrastructure and equipment, maintenance capacity, and local expertise. All of these barriers have been previously discussed in other works. Chung and Lo (2008) for example, stated that incompetence is found not only in the management skills of local governments (including waste authorities) in general but also in technical areas; Marshal and Farahbakhsh (2013) found that donors may be motivated by the bureaucratic procedures or goals of their home offices rather than an understanding of the local situation. Moreover, they found donor biases towards certain technical approaches or an insistence on using equipment that supports their own export industries, even though that equipment is often inappropriate for local conditions.

3.3.1.7. *Community Linkages*

In Maputo City, experts view two types of barriers to community linkages. One is the weak and non-comprehensive institutional framework for addressing this issue, including communities being underrepresented by their elected bodies (e.g., authorities and decision-makers failing to integrate participatory schemes to gather public opinion, facilitate involvement, and promote transparency and accountability). The other is faulty community conduct that expects successful realisation of programs without joint action with authorities or a commitment to achieving and maintaining satisfactory results. A similar issue was also cited by Chung and Lo (2008), stating that in one hand a common problem among waste authorities in developing countries is that they are weak in mobilizing the trust and cooperation of the community; and on the other hand, community support for waste management work is not entirely adequate because littering is frequent in the community, evasion of waste charges occurs frequently, and community members fail to cooperate with official waste collection hours.

3.3.2. ISM analysis

ISM analysis is fundamentally computational and has four main steps: constructing a structural self-interaction matrix (SSIM) with four types of possible relationships between the elements (*i* & *j*); transforming the SSIM into an initial reachability matrix (RM) following the rules for the substitution of 1s and 0s to obtain a final RM; partitioning the levels of the final RM; and building an ISM digraph and model and applying the Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) analysis (Attri et al., 2013).

3.3.2.1. *Step 1: constructing a structural self-interaction matrix (SSIM) into four types of possible relationships between the elements (i & j)*

To be able to analyse the elements, a contextual relationship of “leads to” or “influences” type must be selected. This means that one element influences another. Four types of classification exist in ISM element interrelationships (Attri et al., 2013). The contextual relationship chosen was “Does Solving/Eliminating Barrier *i* leads to Solving/Eliminating Barrier *j*?”. To complete this step, the author, together with three out of the seven experts who participated in the Delphi method, classified the pair-wise relationship between barriers using the four ISM classification categories. First, letter V represents the relationship through which barrier *i* influences barrier *j*. Second, letter A represents a relationship between barriers *j* and *i*. Third, letter X is used for both directional influences between barriers *i* and *j*. Lastly, letter O represents the absence of a relationship between barriers *i* and *j*. Based on these rules, for each classification obtained from the participant experts and authors of the study, the mean answer was identified and the SSIM (**Table A.1 from Appendix A**) was constructed.

3.3.2.2. *Step 2: transforming SSIM into an initial reachability matrix (RM) according to the rules for the substitution of 1 s and 0 s to obtain final RM*

The rules to transform SSIM into a binary matrix are as follows: if the (*i, j*) entry in SSIM is V, the (*i, j*) entry in the RM becomes 1 and the (*j, i*) entry becomes 0; if the (*i, j*) entry in the SSIM is A, the (*i, j*) entry in the matrix becomes 0 and the (*j, i*) entry becomes 1; if the (*j, i*) entry in the SSIM is X, the (*i, j*) entry in the matrix becomes 1 and the (*j, i*) entry also becomes 1; if the (*i, j*) entry in the SSIM is O, the (*i, j*) entry in the matrix becomes 0 and the (*j, i)* entry also becomes 0. Having done that, the transitivity relationship of this binary matrix is checked (Attri et al., 2013). As Sharma and Singh (2012) noted, transitivity can be defined as how element x relates to element y (i.e., xRy) and how element y relates to element z (i.e., yRz); therefore, transitivity implies that element x will also relate to element z (i.e., xRz). Accordingly, after clarifying the transitivity relationships, the initial RM can be converted to a final RM. The process to obtain the final RM (Table A.2 from Appendix A) was performed using ISM for Windows Software, developed at George Mason University in the USA.

3.3.2.3. *Step 3: partitioning the levels of the final RM*

From the final RM, the reachability, antecedent, and intersection sets for each barrier were derived. The reachability set consists of the barrier itself and the other barrier(s) it could affect, and the antecedent set consists of the barrier itself and the other barriers that could affect it. The intersections of these sets can be derived for all the barriers, and the levels of the different barriers can be determined. The barriers whose reachability and intersection sets are the same, occupy the top level of the ISM hierarchy. The top-level barriers are those that do not influence barriers above their own level in the hierarchy. Once a top-level barrier is identified, it is removed from consideration. Then, the same process is repeated to identify the barriers on the next level. This process is continued until the level of each barrier is found; these levels help build the ISM diagram (Ravi and Shankar, 2005; Sharma and Singh, 2012). The reachability, antecedent, and intersection sets for the 26 barriers were derived, and the levels were identified as presented in Appendix A, Table A.3.

3.3.2.4. *Step 4: building an ISM diagram and MICMAC analysis*

Using the final RM and level partitioning, the ISM diagram can be built. To do so, the first-level barrier is positioned at the top of the diagram, the second-level barrier is placed in the second position, and so on until the last level is placed at the lowest position in the diagram, as shown in Figure 9. The top level consists of barriers with limited relationships; the more interrelated the barrier is, the lower a position it occupies in the diagram. The driving power of a barrier corresponds to the sum of all values in each row of the RM matrix and represents the number of barriers that can be resolved by the barrier being analysed. The dependence of a barrier is the sum of all the values in each column of the RM matrix, thus representing the number of barriers that can help resolve that barrier (Chandramowli et al., 2011; Sharma et al., 2012). In addition, MICMAC analysis was performed to visualise the dependence and driving power among the barriers.

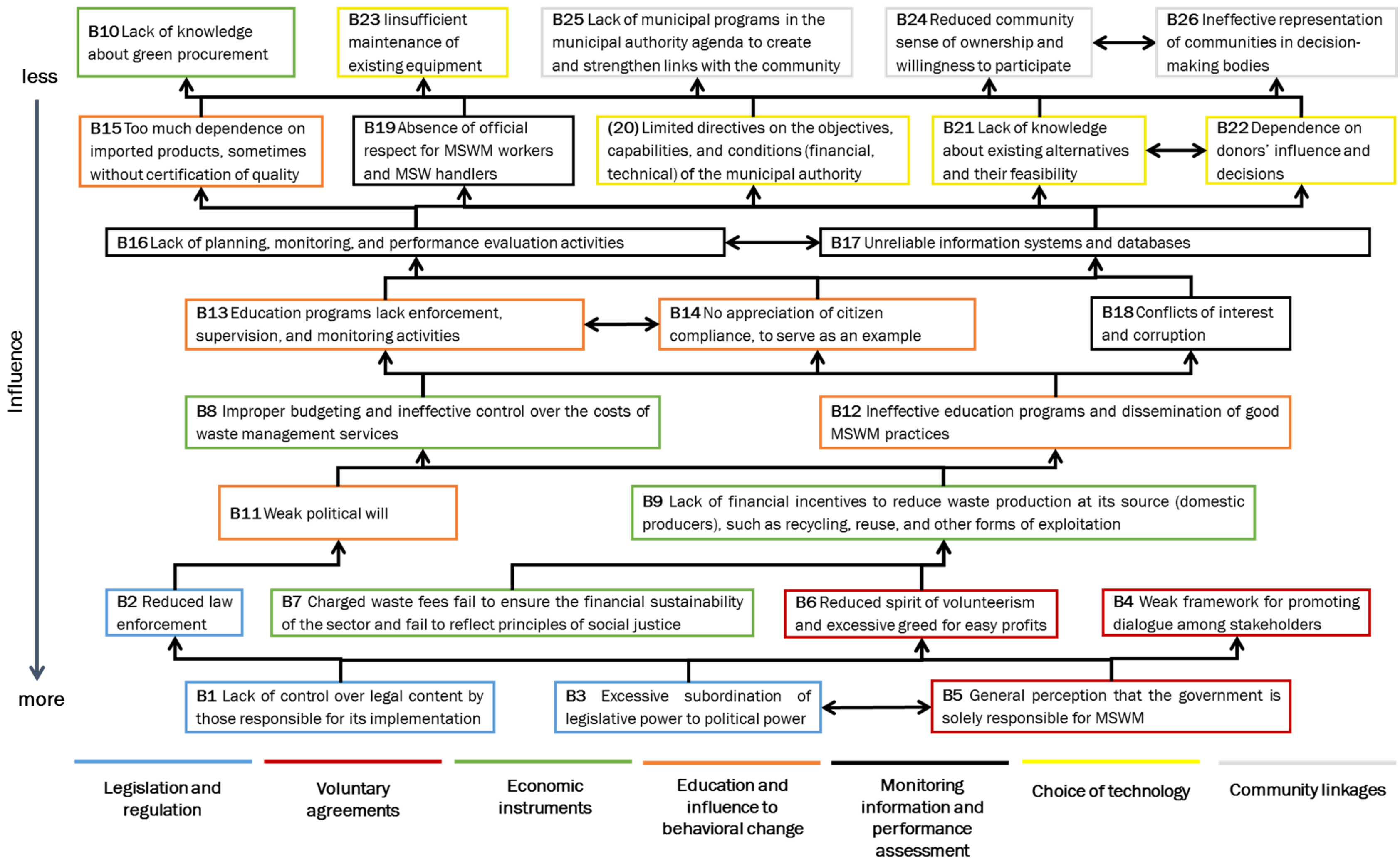


Figure 9 ISM-diagram

MICMAC analysis was first conveyed by Duperrin and Godet in 1973 to analyse the influence and dependence of model elements by plotting their dependence versus driving power, as clarified by the reachability matrix. Taken together with ISM, the MICMAC analysis classification helps clarify how a variable will perform in the system and how it should be managed based on the plotted location. The variables are then classified into four clusters. The first cluster (I) comprises autonomous or excluded variables that have weak driving power and weak dependence. They are relatively disconnected from the system in comparison to the other barriers and can be handled somewhat separately from the rest of the system. The second cluster (II) includes dependent variables with very weak driving power that depend heavily on other variables. Action on such variables should generally wait until their driving variables have been addressed. The third cluster (III) comprises linkage variables that possess strong driving power and strong dependence. These variables are both driving and dependent and are affected by their own actions, thus making them unstable and difficult to address. The fourth cluster (IV) includes independent or influential variables that have strong driving power but weak dependence, such variables should be addressed as early as possible (Chandramowli et al., 2011; Sharma et al., 1995; Wang et al., 2008;).

The results of the ISM analysis include the ISM diagram and the diagram from the MICMAC analysis (**Figure 10**). First, it is important to note that no barriers are in cluster III (linkage barriers), of the MICMAC diagram, which indicates that all 26 studied barriers are stable, and there is no particular level of difficulty in addressing them. Next, the independent barriers placed in cluster IV and at the bottom part of the ISM diagram (B1, B2, B3, B4, B5, and B6), are all related to policy instruments, legislation, regulation, and voluntary agreements. Barriers related to economic instruments, education, and influence over behavioural change (B7 and B11), are also included in this group. These barriers have high driving power and weak dependence and thus are the most influential barriers to the performance of the waste management policy. The barriers placed in cluster I are categorized as autonomous, such as the remaining barriers related to economic instruments (B9, B10, and B10); barriers to education and influence over behavioural change (B12 and B15); barriers to monitoring, information, and performance assessment (B18 and B19); and one barrier related to community linkages (B25). Finally, the dependent barriers from cluster II are at the top of the ISM diagram. These are all related to the choice of technology (B20, B21, B22, and B23); education and influence over behavioural change (B13 and B14); monitoring, information, and performance assessment (B16 and B17); and community linkages (B24 and B26).

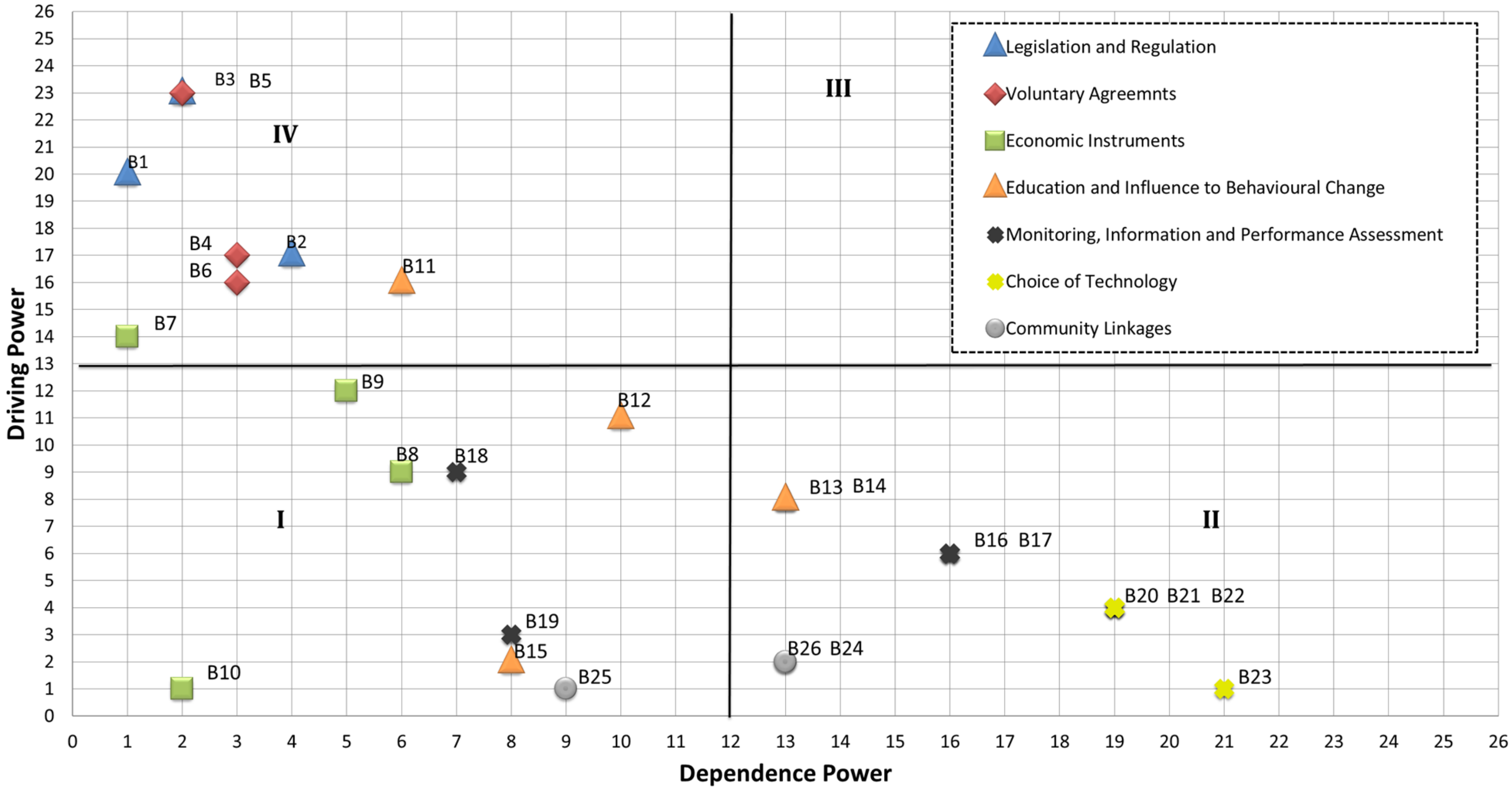


Figure 10 Dependence and driving power of the barriers from MICMAC analysis

3.3.3. DEMATEL analysis

The steps to complete the DEMATEL analysis are as follows: constructing the average matrix A; calculating the direct influence matrix D; deriving the total influence matrix T; and, constructing the cause–effect diagram and net influence matrix (Wang et al., 2012). The computations were performed using the matrix operation tools and formulas from Microsoft Office Excel 2010.

3.3.3.1. *Step 1: constructing the average matrix A*

As with ISM, the application of DEMATEL also required the classification of the interrelationships between barriers. The classification process is similar to the one applied in ISM method. Three experts and the author of the study completed the classification using four categories for each barrier's pair-wise relationship judgment: 0, which represents “no influence” between one barrier and another; 1 represents “low influence” 2 represents “high influence” and 3 represents “very high influence” (Chuang et al., 2013). According to DEMATEL application's structure, if *h* experts are available to solve a complex problem with *n* barriers being considered, the scores assigned by each expert yield an *n x n* non-negative answer matrix X^k, with $1 \le k \le h$. Hence, X^1, X^2...X^h are the resulting matrices for each of the h experts, and each element of X^k is an integer, denoted as x_{ij}^k. The diagonal elements of each resulting matrix X^k are all set to zero. The *n x n* average matrix *A* can then be computed by averaging the value (or score) matrices from the h experts. The (i, j) element of the average matrix *A* is denoted as average influence a_{ij}, represented in **Equation 1** (Shieh et al., 2010; Wang et al., 2012).

$$a_{ij} = \frac{1}{h}\sum_{k=1}^{h} x_{ij} \qquad \text{(Equation 1)}$$

The matrix presented in **Appendix A, Table A.4** has the average number of the scores assigned by each respondent to each barrier, according to a pair-wise relationship judgment.

3.3.3.2. *Step 2: calculating direct influence matrix D*

The direct influence matrix D (**Table A.5** from **Appendix A**) was obtained by normalizing the average matrix A, which is equal to, D=sA, where s is a constant that represents the maximum values, considering the sums of all the rows and the sums of all the columns, which were calculated according to **Equation 2** (Wang et al., 2012):

$$s = Min\left[\frac{1}{max_{1\le i\le n}\sum_{j=i}^{n}|a_{ij}|}, \frac{1}{max_{1\le j\le n}\sum_{i=1}^{n}|a_{ij}|}\right], \text{i,j} = 1, 2,\ldots n \qquad \text{(Equation 2)}$$

3.3.3.3. *Step 3: deriving total influence matrix T*

Following Step 2, the total influence matrix (**Table A.6** from **Appendix A**) is obtained using the identity matrix "I" in **Equation 3** (Chuang et al., 2013; Wang et al., 2012):

$$T = D + ID = D + D^2 + D^3 + \cdots = \sum_{i=1}^{\infty} D^i = D(I - D)^{-1}, \qquad \text{(Equation 3)}$$

3.3.3.4. *Step 4: constructing the cause–effect diagram and net influence matrix N*

If t_{ij} is the *(i, j)* element of matrix T, the sum of the ith row d_i, and the sum of the jth column; r_j and d_i can be obtained using **Equation 4a**, and r_j can be obtained using **Equation 4b.** In this case, d_i denotes the sum of the direct and indirect influences of barrier *i* on the other barriers, and r_j means the sum of the direct and indirect influences on barrier *j* by the other barriers (Wang et al., 2012).

$$d_i = \sum_{i=1}^{n} t_{ij} \ \ (i = 1,2,3 \ldots, n); \qquad \text{(Equation 4a)}$$

$$r_j = \sum_{j=1}^{n} t_{ij} \ \ (j = 1,2,3 \ldots, n) \qquad \text{(Equation 4b)}$$

The cause–effect diagram presented in **Figure 11,** was drawn by mapping the data set of (d_i+r_i, d_i-r_i). The horizontal axis vector (d_i + r_i), known as the "prominence," was constructed by adding d_i to r_i, which shows the degree of importance of the barrier. Similarly, the vertical axis (d_i - r_i), known as the "relation," was constructed by subtracting d_i from r_i, which shows the net effect that the barrier in analysis contributes to, in the system. When (d_i-r_i) was positive, the barrier belonged to the cause group; otherwise, the barrier belonged to the affected group. In addition, a net influence matrix N, presented in **Appendix A, Table A.7**, which is used to evaluate the strength between barriers, was derived using **Equation 5** (Chuang et al., 2013; Falatoonitoosi et al., 2014; Wang et al., 2012).

$$N = Net_{ij} = t_{ij} - t_{ji} \qquad \text{(Equation 5)}$$

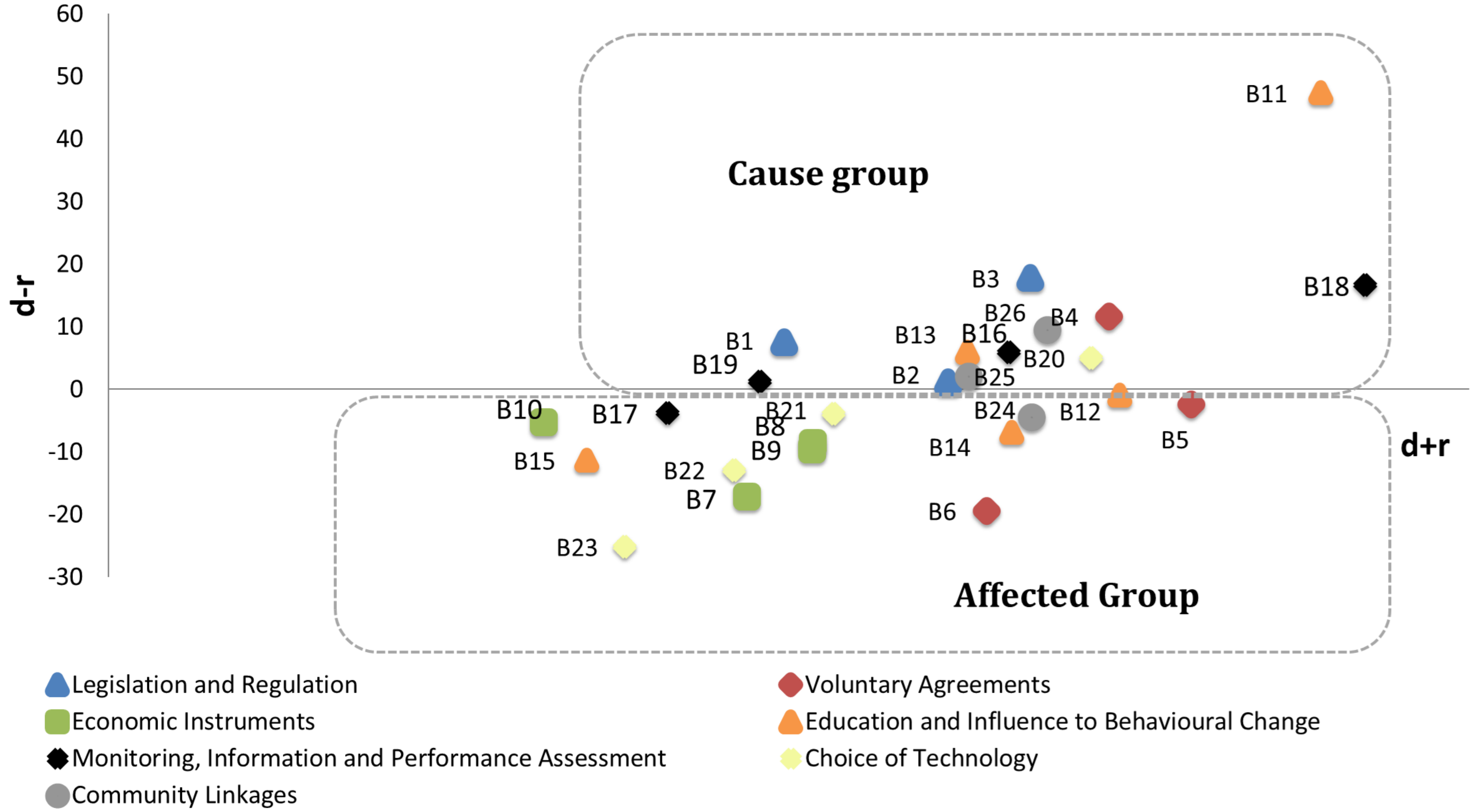


Figure 11 DEMATEL-diagram

From the results of the DEMATEL analysis, the barriers were divided into the cause group and the affected group. All the barriers related to legislation and regulation (B1, B2, and B3) and the majority of the barriers related to monitoring, information, and performance assessment (B16, B18, and B19), belong to the cause group. Moreover, the cause group contained barriers related to education and influence over behavioural change (B11 and B13); community linkages (B25 and B26); voluntary agreements (B4); and choice of technology (B20). The affected group, therefore, represents the opposite polarity and comprises all the barriers related to economic instruments (B7, B8, B9); B10, B12, B14, and B15 from education and influence over behavioural change; B21, B22, and B23 from choice of technology; B5 and B6 from voluntary agreements; B17 from monitoring, information, and performance assessment; and B24 from community linkages.

One of the outstanding features of DEMATEL is the net influence matrix. This matrix enables an in-depth understanding of how barriers associate with each other by assigning numerical values to each barrier. Thus, it is possible to easily identify the strength of the influence a barrier has on, and receives from, other barriers. For example, the net influence that barrier B11 exerts on barrier B2 is + 3.017 (= 4.436−1.419, which are values from influence matrix T).

3.3.4. Combination of ISM and DEMATEL results

Although in its majority the findings from ISM and DEMATEL overlap, this section examines the existing discrepancies. For example, B5, B6, and B7 are classified as independent (cluster IV) / cause barriers in ISM, but they are among the affected barriers in DEMATEL. On the other hand, B13, B16, B20, and B26 are dependent barriers in ISM, while they belong to the cause group in DEMATEL. Taking barrier B5 as an example, this barrier is located at the very bottom of the ISM diagram and has the highest driving power (= 23) and one of the lowest dependence powers (= 2) in MICMAC analysis; however, in DEMATEL analysis, B5 has a very low negative "*d-r*" value (= −2.458) and is located close to the border between the cause and affected groups. These facts suggest that although B5 is considered as an affected barrier, its position in DEMATEL diagram indicates that it is marginally affected by other barriers. Hence, combining ISM and DEMATEL findings led to the consideration that B5 can justifiably be interpreted as being a cause barrier. The same type of deliberation was made for barriers B6, B7, B13, B16, B20, and B26. In addition, this examination was extended to clarify the type of influence ISM's autonomous or excluded barriers (cluster I) hold. As previously mentioned, these barriers should be regarded carefully because while they are disconnected from the group of barriers in terms of not having significant interrelationships, they are still capable of influencing the progress of the waste management policy. For example, the autonomous barrier B25 is located at the very top of the ISM diagram and has very low driving power (= 1) and only moderate dependence power (= 9); in DEMATEL, however, B25 falls into the group of cause barriers, but its “d-r” value is low (= +2.083) - the barrier is located close to the border between the cause and affected groups. In this case, we concluded that the best fit for barrier B25 is to be considered a dependent/affected barrier. The same approach was used to analyse the additional autonomous barriers B8, B9, B10, B12, B15, B18, and B19.

3.3.5. Implications of ISM and DEMATEL results

In Maputo City, the waste management and its policy have progressed over the years, particularly in the last decade with the establishment of a city master plan and city by-laws. However, the actual situation is quite far from the planned. According to the findings from this analysis, the failures related to the waste management policy can be attributed to a total of 26 barriers that correspond to seven key policy instruments. Considering that the type of influence and the importance of the different barriers vary widely, the proposed and applied framework it is valuable because it helps in the clarification of those aspects. Furthermore, based on ISM and DEMATEL results, decision-makers from Maputo City can design effective policy improvement strategies.

To begin with, two main groups of barriers can be recognised: the influential/cause barriers and the dependent/affected barriers (**Figure 12**). The influential/cause group contains nine barriers – those that can highly influence the waste policy and consequently should receive the most attention and priority from decision makers. The group is mostly composed of barriers related to the weak waste management institutional structures, the inadequacy of law application and enforcement, political interference, and the absence of effective mechanisms to foster active involvement from other stakeholders. These barriers are commonly referred to as governance issues (Bhuiyan, 2010; Chiplunkar et al., 2012; Marshall and Farahbakhsh, 2013). Besides, the influential/cause barriers represent strategic issues and as such, ought to be addressed accordingly. For instance decision-makers in Maputo City, should ensure the presence of skilled professionals within the waste management institution; the decisions should ultimately seek to address waste management issues, instead of being set to align with political motives; and, in connection with the previous point, when designing policies, all stakeholders (e.g. producers, consumers, service providers, scavengers, and civil society), should be considered and involved; furthermore, an authentic community representation in the decision-making process rather than allowing damaging interference from individuals and/or a group of interests, is required.

Influential/Cause barriers	Dependent/Affected barriers
B1 Lack of control over legal content by those responsible for its implementation **B2** Reduced law enforcement **B3** Excessive subordination of legislative power to political power **B4** Weak framework for promoting dialogue among stakeholders **B5** General perception that the government is solely responsible for MSWM **B11** Weak political will **B12** Ineffective education programs and dissemination of good MSWM practices **B18** Conflicts of interest and corruption **B26** Ineffective representation of communities in decision making bodies	**B6** Reduced spirit of volunteerism and excessive greed for easy profits **B7** Charged waste fees fail to ensure the financial sustainability of the sector and fail to reflect principles of social justice **B8** Improper budgeting and ineffective control over the costs of waste management services **B9** Lack of financial incentives to reduce waste production at its source (domestic producers), such as recycling, reuse and other forms of exploitation **B10** Lack of knowledge about green procurement **B13** Education programs lack enforcement, supervision and monitoring activities **B14** No appreciation of citizen compliance (to serve as an example) **B15** Too much dependence on imported products, sometimes without certification of quality **B16** Lack of planning, monitoring and performance evaluation activities **B17** Unreliable information systems and databases **B19** Absence of official respect for MSWM workers and MSW handlers **B20** Limited directives on the objectives, capabilities, and conditions (financial, technical) of the municipal authority **B21** Lack of knowledge about existing alternatives and their feasibility **B22** Dependence on donors' influence and decisions **B23** Insufficient maintenance of existing equipment **B24** Reduced community sense of ownership and willingness to participate **B25** Lack of municipal programs in the municipal authority agenda to create and strengthen links with the community

Figure 12 Influential and dependent barriers to waste management policy in Maputo City

In the other hand, the influential/cause barriers are intrinsically connected to and can be considered as the root cause of the dependent/affected barriers. Thus, in order to reduce the impact or eliminate altogether any of the 17 dependent/affected barriers, the decision-makers must first ensure that the process of resolving the influential barriers is well under control. Afterwards, practical measures should be applied to achieve economic sustainability; choose effective waste handling technology; enhance education and influence behavioural change; establish robust monitoring, information, and performance assessment systems; promote voluntary initiatives; boost public participation and the sense of ownership; and, to include community-based programs in the waste management policy.

3.4. Conclusions and recommendations

A waste management policy is the core element of a waste management plan because it reflects the plan's goals and objectives to ensure responsible, coherent, effective, and environmentally sound waste management. However, several barriers can hinder the implementation of such waste management policy. This situation is also aggravated by lack of understanding of the complex interrelationships among those barriers and the different types of influence they exert. A reality analogous to the present situation in Maputo City, where authorities have been struggling with an array of barriers that have caused the waste management system to underperform. Considering that, the barriers to selected key policy instruments were identified and its relationship structure was elucidated. The concluding remarks are presented next.

(1) Following several rounds of the Delphi method application, the expert participants reached a consensus, and 26 barriers to waste management policy instruments were identified: three for legislation and regulation; three for voluntary agreements; four for economic instruments; five for education and influence over behavioural change; four for monitoring, information and performance assessment; four for choice of technology; and three for community linkages.

(2) ISM and DEMATEL methods could clarify the complicated relationships between the barriers of the waste management policy in Maputo City. In one hand, the output of ISM application allowed visualisation of the hierarchical relationship structure, according to the nature of inter-dependence between barriers (autonomous, dependent, linkage, or independent). On the other hand, DEMATEL output gave a further detailed depiction of barriers' cause-effect relationship, including assignment of numerical values that correspond to the strength each barrier exerts on the others and to the group of barriers as a whole.

(3) The combination of ISM and DEMATEL also proved suitable to identify the most influential barriers, which corresponded to nine barriers that require higher priority for intervention. The results indicated that the barriers contributing to poor waste policy performance are mainly related to institutional weakness and lack of cooperation among stakeholders – governance aspects.

In order to eliminate/reduce the barriers to MSWM policy in Maputo City, and create a system with sound and effective policies, the following measures must be prioritised:

- Skilled professionals and experts, who understand and master waste management issues and the implementation of the policy, and professionals that are capable of modifying the policy to respond to the arising challenges, should be a fundamental part of the structure of the waste management institution.
- Policy-and-decision-makers and other waste practitioners must work to raise the political interest in waste management issues, and equally, to eliminate the conflicts of interest and corruption practices.
- Development of a practical strategy to give rise to the awareness and participation of stakeholders, with the inclusion of authentic community representation.

4. Stakeholder analysis and social network analysis to evaluate the stakeholders of Maputo City MSWM system

4.1. Introduction

As defined by Varvasovszky and Brugha (2000, stakeholders are “actors who have an interest in the issue under consideration, who are affected by the issue, or who – because of their position – have or could have an active or passive influence on the decision-making and implementation processes.” The experience in several countries has shown that cooperation and coordination among different stakeholder groups will result in increased sustainability of a waste management system, namely, changes in behaviour and sharing of financial responsibilities. Conversely, the neglect of certain activities or groups will result in reduced sustainability of the system (Klundert & Anschütz, 2000). Moreover, in the context of low-and-middle-income countries, particularly, the characteristic of ISWM being open to all the stakeholders, have been explicitly considered primary (Wilson et al., 2013).

Because no single waste management solution is available, as each city has different characteristics regarding the physical environment, institutional organisation, municipal capacities, financial resources, and sociocultural and socioeconomic contexts, several management decisions are required to provide effective, efficient and sustainable solid waste services. Such decisions have an effect on many stakeholders, as well as are influenced by some of them. Thus, solid waste management experts must have a wide and comprehensive view of the situation and context, taking into consideration the complex interaction of stakeholders (Caniato et al., 2014). Most exemplary SWM systems have come into being as the result of a deliberate intervention on the part of one or more stakeholders in waste management, that is, those who have an interest in seeing something happen. And in most cases, that intervention begins with an assessment and planning process, so that the authorities and other stakeholders understand the current situation, agree on what works and what does not, develop shared priorities and formulate a strategic, long-term vision of what they want to do, and finnaly define and implement the technical and organisational basis to make that vision real (Anschütz et al., 2004).

As reported by Bryson et al. (2002), several kinds of literature, including political science, planning, and public and non-profit management, highlighted how important the study of stakeholders is. They added, “Stakeholder support is needed to create and sustain winning coalitions and to ensure the long-term viability of organisations, policies, plans, and programs. Key stakeholders must be satisfied, at least minimally, or public policies, institutions, communities, or even countries will fail” (Bryson et al., 2002). The identification of the key stakeholders, followed by an assessment of the stakeholders’ knowledge, interest, views, coalitions, and influence over a given topic, is crucial for policy, decision-makers and managers, since it improves the communication between them and the stakeholders, as well as increases the possibility of obtaining the stakeholders' support (Schmeer, 1999). Data collection and analysis regarding stakeholders, also provides an understanding of and the identification of opportunities to influence how decisions are made in a certain context (Brugha & Varvasovszky, 2000).

In this chapter, the aim is to demonstrate the value of combining the complementing stakeholder analysis (SA) and social network analysis (SNA), to add into the decision-making process to better the engagement and interaction of stakeholders in a municipal solid waste management system, in a case of Maputo City MSWM system. Specifically, the objectives are to:

(1) Identify the stakeholders and their roles.
(2) Assess the stakeholders' power and interest, and their overall access to information, knowledge and satisfaction with the system.
(3) Clarify and map the stakeholder's connections in regards to the *partnerships and collaborations* and the *sharing of information*.

4.2. Stakeholder analysis and social network analysis

4.2.1. Stakeholder analysis (SA)

Stakeholder analysis defines aspects of a social and natural phenomenon affected by a decision or action, identifies individuals, groups and organisations who are affected by, or can affect those parts of the phenomenon, and prioritises these individuals and groups for involvement in the decision-making process (Reed et al., 2009). Is a process of collecting and analysing qualitative information in a systematic way, to determine whose interests are relevant in the process of setting up and implementing a given policy or program (Holland, 2007; Schmeer, 1999). In addition, Grimble (1998) defined SA as, "a methodology for gaining an understanding of a system, and for assessing the impact of changes to that system, by means of identifying the key stakeholders and assessing their respective interests". The main objective is to evaluate and understand the stakeholders from an organisation standpoint, or to determine their relevance to a project or policy, by questioning about the interest, influence, position and other characteristics of stakeholders (Brugha & Varvasovszky, 2000). Usually, part of social impact assessments, this analysis is also used in project development from different sectors of activity (Zurbrügg et al., 2014).

SA as a tool for policy analysis has its roots on the early work of policy scientists who were concerned with the power distribution and the role of interest groups in the decision-making and policy process (Brugha & Varvasovszky, 2000). Given that participatory methods are broadly seen as essential to address the difficulties of environmental policy and decision-making, SA is one of the most common approaches for better understanding of the interests of the main parties (Lienert et al., 2013). For instance, SA can be used to understand the environmental systems by defining the aspects of the system under study, to identify who has a stake in those areas of the system, and to prioritise which stakeholders must be involved in the decisions (Prell et al., 2009). As global and environmental change has come to the forefront in recent times, particularly in relation to waste management, stakeholders can now include several other stakeholders apart from the conventional investors and shareholders. Thus, the stressed importance of being aware of who the relevant stakeholders are, and how they might be managed appropriately in the waste and environmental management fields (Heidrich et al., 2009). Examples of SA studies related to environmental field include: a study to identify the most influential actors involved in hydrogen research in Denmark (Andreasen & Sovacool, 2014); an SA for industrial waste management systems, using a small recycling company case study (Heidrich et al., 2009); a multi-SA study related to the design of offsets principles, policies, and regulatory processes, to mitigate environmental impacts from large infrastructure projects (Martin et al., 2016); and an analysis of local waste management systems in Pakistan and India (Snel & Ali, 1999).

4.2.2. Social network analysis (SNA)

Social network analysis began in the 1930s when Moreno in 1934 invented the sociogram, using nodes to represent individuals groups or organizations, and lines, to represent and investigate the relationships or flows between the nodes and relationships between them (Holland, 2007; Reed et al., 2009; Vance-Borland & Holley, 2011). Those links can be social contacts, information and knowledge, influence, money, membership of organisations, participation in specific events, or many other aspects of relationships (Holland, 2007). Ackermann and Eden (2011), described SNA as an approach that focuses its attention on how the relationships among stakeholders constitute a framework or structure that can be studied and analysed in its own right. Furthermore, the network perspective assumes that: (a) relationships among stakeholders are important; (b) stakeholders are interdependent rather than autonomous; (c) a relationship between two stakeholders accounts for a flow of material or non-material resources; and lastly, (d) network structures enhance or inhibit stakeholders' ability to act (Vance-Borland & Holley, 2011). SNA uses a network model and graph theory, and the role of the analyst is to examine the stakeholders and the patterns characterising their relationships within the network (Otte & Rousseau, 2002; Park et al., 2015; Prell et al., 2009). A number of studies applied SNA to address natural resource management, environmental management and sustainability, such as the following: Ghali et al. (2016) analysed the potential role of online social networking to stimulate social connections and enable the material flow`s compatibilities, to foster the formation of industrial synergies; Kreakie et al. (2016) suggested internet-based social networks as effective approaches for building stakeholder networks among conservation and natural resource management professionals: Morone et al. (2015) provided insight into the potential use of bio-waste as feedstock; Park et al. (2015) proposed a network model that can be used to select the sustainable technology from patent documents; in a study focused on bioplastics production; and Vance-Borland and Holley (2011) explored conservation SNA and weaving in Lincoln County on the Oregon coast, United States.

4.2.3. Combining SA and SNA

With SA, the qualitative data on perceptions and interest of stakeholders makes it possible to clarify the interests and influence of a given topic and to report on the threats of an intended policy change. However, there are some significant limitations to current techniques for SA, for instance, the identification and categorisation of stakeholders are commonly done using a subjective assessment (Holland, 2007; Prell et al., 2009). Also, as recognised by Prell et al. (2009), even though widely varied categorisation methods have been developed, those often neglect the role communication networks have to effectively categorise and understand the relationships among stakeholders. In addtion, while stakeholder systems are often considered as a set of stakeholders, isolated and not subjected to continuous interaction, within a network perspective, the relationships and its characteristics are important, the stakeholders are not autonomous, and the network structures can both enhance or inhibit the interactions and influence the outcome of the project (Caniato et al., 2014). To address the limitations of SA, SNA is a complementary approach that offer a valuable and viable solution (Caniato et al., 2014; Holland, 2007; Lienert et al., 2013; Prell et al., 2009). Contrary to SA, the focus of SNA is a systematic and quantitative analysis, and by performing SNA, the process-thought of the analyst is enhanced to elucidate the strength and nature of relationships in the context of analysis (Caniato et al., 2014; Lienert at el., 2013; Prell et al., 2009). As a result, through sharing the conclusions with the stakeholders, increasing involvement and emergence of new initiatives can be noted (Caniato et al., 2014). Overall, in one hand, SA deals with stakeholder's attributes, and on the other hand, SNA clarifies the structure of relationships between those stakeholders, which render those methodologies complementary and its combination a significant contribution (Holland, 2007; Zurbrügg et al., 2014). The combination of SA and SNA is not a new approach and has been applied in several study fields such as, institutional, political and social analysis, organisation, human resources and business planning, natural resources, urban and project management, among others (Gubbins & Garavan, 2016; Holland, 2007; Prell et al., 2009; Rădulescu et al., 2016; Teo & Loosemore, 2010; Zhou et al., 2014). Additionally, Heidrich et al. (2009) argued that there is evidence showing financial and/or environmental benefits in applying stakeholder approaches to environmental or waste management systems. However, in the waste management field, few studies have been published. A few examples include, Caniato et al. (2014), integrated SA and SNA to an infectious SWM system survey of in Bangkok, Thailand; Caniato et al. (2015), used this approach to investigate how stakeholders' networks functioned in the region of the Gaza Strip, in regards to healthcare waste management; and a case study conducted by Lienert et al. (2013), in which potential fragmentation of stakeholders within the infrastructure planning for both water supply and wastewater sector within the Swiss water sector was analysed;

4.3. Research procedures

4.3.1. Sampling

A literature survey on stakeholders of waste management systems, and on stakeholders as one of the dimensions of ISWM concept was conducted, to categorise the stakeholders within a given MSWM system. As a result, six groups, according to different sectors of intervention, were selected to be analysed in the study: government, civil society, academia, service users, donors and cooperation agencies, and private sector (Caniato et al., 2014; Heidrich et al, 2009; Klundert and Anschütz, 2001; Schmeer, 1999; Wilson et al., 2013).

Next, to identify the constituents of each group, a literature survey on Maputo City's MSWM system was conducted, and an initial list of 25 potential stakeholders was produced. Following, an expanding snowball sampling approach (Doreian & Woodard, 1992) was adopted, in which four available representatives from civil society, private sector, and academia, named 10 additional stakeholders, totalling the number to 35 identified stakeholders (including organisations and groups of individuals).

4.3.2. Data collection

After identifying the six groups of stakeholders and the 35 corresponding constituents, a series of online surverys and self-administered questionnaires were conducted with respondents from each group (15 respondents in total): three from the government group; one from civil society; two from academia; six from service users; one from donors and cooperation agencies; and two from the private sector. The process began in January 2016 and ended in July 2016, via an online survey toll (*Survey Monkey®*), or via e-mail (through *Microsoft Word*), using a structured questionnaire, presented in **Appendix B**.

The first part of the questionnaire, focused on the assessment of the respondents' knowledge about MSWM in general, and about the system in Maputo City in particular, and questioned about their involvement in the system. In the second part, respondents were asked to describe their or their organisation's role in the system, to rule on the power and interest they or their organisation have, and on the level of satisfaction regarding the functioning of the system. The last part looked into the respondent's or their organisation`s perception on other stakeholders' power and interest, the perceived satisfaction of the other stakeholders2, and their views regarding the access to information, the existing partnerships and collaborations, and sharing of information.

For the majority of questions, a Likert scale with five points (and at times seven points), was used, as described in **Table 9**, and respondents were sometimes asked to provide explanation on the chosen point.

---

[2]Regarding the question on the satisfaction of the other stakeholders (Appendix B, Question 12, iii.), because the majority of respondents did not answer or gave incomplete answers, this question was completely disregarded.

Table 9 Characteristics and value scales from the questionnaire

Characteristics	Point scale		
Power – the capacity of stakeholder to influence the MSWM system in Maputo City.	1 (very little power) – 5 (very significant power)		
Interest – the interest the stakeholder has on the MSWM system in Maputo City.	1 (very little interest) – 5 (very significant power)		
Satisfaction – the stance of the stakeholder in relation to the current structure and functioning of the MSWM system in Maputo City.	1 (very satisfied) – 5 (very dissatisfied); 6 (do not know) and 7 (no opinion) –not considered answers		
Knowledge – the level of understanding about how the MSWM system in Maputo City is structured and function.	1 (very poor knowledge) – 5 (very good knowledge)		
Access to information – the level of difficulty or easiness to access to information on the MSWM system in Maputo City	1 (very hard to access) – 5 (very easy to access)		
Partnerships and collaborations – identification and classification of *Partnerships and collaborations*' relationships between stakeholders.	0 (none) – 5 (very strong)		
Sharing of information - identification and classification of *Sharing of information's* relationships between stakeholders, resulting from a combination of means and frequency of interactions, as described below:	0 (none) – 5 (very significant)		
Means	*Frequency*		
	Regularly	Occasionally	Rarely
› Meetings (M)	= 3	= 2	= 1
› Reports (R)	= 3	= 2	= 1
› Media (Md)	= 3	= 2	= 1
› M + R	= 4	= 3	= 2
› M + Md	= 4	= 3	= 2
› R + Md	= 4	= 3	= 2
› M + R + Md	= 5	= 4	= 3
› Other (O)	= 3	= 2	= 1

4.3.3. Data analysis

Microsoft Excel was used to structure and organise the data and then construct the power versus interest grid, and the diagrams representing access to information, satisfaction and knowledge, as outputs of the SA. Ackermann and Eden (2011), documented that "among many stakeholder management researchers, Freeman has identified dimensions of power and interest as being significant, and suggested the use of a 'Power-Interest Grid' to assist in balancing the need to take a broad definition of stakeholders whilst still yielding manageable numbers." The power versus interest grid is a commonly applied method to categorise stakeholders within its four quadrants – *Players, Context setters, Subjects* and *Crowd* (Ackermann & Eden, 2011; Bryson et al., 2002; Reed et al., 2009). Stakeholders in the upper two quadrants are those with the most interest in the system, but with varying degrees of power, that is: those to the right-hand side enjoy more power to affect the system - *Players*, while *Subjects* have less influence and significant interest. As for the two lower quadrants, they contain stakeholders with less interest in the system, the *Context setters* that have a high degree of power and the *Crowd* do not hold both interest and power to influence the system (Ackermann & Eden, 2011; Bryson et al., 2002). The power versus interest grid was constructed according to average value from the answers of all respondents.

The assessment of stakeholders' access to information, knowledge and satisfaction with the structure and functioning of the MSWM system in Maputo City, were also completed. As recognised by Reed et al. (2009), the analytical power of approaches such as power versus interest grid, can be improved by adding further attributes to the stakeholders, as such, any number of stakeholder attributes can be included, and the results and implications examined. In this case, since there were self-characterisation questions, and the results and analysis, were presented according to the average value of the answers from respondents from the same stakeholder group.

The SNA data was analysed using UCINET software (Borgatti et al., 2002), and the analysis metrics chosen were (Grandjean, 2015; Otte & Rousseau, 2002; Prell et al., 2009):

- *Density*, an indicator of the level of connectedness of a network, given as the number of lines in a graph divided by the maximum number of lines, hence, it is a relative measure with values between 0 (fully disconnected) and 1 (all stakeholders in the network are directly tied to one another); and
- *Degree centrality*, equal to the number of connections that a stakeholder has with other stakeholders.

4.4. Results and discussion

4.4.1. Identification of stakeholders and their role

Through literature survey and the conducted questionnaires, within the six groups of stakeholders, the roles, power and interest of 35 stakeholders, comprising public and international institutions, civil society and private sector, and individuals, were identified, and are described next.

The Ministry of the Environment, the Fund for the Environment and the Municipal Department of Solid Waste Management and Health are the three leading *government* institutions with responsibilities concerning MSWM in Maputo City. The Ministry of the Environment and the Fund for the Environment provide the legal instruments, policies and action plans on a national level, and training to environmental teachers. On a local level, the Municipal Department of Solid Waste Management and Health mainly works on: developing local legal bounds and regulations for MSWM, and enforce them; developing and executing strategies and solutions for MSWM issues; delivering MSWM services, issuing licenses, and coordinating the activities of service providers; and, developing activities for public education and raise awareness (Cabinet of ministers, 2006; Maputo Municipal Council, 2008; MICOA, 2012).

The *civil society* is mainly composed of non-governmental and non-profit organisations, volunteers' associations and the media. Namely, the primary stakeholders from this group include the Centro Terra Viva (CTV), LIVANINGO, Youth Development and Environmental Law (Kuwuka JDA), Women in Informal Employment: Globalizing and Organizing (WIEGO), LVIA, Association KUTENGA, and the several media outlets. These stakeholders promote environmental education and public participation, particularly in the matter of conscious consumption, reuse, and recycling; support the creation of MSWM projects; coordinate with several other stakeholders within the civil society, diplomatic representations, and the private sector, in cleaning campaigns in problematic neighbourhoods and in the local beach area; conduct and/or finance studies on MSWM; and support and manage waste processing and treatment initiatives. Their role also includes informing the public on current and critical issues, as well as significant advances in the sector, and lobbying for the introduction and improvement of pertinent laws and policies (Allen & Jossias, 2011; Buque, 2013).

The tertiary education institutions were identified as the most representative stakeholders of the *academia*, and their part has been to offer environmental related programs and subjects and to engage in academic research on MSWM. Furthermore, the students' associations have an active role in organising and supporting public participation and awareness raise activities. The stakeholders identified in this group are the Pedagogical University and the Faculty of Engineering, the Faculty of Education, the students' association from the Faculty of Law, and the general students' association, all from the oldest and largest university of the country, Eduardo Mondlane University (UEM).

Small and big MSW generators are the constituting stakeholders of the *service users*. Small generators comprise the more than 1 million residents of the seven municipal districts that make up Maputo City. Their role has been to pay the waste service fee (household waste fee), and to comply with rules and directives related to MSWM at storage points and in public spaces, particularly, in regards to proper handling, deposit and storage before collection. Similarly, big MSW generators, the ones generating more than 25 kg or 50 l of waste per day, must comply with the existing ruling, pay waste fees, and should also arrange for proper waste collection (Maputo Municipal Council, 2008; Stretz, 2012a).

Along the years, several international agencies have been providing financial, technical, and capacity building support, directly to the local authority and to MSWM related projects. Past prominent donors include the World Bank, the Danish Cooperation Agency, and the German Development Agency (GIZ), which most recently ended its MSWM project with the local authority. The Japanese International Cooperation Agency (JICA) was identified as the main current stakeholder of the *donors and cooperation agencies*, together with the GIZ. That is because, even though the cooperation no longer exists, because its exit is a newfound, a substantial number of interviewees still acknowledged the GIZ as a current stakeholder of this group (Allen & Jossias, 2011; JICA & Government of the Republic of Mozambique, 2013; Maputo Municipal Council, 2008).

The *private sector* is profit driven and includes formal and informal sectors. Key private formal sector stakeholders are the waste collection service providers such as EnviroServ and ADASBU; selective collection and material recovery related businesses and/or marketplace such as COMSOL, AMOR, RECICLA, PagaLata, Vulcano, and the waste composting initiative recently closed, FERTILIZA, which similarly to the case of GIZ, interviewees still identified as a current stakeholder. Also part of this group, are business involved in in-house material recovery and in sponsorship of public participation and awareness activities, such as Facobol, Africatubo, Agriplástico, Limetal, Cervejas de Moçambique (CDM), Casino Polana, and Eco Banco. The private informal sector refers to the more than 150 scavengers operating in the streets of Maputo City and the over 500 scavengers working in the local open dump, that have a crucial role in the collection, pre-sorting and preparation of recyclables before recovery activities (Allen & Jossias, 2011; Mertanen et al., 2013).

The process to identify the stakeholders was a straightforward one, with the existing studies, reports and media articles, as well as the interview process, contributing to the identification of the majority stakeholders in Maputo City MSWM system. Nevertheless, there were cases that even though some sources indicated the existence of certain stakeholders, other sources did not acknowledge the intervention and existence of those stakeholders. This fact was recurrent for some civil society organisations and for some entities from the private sector. Also, regarding some stakeholders that though no longer intervene or that no longer exist, several sources still acknowledge them, such as the cases mentioned above of GIZ and FERTILIZA. Thus, having a complete and updated database, in which it is evident who the stakeholders are and how they intervene, can ensure the rightful inclusion within the decision-making, of all relevant stakeholders. Furthermore, making such database accessible and allowing it to be developed in a joint effort between the local authority and the other stakeholders (e.g. through obligatory and voluntary mechanisms), can undeniably improve the recognition of all relevant stakeholders of the system.

4.4.2. Power *versus* Interest

Following the identification of stakeholders, the power versus interest grid presented in **Figure 13**, was constructed, to support the assessment of the relevance of the stakeholders.

From **Figure 13**, no stakeholders were identified as part of the *Context setters'* quadrant. On the other hand, the *Players* quadrant is occupied by all the stakeholders from the government group, a donor and cooperation agency, a stakeholder from private sector, one from academia, and two civil society organisations. An encouraging aspect is that this is such a heterogeneous set of stakeholders, that there is an opportunity to tackle the issues of lack of representation in the decision-making process. However, that depends on the existence of a coordinated work environment, in which the *Players* work together to establish common objectives, prioritise the actions and mobilise the needed resources. Succeeding in that will also ensure a further increase in interest, which is essential because the *Players* can significantly influence the future of the system. The stakeholders part of the *Subjects* quadrant, include the remaining stakeholders from academia, a civil society organisation, and three stakeholders from private sector. Since they already have a significant interest in the system, it is necessary that they fully recognise their potential to have more power and be able to be rightfully included in the decision-making process. That can be achieved through inner alliances, alliances with powerful stakeholders, as well as, with the stakeholders that are part of the *Crowd*. The stakeholders from academia, for example, because of their (typically) recognised scientific and technical expertise, can educate the less knowledgeable and work with the other groups to encourage critical thinking and positively influence the decision-making process. The *Crowd* quadrant is highly populated and includes the majority of private sector, service users, the remaining civil society organisations, and a donor and cooperation agency. Even though by definition, the *Crowd* quadrant has infinitive content, and the stakeholders on it can sometimes be judged as potential, instead of actual stakeholders (Ackermann & Eden, 2011; Caniato et al., 2014), mishandling these stakeholders and failing to establish effective communication channels, can turn them into fierce opponents to the system. Hence, even if a large amount of time and effort is anticipated to secure both their interest and power towards the system, that is an important requirement for a functioning MSWM system, especially because the service users and the private sector make up the majority of this group, and the lack of their understanding and support to the system may translate into conflicts and misunderstandings.

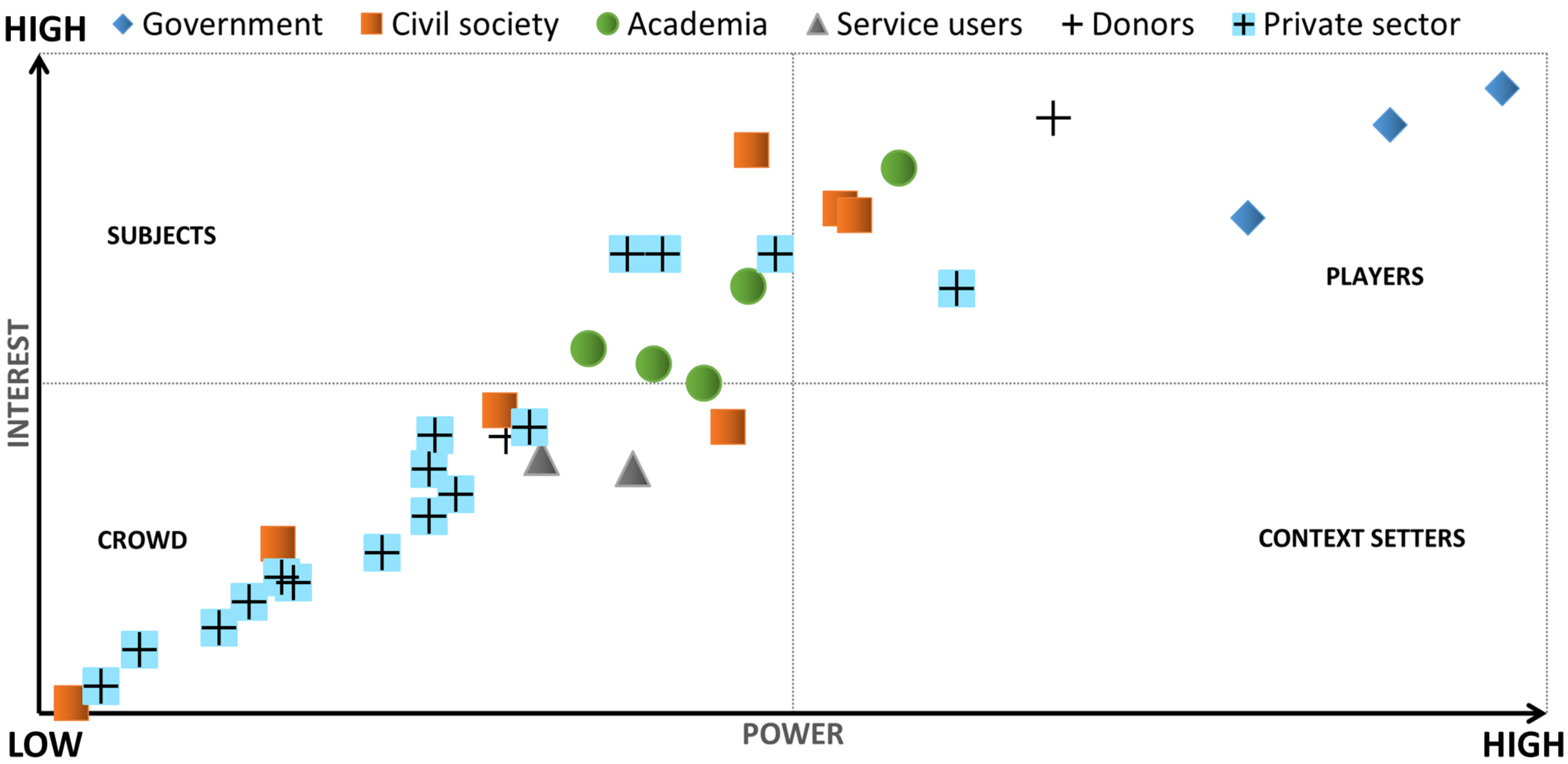


Figure 13 Power *versus* Interest grid

4.4.3. Access to information, knowledge and satisfaction

The civil society, academia and service users, considered access to information as being difficult. The main reasons include, persistent bureaucracy in government institutions, non-dissemination of information in media outlets, lack of transparency regarding the work of the local authority and absence of newsletters to the stakeholders. In contrast, stakeholders from government, deemed information as being (very) easy to access, mentioning the introduction of monitoring and participation programs, the disclosure of information through media outlets, and presence of staff who provides information when requested (particularly to scholars). Donors and cooperation agencies also considered information as being easy to access, mentioning the openness of the local authority to provide the required information whenever necessary.

Concerning knowledge aspects, except for a few service users, all the other groups of stakeholders admitted having basic knowledge about what an MSWM system is, and could easily describe its major elements and functions. Keywords such as “generation”, “collection”, “treatment”, and “final disposal”, continuously appeared in the provided answers. Nevertheless, in regards to the knowledge on the structure and functioning of the MSWM system in Maputo City specifically, the results contrasted significantly. The government assumed having vast knowledge about the system and also believed that it is well-defined, pointing out the existence of clear policies, laws and regulations describing all the MSWM processes in Maputo City, and the existing participatory monitoring system, known as MOPA, that eases the access to information and participation of the citizens. The donors and cooperation agencies, academia and private sector also assumed to have medium to good knowledge about the system in Maputo City. As for civil society and service users, those admitted having limited to very limited knowledge about the system and pointed out as the main reason, lack of or no-available information about how the system operates.

Similarly, in the matter of satisfaction with the structure and functioning of the MSWM system, the government manifested a positive level of satisfaction, yet, recognising the need to enhance the current laws and regulations, staff capacity, waste collection methods, public education, and the involvement of civil society in the decision-making. The private sector also showed a more satisfied position, though, suggested quite a few improvement changes on the matters of material recovery and recirculation, waste treatment and final disposal infrastructure, and law enforcement and government accountability. On the other hand, donors and cooperation agencies assumed a medium level of satisfaction with the system, while reinforncing that significant amount of improvement actions are still required to achieve a more satisfactory positon. The academia in turn, showed significant dissatisfaction with the system, mentioning the ineffective application and enforcement of current legislation, lack of accountability, untrained waste collectors, the need for a national and international cooperation with waste recycling entities, unsuitable MSW landfills (and the incinerators used for industrial waste), and the lack of inclusion of academia in decision-making and deliberations on MSWM. Service users and civil society also revealed dissatisfaction, and in some cases indifference, with the functioning of the system. For instance, they weighed in on the possibility to change from public to a private MSWM system to see the improvement of service quality, the need for public education and awareness raising activities, and for practical rules coupled with strict penalties for the offenders.

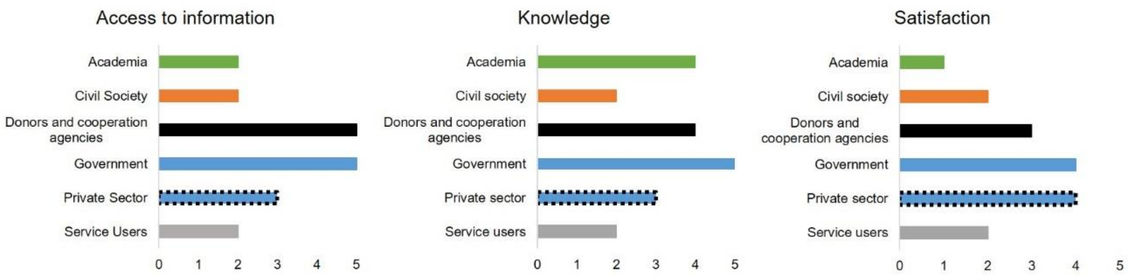


Figure 14 Access to information, knowledge and satisfaction about the MSWM system in Maputo City

Overall, stakeholders have an understanding of what MSWM entails. However, it seems that the majority of stakeholders, excluding the government, cannot fully understand and be satisfied with the existing system. On top of that, even as the government assumes a positive stand, at the same time it also recognises several aspects that ultimately concur to the dissatisfaction with the functioning of the system. This situation can be reversed by making sure that all the stakeholders are aware of what the MSWM system in Maputo City is, as well as, its main structure and objectives. Authorities also need to ease the access to information in order to keep the other stakeholders well informed about the functioning of the system, and the types and status of management activities, and guarantee that communication is done openly and more efficiently. Specifically, for stakeholders that find it difficult to access information about the system that have limited knowledge, and that are dissatisfied with the system, i.e. service users and civil society, education and awareness raising activities should be emphasised, combined with the implementation of simple communication channels and transparent progress reporting. For the dissatisfied stakeholders such as academia, who also hold considerable knowledge, there is an additional need to frequently involve them and acquire their feedback, because they can provide scientifically based proposals that can help improve the system. Succeeding in that can lead to stakeholders being able to reasonably recognise both the advances and short-comings of the system and can also originate or increase support to the MSWM system.

4.4.4. Mapping the networks: partnerships and collaborations, and sharing of information

The partnerships and collaborations, and the information sharing relationships between the 35 stakeholders were mapped in **Figures 15** and **16,** and those will be discussed next. The different shapes and colours of the nodes (stakeholders) are according to the different groups of stakeholders; the thickness of the lines (connections) represent how strong the connection in the analysis is – the stronger the connection, the thicker the line; and, the size of the nodes are in relation to the SNA's metric *degree centrality* - the well-connected stakeholders are represented bigger than less connected stakeholders.

First, despite the fact that the stakeholders in Maputo City may appear to be connected, density scores closer to 0 (i.e., low), such as the resultants from the mapped networks - 0.276 for the partnerships and collaborations (**Figure 15**), and 0.245 for sharing of information (**Figure 16**) -, reflect an overall disconnectivity. Coupled with that, it can also be seen that the networks are characterised by several weak connections, including a disconnected stakeholder from the private sector in **Figure 15**, and few strong connections. Thus, continuously working to reduce or eliminate vulnerable areas of the network, where connections, do not exist or are very weak, is essential. That is because, stakeholders sharing weak connections, communicate less and are less likely to trust and influence and support each other in a time of need (Prell et al., 2009). In addition, by making sure that the existing connections, especially among stakeholders from different groups, are renewed, and those stakeholders are encouraged to work together and deliberate on MSWM issues in the same forums, will diminish the lack of representation, and will foster the emergence of inclusive, diverse and innovative solutions to improve the system.

It can also be seen that stronger connections tend to occur mostly between stakeholders from the same group, which might negatively affect the functioning of the system. For instance, plans and decisions ignoring other relevant stakeholders in place have shown unsustainable results and in extreme situations, stakeholders who may feel shut out if the decision-making processes can cause riots, strikes and destruction of assets (Anschütz et al., 2004). Furthermore, if the same information and knowledge are shared only within the same or restrict group, these will indeed become outdated and peripheral (Prell et al., 2009). Nevertheless, because at least one stakeholder from each group has a strong connection outside of its own group, and except for service users, and donors and cooperation agencies, all the other groups have at least one well-connected stakeholder, those stakeholders are potential linking agents. Their connectivity can be used as a bridge to connect stakeholders, and to create a ripple effect that reaches the not so well-connected stakeholders that they are connected to, which can strengthen the weak connections and ultimately increase the networks' connectivity.

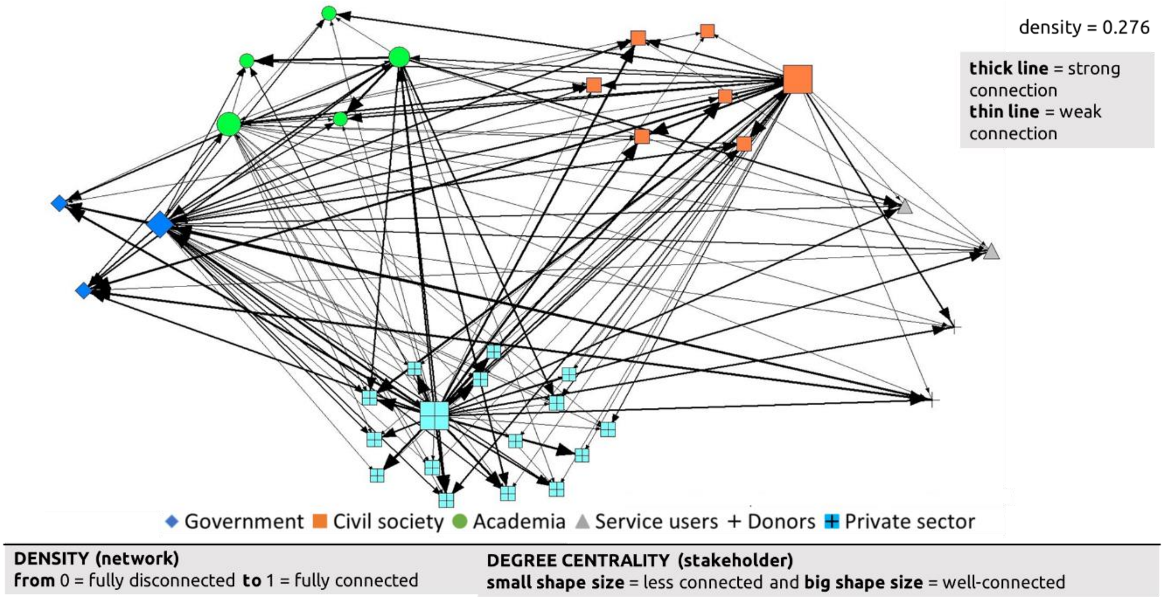


Figure 15 Social network diagram of *collaborations and partnerships* between stakeholders

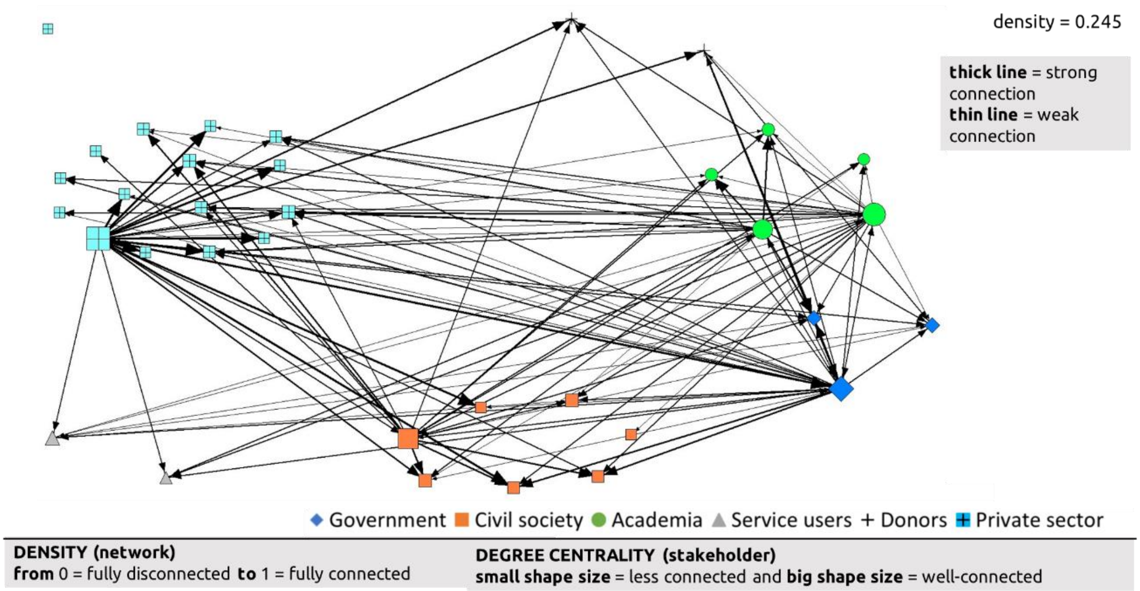


Figure 16 Social network diagram of *information sharing* among stakeholders

Particularly, regarding the case of service users, the network maps show that they lack connectivity in both networks, in particular concerning sharing of information. The relevance of establishing strong and meaningful connections with service users cannot be stressed enough because those are the waste generators, the main recipients of the waste services, and therefore the most influenced by changes occurring in the functioning of the system. Ignoring the importance of working with service users to attend to their needs and concerns will render the decision-making process empty. Thus, it is important to turn the focus to develop and implement comprehensive and practical programs that require engagement and participation of service users, while improving and promoting the communication and information channels already in place. Throughout this process, is also necessary to recognise that different stakeholders require tailored approaches, not only among different groups of stakeholders but also within the groups, because the interest and understanding level can largely vary. There are several examples of good practices in service user inclusiveness, demonstrated in cities such as Bamako in Mali, Belo Horizonte in Brazil, Bengaluru in India and Quezon City in the Philippines (Wilson et al., 2013).

As for donors and cooperation agencies' case, they also present few connections in both networks, and those are mostly limited to the government and some stakeholder from civil society and private sector. This finding is aligned with the reported common occurrence in low-and-middle-income countries, where foreign donor agencies and local decision-makers do not always realise the negative implications of taking ad hoc and decontextualized decisions (Klundert & Anschütz, 2000; Marshall & Farahbakhsh, 2013). Hence, the need for an unrestricted working environment, in which donor and cooperation agencies can branch out their connections to include partnerships and collaborations, as well as, sharing of information, with stakeholders other than the traditional ones

4.5. Conclusions and recommendations

It is indisputable that for a solid waste management system to be sustainable and integrated, all the stakeholders are required to be present and collaborate throughout the processes of planning, implementation and monitoring of how the system is structured and function. However, particularly in low-income contexts, a plethora of issues surrounds the relationship between the stakeholders of MSWM system. The ISWM approach recognises that the stakeholders are the focus and part of the decision-making process, meaning that the implementation of such decisions will more likely be consensual, longstanding, and will benefit from their engagement and resources, e.g., advice, time and financial resources. It also entails improvement in the governance aspect for the management authorities, and the potential, behavioural change of the other stakeholders. Thus, contributing for the establishment of a sustainable MSWM system, particularly, in low-and-middle-income contexts. In this chapter, SA and SNA were successfully combined to provide a preliminary view of who the stakeholders are, how they interact with each other, and which possible strategies can be applied to improve the MSWM system of Maputo City.

(1) The SA, allowed for the identification of 35 stakeholders, differentiated in six groups and their roles were described. The groups include government, civil society, academia, service users, donors and cooperation agencies, and private sector. The identified required action is the clarification of the roles and responsibilities of the stakeholders, coupled with robust monitoring and accountability schemes.

(2) In addition, the stakeholders were assessed according to their power, interest, and access to information, knowledge, and satisfaction with the functioning of the system. Specifically, a position based on the power and interest of each stakeholder was allocated, of either *player*, *subject* or *crowd*. The findings suggest that benefits can be attained, in case the most powerful and interested stakeholders *(players*), work together continuously towards similar goals, and if stakeholders with high interest and less power (*subjects*), harness the latent potential to have more power, by forging alliances with other stakeholders. Also, acting towards the increase of power and interest of stakeholders who have less of both (*crowd*), can diminish the apathy that causes low participation and support, and the imminent risk of those stakeholders converting into fierce and overpowering stakeholders. To address limited access to information, and to increase the knowledge and satisfaction with the system, is important to: ensure that stakeholders are aware of what the MSWM system in Maputo City is; that the access to information is made simple; guarantee efficient communication and information; and emphasise awareness raising activities and full involvement of all stakeholders.

(3) The SNA helped to elucidate the stakeholders' connections in regards to partnerships and collaborations, and sharing of information, by providing the mapping of these networks. Mapping the networks showed that generally, there is a lack of connection among stakeholders in both types of connections as the networks have low-density score values and are characterised by several weak connections. However, there are strong meaningful connections and prominent stakeholders that deserve particular attention, as they can serve as a link for the otherwise not connected stakeholders, and can drive the strengthening of the weaker connections. Decision-makers should focus on raising stakeholders' awareness and participation, developing tailored strategies according to the stakeholders' characteristics, to ensure the inclusion and diversity in representation of different stakeholders in decision-making processes.

To boost the inclusivity and participation of stakeholders and to cultivate meaningful connections among them, several measures are required:

- Clarification of the roles and responsibilities of each stakeholder, coupled with education and awareness actions, followed with vigorous monitoring and accountability schemes.

- Stakeholder engagement strategies must be tailored, according to the stakeholders' characteristics.
- The most powerful and interested stakeholders must continuously work together, towards similar goals, while stakeholders with less power and high interest, must forge alliances with other stakeholders, to reach powerful positions and be able to participate in the decision-making processes.
- To lessen the risk of a rapid and forceful rise of opposition to the system, that can be caused by misunderstanding and miscommunication, meaningful public awareness and participation work towards increasing the power and interest of the less powerful and interested stakeholders, must be conducted.
- The well-connected stakeholders must take the connecting role between the other stakeholders of the networks, with the focus to foster diversity in the stakeholders' representation.

5. The MSWM flow in Maputo City considering the data uncertainties

5.1. Introduction

In order to understand the elements of a waste system and its flows, a key approach commonly applied is the material flow analysis (MFA) (Anschütz, et al., 2004; Wilson et al., 2012). MFA is an analytical method that describes systems of any complexity and is based on two fundamental scientific principles - mass conservation and systems analysis. When correctly conducted, it can depict the flows resulting in products and emissions, and also the leaks and losses of waste materials in a visually clear and transparent manner. Therefore, MFA can assist in formulating strategies that optimise the overall performance of a waste management system (Fehringer et al., 2000; Tang & Brunner, 2014).

Despite the pointed out capabilities, in low-and-middle-income countries, particularly, there is an issue of high uncertainty regarding both data collection and trustworthy reporting, which often weakens the legitimacy of assessments based on these datasets (Baker & Lepech, 2009; Walker et al., 2003). For instance, Zurbrügg et al. (2014), argued that even though MFA tool is useful and there is a growing number of studies conducted in low-and-middle-income countries, its applicability is, for the most part, constraint by the limited data availability, reliability, or means of data collection. In those contexts, data quality is low, mainly because scarce information has been published to the public domain; moreover, the available information is very limited, incomplete, or scattered among various institutions, greatly hindering the possibility to understand the MSWM systems (Guerrero et al., 2013). Marshall and Farahbakhsh (2013) further admitted that efficient MSWM plans are difficult to implement in such countries because the data on waste generation and composition are largely unreliable and insufficient and rarely capture the losses within the system or informal activities.

To address the issue of uncertain input data in MFA, Danius and von Malmborg (2002) proposed a framework that combines a model developed by Hedbrant and Sörme in 2001 (Hedbrant and Sörme model) and the sensitivity analysis. First, the Hedbrant and Sörme model describes the unidentified uncertainties for all input data and calculate the uncertainty of the MFA results, then, the sensitivity analysis elucidates which parameters influence the results the most, and how much these parameters have to change to alter the results (Danius & von Malmborg, 2002).

Therefore, in this chapter, through the combination of the MFA and the data uncertainty analysis framework proposed by Danius and von Malmborg, an evaluation of the MSWM system elements and flows in Maputo City, will be presented. The analysis will comprise two different years - 2007 and 2014, for the following reasons. In the year 2007, the local authority published the first version of its key representative and comprehensive study, titled the *Master Plan for the Management of Municipal Solid Waste in the City of Maputo*, providing the first substantial dataset on the Maputo City MSWM system. Thus, the data from such document is assumed sufficiently accurate and standard to ensure acceptable and indicative MFA results. Alternatively, the year 2014 was chosen to assess the current situation and to allow comparison with the earlier year. Therefore, the main objective is to provide clear and updated information on the past (the year 2007) and present (the year 2014) status of the waste system elements and flows in Maputo City MSWM system, and to clarify the uncertainties of the input data and its influence on the overall results. The specific objectives are to:

(1) Identify and quantify the main flows of MSW, through MFA application, to allow the identification of, flows with unexploited potential; the presence and magnitude of mismanaged flows; and flows that are currently neglected by decision-makers, either knowingly or unknowingly.
(2) Classify and determine the input data uncertainty, with the Hedbrant and Sörme model.
(3) Evaluate the influence of each parameter on the MFA results, performing a sensitivity analysis.

5.2. Materials and methods

5.2.1. Material Flow Analysis

MFA method studies the changes of resources used and transformed as they flow through a certain area. It is broadly applied in environmental management and engineering, resource conservation, regional materials management, industrial ecology and waste management (Brunner and Rechberger, 2004; Montangero, 2007). An MFA is constructed through several steps. In general, first, the problem is defined and the goals are established. Next, the appropriate substances and system boundaries, processes and the goods are selected. The mass flows of the goods and substance concentrations in these flows are then assessed. Following, substance flows and stocks are calculated and the uncertainties are considered. From the results, it is possible to envision the conclusions and formulate goal-oriented decisions. Ideally, the MFA process should be iterative and the procedures must be optimised throughout each iteration (Brunner and Rechberger, 2004; Fehringer et al., 2000). In MFA, processes are defined as transformations, transportations, storage and value changes of substances and goods. The transformation is a physical and/or chemical change of the input goods, while the transportation changes the position of a good without affecting its characteristics, lastly, the storage process stocks the goods, being it for later use or for bio-geo-chemical processing (Fehringer et al., 2000). Some examples of studies in which MFA was used as a tool in low-and-middle-income countries, include: the development of a new methodology to assess SWM in a situation of armed conflict, in a case study in Palestine by Caniato and Vaccari (2014); an evaluation of the co-benefits in term of GHG reduction, and avoided landfill costs by implementing a community-based management program for MSW in Thailand by Challcharoenwattana and Pharino (2015); the work of Dahlman (2009), who modelled sanitation scenarios in Ghana, based on an MFA model; the assessment of emerging waste streams in Thailand by Jacob et al. (2014); a case study in Uganda, on the generation of stakeholder's knowledge for SWM planning by Lederer et al. (2015); an assessment of the current MSWM system in Lahore, Pakistan by Masood et al. (2014); an assessment of material flows as part of the environmental sanitation planning process in developing countries, on a case study conducted in Vietnam, by Montangero (2007); and the application of MFA for waste management in small municipalities in a Serbian case study by Stanisavljevic et al. (2015); an investigation of the role of different stakeholders in informal waste recycling/ trading system in an Indian city by Suthar et al. (2016).

5.2.2. Hedbrant and Sörme model

It is an intricate model that determines the uncertainty in input data and calculates the uncertainty in the result. Originally developed for heavy metal flows in urban systems, it quantifies the representative uncertainties in MFA by classifying the input data corresponding to their distinct sources (Danius, 2002).

When using Hedbrant and Sörme's method, the first step is to determine what level every single input datum belongs to in regards to the data source (e.g., recognised authorities or informal estimates) and the specificity (e.g., data collected from a specific region or from wider regions), from ×/1.1 for high-quality data, to ×/10 for low-quality data (**Table 10**). After assigning uncertainty factors to each uncertainty level, the corresponding uncertainty intervals are calculated. The upper and lower bounds of the intervals are derived by multiplying and dividing the data by the corresponding uncertainty factors, respectively. The intervals are guaranteed asymmetric and positive, as desired for characterising MFA data, meaning that the uncertainty of input datum X with uncertainty interval ×/2 ranges from X/2 to X×2, and the probability that the interval contains the actual value is 95%. The second step is to calculate the uncertainty in the result by a multiplication equation (**Equation 6**) and an addition equation (**Equation 7**), which increases and decreases the uncertainty, respectively (Danius, 2002; Laner et al., 2014; Laner at al., 2015)

Table 10 Uncertainty levels, corresponding information sources and examples from Hedbrant and Sörme's 2001 study

Uncertainty factors [a]	Source of information	Example
interval ×/1.1	Official statistics on local levels. Information from authorities/construction/production.	Number of households, cars, etc. Metal content in products for a specific application.
interval ×/1.33	Official statistics on (local) regional and national levels. Information from authorities/construction/production.	Percentage of leather shoes among shoes. The amount of metals in products.
interval ×/2	Official statistics on national level downscaled to the local level. Information on request from authorities/construction/production.	The share of Volvo cars among all cars. Annual use of stainless steel on roofs and fronts.
interval ×/4	Information on request from authorities/construction/production.	The weight of catalytic converters.
interval ×/10	Generalising data.	Cadmium content in Zinc in a type of good, e.g. galvanised goods.

[a] Instead of defining the uncertainty interval as ± X (symmetrical interval), the uncertainty interval is defined as ×/X (asymmetric interval). Example: The entity 100 kg (Y) can be as high as 200 kg (100×2 kg (Y×X)), or as low as 50 kg (100×½ kg (Y×1/X), written as 100×/2 (Y×/X)).

Source: Danius and von Malmborg, 2002

$$m_{a\times b} = m_a \times m_b$$
$$f_{a\times b} = 1 + \sqrt{(f_a - 1)^2 + (f_b - 1)^2}$$ (Equation 6)

$$m_{a+b} = m_a + m_b$$
$$f_{a+b} = 1 + \frac{\sqrt{[m_a \times (f_a - 1)]^2 + [m_b \times (f_b - 1)]^2}}{m_a + m_b}$$ (Equation 7)

where *m* is the likely value, and *f* is the uncertainty factor.

Given that the original method was developed for data concerning heavy metals, it is possible to make modifications deemed necessary, to fit the data for a particular analysis (Danius, 2002). Furthermore, although the assignment of data sources to specific uncertainty levels and choices of uncertainty factors are subjectively performed by the analyst, Hedbrant and Sörme's approach transparently categorises the uncertainty ranges of data from different sources (Laner et al., 2014).

5.2.3. Sensitivity analysis

Sensitivity analysis varies each parameter and determines its fluctuation effects on the system variables. In a simple input–output model, the parameters are the import flows and the transfer coefficients. It investigates the responses of the variables of the system to changes in its parameters and subsequently determines the most sensitive parameters for a system variable or the entirety of the system. All of the input parameters are methodically altered and tested in this manner. The results provide an understanding and guidance to improve the whole system. This analysis also assists in the design of effective measures and detects the parameters that require a more specific assessment, to reduce the variable uncertainty. Thus, it creates a reference to start defining the priorities in follow-up research and calculations. Sensitivity analysis is also essential when limited data and collection resources are available, as it reduces the number of parameters requiring additional quantification (Fehringer et al., 2000; Montangero, 2007).

5.2.4. Data sources and boundaries

The overall input data were collected from national records of Mozambique, the municipal authority of Maputo and from relevant studies and reports on Maputo City. When such records were unavailable, the data were inferred from Lusaka City in Zambia, a city, which was found to have similar characteristics to Maputo City, as seen in Table C.1 from the Appendix C.

The spatial boundary of the analysis is the geographical area corresponding to Maputo City and its seven municipal districts, while the temporal boundary comprises the years, 2007 and 2014. The functional unit is tonnes per year of MSW material, which includes household and commercial wastes, waste from wet markets and fairs, non-hazardous industrials, construction and demolition debris, green waste, waste from sweeping and bulky household wastes.

The three main elements of the system considered, are MSW generation including reuse and recycle at the source, MSW collection, and MSW treatment and final disposal.

5.2.5. Calculations of MSW flows

The average household waste (HHW) generation per capita value (197 kg year^{-1} = 0.54 kg day^{-1} × 365), was retrieved from the 2007 master plan compiled by the Maputo City municipal authority, and based on the same document, the remaining waste types were calculated as functions of the HHW (Maputo Municipal Council, 2008). The waste reused and recycled at the source for both years, was calculated as 8% of the HHW, a percentage from the Lusaka City data (Scheinberg et al, 2010), as data from Maputo City were unavailable. The input data and calculations for this process are presented in **Table C.2** from the **Appendix C**.

Concerning MSW collection, the collection rates in 2007 and 2014 were assumed as 30% and 90% respectively, as presented in **Table 5** in Section 3.1.3. The calculated total amounts of MSW collected in the inner city and the districts MD6 and MD7, as well as the uncollected MSW, are listed in **Table C.3** from **Appendix C**.

As previously described, the MSW flows after collection significantly differ between the inner city and districts MD6 and MD7. Whereas the MSW generated in MD6 and MD7 is forwarded to informal dumpsites (hereafter called informal dumping), the MSW generated in the inner city is collected and sorted as follows:

- Mixed MSW is collected for final deposition in the Hulene dumpsite.
- Recyclable materials (including recyclables collected from the Hulene dumpsite) are directed to recycling processing plants. In 2007, 3,100 tonnes of recyclable materials were collected, increasing to 6,250 tonnes in 2014.
- A portion of the organic waste has been directed to a single composting facility since 2008; however, only data from 2011 were available. Thus, the composting was considered null for 2007, and for 2014, 600 tonnes of compost were computed.
- The amount of collected but illegally dumped MSW was calculated as 30% of the total MSW generated, a value retrieved from Lusaka City.

Additional calculated elements were the material recovery, which includes the total quantity of MSW recovered as recyclable and compost materials and placed in the recyclable and composting markets respectively, and the waste unaccounted for, computed as the sum of uncollected MSW, the illegally dumped MSW and the informally dumped MSW. The corresponding calculations for those elements can be found in **Table C.4** from **Appendix C**.

5.3. Results and discussion

Figure 17, presents the MSW flows in 2007 and 2014 as an MFA diagram. The discussions points are presented next.

5.3.1. MSW generation and waste reused and recycled at source

The total amount of MSW generated, increased from 397×10^3 tonnes in 2007 to 437×10^3 tonnes in 2014, which is expected, because the calculations were based on population size and a constant average value for waste generation per capita, for both years. Correspondingly, the MSW generation in each district increased proportionally to the population increase, however, it is evident that a differentiated and detailed investigation for each district is needed. According to the local authority's records, the actual value for waste generation per capita, differs among districts - the urbanised and affluent district (MD1) has higher values, followed by the suburban (MD2 and MD3) and rural districts (MD4 to MD7). Nevertheless, apart from acknowledging that the average waste generation per capita value of 0.54 kg $capita^{-1}$ day^{-1}, stems from simple calculations and experiential assumptions based on previous studies, in the master plan it is not clear what was the process applied to determine this value, thus, revealing a degree of uncertainty. Yet, the results for the total MSW generation are in conformity with the global trend, in which waste generation increase is correlated with economic growth (Chalmin & Gaillochet, 2009; Japan Ministry of the Environment, 2011). For instance, from 2008 to 2012, Maputo City's GDP increased from $1,850 million to $2,523 million, respectively (Ferrão, 2006; Maputo Municipal Council City, 2007; National Statistics Institute, 2014). The emphasis concerning this system's elements must be the acquisition of actual waste generation data, by conducting, for example, field survey campaigns. Detailed waste quantity and composition studies will clarify the actual waste generation scenario in Maputo City, therefore allowing the development of appropriate waste management measures and practical waste reduction strategies. Those include, quantitative goals for the whole city, and for each district, taking in account the types of generators, characteristics of the area of the city (urban, suburban or rural) and types of activities, population density, household income, among other aspects. Defining tailored strategies can also ease the implementation and monitoring phases.

Waste reuse and recycled at source in 2007, resulted in approximately 18×10^3 tonnes, while in 2014 the value increased 1×10^3 tonnes. Since the input data for the rate of waste reused and recycled at source, does not correspond to Maputo City, there is also a level of uncertainty that needs further investigation. Nevertheless, the results are a reference to explore a latent potential for waste reuse and recycling at the source, since there are records indicating that those practices are common within low-income households in Maputo City. Increasing the waste reused and recycled at the source will reduce the amount of waste entering the MSWM system, which is desirable. To promote this practice, authorities must stress its relevance to the other stakeholders, and introduce incentives for dissemination, with a particular focus on higher income households and the commercial and industrial sector, which are currently disinclined to reuse and recycle MSW at the source.

5.3.2. Material recovery market

The quantity of MSW passing through waste processing and treatment schemes is a negligible proportion of the total MSW generated in the city. The rates of waste processing before recycling increased by just 0.7% from 2007 to 2014. Meanwhile, the composting rates in both years were well below 1%. Nonetheless, an assessment done in 2014, revealed that from the regional demand for recyclable materials, which is 673×10^3 tonnes per year, Maputo City can supply approximately 30×10^3 tonnes of recyclable material (8% of the total MSW generated); in addition, the wet markets alone, can generate approximately 37×10^3 tonnes of organic waste per year (Tas & Belon, 2014).

In Maputo City, particularly regarding waste recycling activities, putting a focus on waste separation at source and selective collection, is crucial to establish integrated and sustainable waste treatments schemes. The formal integration of scavengers within the waste recovery activity is equally urgent. As a reference, there are well-known cases of fruitful partnerships and successful integration of scavengers in the MSWM systems, such as in Belo-Horizonte, Quezon City, Pune and Lima, that resulted in increased recycling rates, avoided collection costs, social inclusion, job creation and income generation (Dias, 2011; Gunsilius et al., 2011). In Maputo City, scavengers are the main stakeholders dealing with waste separation in the city, however, for the most part, those are seen as an annoyance, criminals or outsiders. Despite the fact that attitude towards the scavengers have changed over the past few years, from being considered a nuisance, to the recognition of their activity for livelihood purposes, officials from the local authority, still believe that scavengers barely have an impact on waste reduction, and that they complicate the waste management processes (Allen & Jossias, 2011). Yet, these contrast with reports that indicate that more than 30% of the MSW generated in the city, does not reach the local dumpsite, mainly due to the scavengers' interventions combined with the existing material recovery initiatives (Mertanen et al., 2013), a fact that shows how important it is to integrate the scavengers as formal agents within the material recovery activities.

Furthermore, the integration of different waste treatment processes according to the waste type, market conditions, local resources, among other factors, must also be considered. For instance, while composting is widely recognised as a suitable alternative in low-income contexts, aspects such as technical expertise on the composting process, location and scale of the project, acceptance in the usage of compost, and financial sustainability, ought to be taken into account. As an example, when the only composting initiative in Maputo City initiated the activities, there was no composting market available, which led to the managers having to create one. Another example illustrating the need for technical expertise, as well as a survey on the public acceptance, is the incident that caused the interruption of operations in 2011, of the said facility, due to disputes with the neighbouring residents, caused by the unpleasant odour originating from the composting process (Buque, 2013).

Once more, the issue of uncertainty emerged due to the lack of data uniformity, data being scattered, and the indistinguishable account for the contribution of scavengers in the material recovery, which increases the difficulty to triangulate the data, thus, comprising the reliability of the results. However, there is encouraging evidence in regards to the potential to recover waste materials in Maputo City that should require the attention of decision-makers. Besides, in a study done by Mbiba (2014), showed empirical evidence of household readiness to engage in expanded waste separation programs at the source, in urban households of Eastern and Southern Africa.

5.3.3. MSW collection and final disposal

With the expansion of formal waste collection services, the proportions of collected and uncollected MSW dramatically changed between 2007 and 2014. In 2007, the estimated quantities of collected and uncollected MSW were 111×10^3 tonnes and 265×10^3 tonnes, respectively. In 2014, the collected MSW increased to 369×10^3 tonnes while the uncollected MSW fell to 42×10^3 tonnes. As reported by Stretz (2012b), the participation of the private sector at both local and international levels has been crucial for successfully waste collection operations in Maputo City.

Despite the high waste collection rate, which means lesser MSW nuisance at the generation points, the problem has been diverted to open dumping, an environmentally and socially unacceptable final disposal alternative. The amount of dumped waste in Maputo City tripled from 76×10^3 in 2007 to 253×10^3 in 2014, highlighting a major undesirable and unsustainable situation. According to the 2014 Waste Atlas, the Hulene dumpsite ranks among the 50 biggest dumpsites in the world, holding approximately 1.75×10^6 to 2.5×10^6 tonnes of MSW and hazardous waste (ISWA et al., 2014). Problems associated with this open dump include the collapse of the only wall placed in front of the facility (more than two collapses within the past two years), the constant smoky haze over the dumpsite sourced from open burning activities, groundwater contamination during the rainy season, health risks to scavengers (cold-related headaches, diarrhoea, malaria, accidental cuts and backaches) environmental risks to the sea (Maputo City's main natural resource) and risks to the nearest settlement just 200 meters from the dumpsite. To make matters worse, an estimated 2.7 million inhabitants, including the population outside Maputo City, reside within a 10-kilometer radius from the site (ISWA et al., 2014; Notícias, 2015).

While the investment and improvement of waste collection services must continue, that should be combined with proper and sustainable schemes for subsequent waste treatment and final disposal. Consequently, a swift and engineered landfill closure of the dumpsites in operation, with the inclusion of remediation processes, is required. To do so, an exhaustive assessment of the actual quantity and composition of the waste deposited, as well as, the landfill gas and leachate generations, should be the first and imperative steps. It is equally crucial to address the presence of scavengers in the final disposal sites, particularly in Hulene dumpsite. Estimates suggest that more than 500 scavengers, mainly women and children, are active in that site alone (Allen & Jossias, 2011). There is an opportunity to integrate and formally recognise the scavengers, as valid and essential stakeholders within the MSWM system. Positive outcomes in the technical financial and social domains can be achieved through the implementation of programs to ensure safe and suitable working conditions and a stable income, reassure and empower the scavengers as lawful members of society, prevent and prohibit child labour, and programs to educate the other stakeholders to change the negative perception towards the scavengers.

Additionally, the final disposal of MSW in the MD6 must be carefully considered, given that an expansion of this district is expected for the near future. The population of MD6 should be swelled by the bridge connecting MD6 to the inner city, which is currently under construction (BETA, 2011). As the current waste collection and final disposal methods have rudimentary characteristics in this district, improving the current situation while planning, will avoid the aggravation of existing issues and the emergence of new and complex ones.

5.3.4. The unaccounted for MSW

Between 2007 and 2014, the quantity of waste unaccounted for, reduced by approximately 142×10^3 tonnes, mainly due to the local authority's successfully increase of collection rates. Despite this achievement, the amount of illegally dumped MSW is a serious concern, as it represents the bulk contribution of the unaccounted waste in 2014 - the estimated quantity of illegal dumping increased from 32×10^3 tonnes in 2007 to 108×10^3 tonnes in 2014. This phenomenon seems to be linked to non-compliance with some economic policies introduced in 2007, such as the proof of service that confers waste management responsibilities to large-scale waste generators, and the waste disposal fee, charged to private companies and individuals at the Hulene dumpsite (Stretz, 2012a). The situation is aggravated by the fact that most of the large-scale waste generators - commercial and industrial institutions, are also the main generators of hazardous wastes.

Even though illegal dumping in Maputo City does occur, and as such, should be taken seriously, the uncertainty concerning the actual values obtained in this study exists, due to the uncertainty of the input parameters and the simple estimation methods applied. For instance, aspects concerning scavengers' intervention and possible waste reuse and material re-circulation within commercial and industrial sectors, were not considered. Thus, clear understanding and categorization of illegal dumping practices, considering the uncertainties, is required.

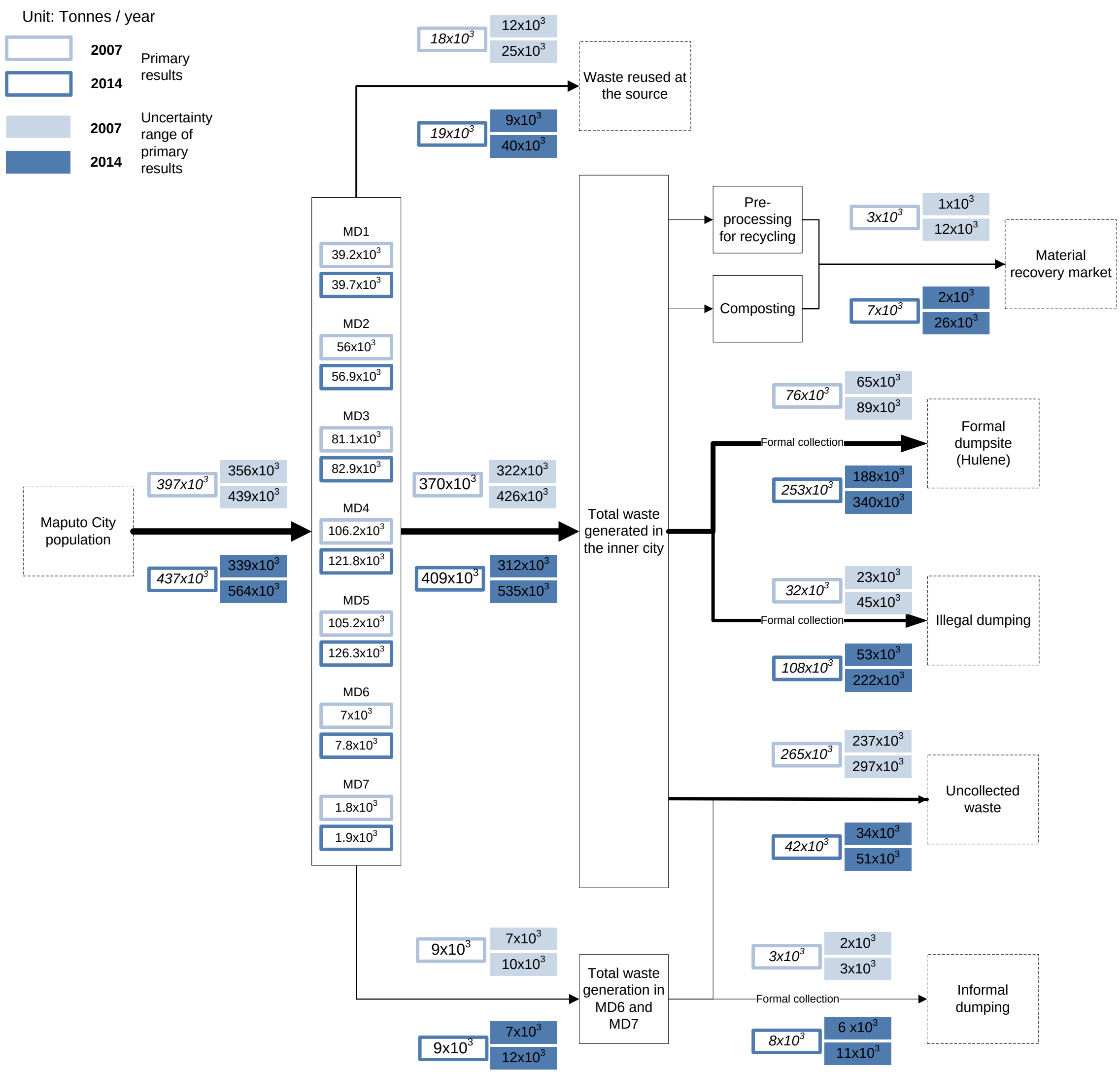


Figure 17 MFA results with corresponding uncertainty ranges in the of 2007 and 2014

5.3.5. Data uncertainty analysis

Each input datum was assigned a corresponding uncertainty factor as shown in **Table 11**. Since the master plan for MSWM in Maputo City, only reports on data from 2007, the majority of the data for that year were assigned the lowest uncertainty factors.

Data for the rate of waste reused at the source and the rate of illegal dumping were unavailable, and in those cases, they were filled with data from Lusaka City. However, they were too, restricted to the year of 2007. Consequently, applying them to the 2014 data introduced an additional temporal disparity; hence, the corresponding uncertainty factors assigned to 2014 were one-step higher than those assigned to 2007.

Additionally, the lowest quality data were related to processing for recycling and composted waste, for two main reasons. First, the data on those processes were scattered and inconsistent; second, missing data needed to be filled by guess-estimated values.

Table 11 Uncertainty factors assigned to input MFA data

Input data	Uncertainty factor		Comments on input data
	2007	2014	
Total population of the city	×/1.1	×/1.1	Data calculated for Maputo City (National Statistics Institute, 2015).
Population distribution per municipal district	×/1.33	×/1.33	Official statistical data for the city municipal districts (Maputo Municipal Council, 2008).
Waste generation per capita	×/1.1	×/1.33	Official calculation for Maputo City for 2007.
Rate of waste reused and recycled at source	×/1.33	×/2	Calculation for Lusaka City for 2007 (Scheinberg et al., 2010).
Percentage of different types of waste	×/1.33	×/2	Calculation from officially reported data for 2007 (Maputo Municipal Council, 2008).
Collection rate	×/1.1	×/1.1	Estimates for Maputo City, from German International Cooperation Agency (Stretz, 2012a).
Illegal dumping rate	×/1.33	×/2	Calculation for Lusaka City for 2007 (Scheinberg et al., 2010).
Waste processed for recycling	×/4	×/4	Estimation from reports for 2006 to 2014 (AMOR, 2011; Buque, 2013; LVIA & Caritas, 2009; Tas & Belon, 2014).
Composted waste	×/4	×/4	

The primary results obtained in the previous MFA study and the calculated uncertainty factors are presented in **Table 12,** and **Figure 17** shows the uncertainty ranges of the MFA resulting flows.

Table 12 Calculated uncertainty factors of main MFA flows

Flow	Calculated uncertainty factor	
	2007	2014
MSW generation → waste reused and recycled at source	×/1.41	×/2.06
MSW generation → material recovery market	×/4.0	×/3.75
MSW generation → formal collection in the inner city → final disposal in Hulene dumpsite	×/1.17	×/1.35
MSW generation → formal collection in MD6 and MD7 → final disposal in informal dumps	×/1.18	×/1.32
MSW generation → uncollected waste	×/1.12	×/1.22
MSW generation → formal collection in the inner city → illegal dumping	×/1.38	×/2.05

The overall uncertainties were lower in the 2007 data than in the 2014 data. For instance, the average lower and upper bounds were 29% and 71% respectively in 2007, and in 2014, these bounds were raised to 41% and 96%, respectively. The trend was similar within all flows, except for *waste generation to material recovery*, which uncertainty was slightly higher in 2007, mainly because there was no composting activity in 2007, i.e. the value for that year was null. The uncertainty results in 2014 were around two times higher than in 2007, as the majority of data from that year were considered high-quality data comparing with the data from 2014, which was also less available, and presented significant spatial and temporal discrepancies. Since the 2007 master plan, the following studies and reports dealing with the issue of waste data in Maputo City, presented and/or estimated their values based on the same master plan, meaning that updated and measured data could not be found available. Furthermore, the very high uncertainty of the flow *waste generation to material recovery* - in 2007 lies between 75% (lower bound) and 300% (upper bound), whereas in 2014 lies between 73% (lower bound) and 275% (upper bound) -, was not only caused by lack of data, but also, due to the dissonance in the consistency of the existing data. In Maputo City, material recovery is done by formal and informal private sector, with minimal to no direct intervention by local authorities, meaning that, if available, accurate and comprehensive data is scattered among different stakeholders.

Failing to have MSW appropriately accounted for, means increasing the risk of incorrectly estimate (over or under) the future needs for the MSWM system in Maputo City, in the process of developing strategies for waste reduction, as well as, during planning for new treatment and final disposal facilities. To reduce these uncertainties, an assessment of the MSWM system flows with the establishment of a waste database that integrates the values and flows of waste generation, collection rate, material recovery and final disposal, must be completed. Decision-makers can establish both mandatory and voluntary schemes, to feed such database and to allow the data to be available and shared between all relevant stakeholders. That is particularly important for new and newly recognised flows, which the authority does not directly manage.

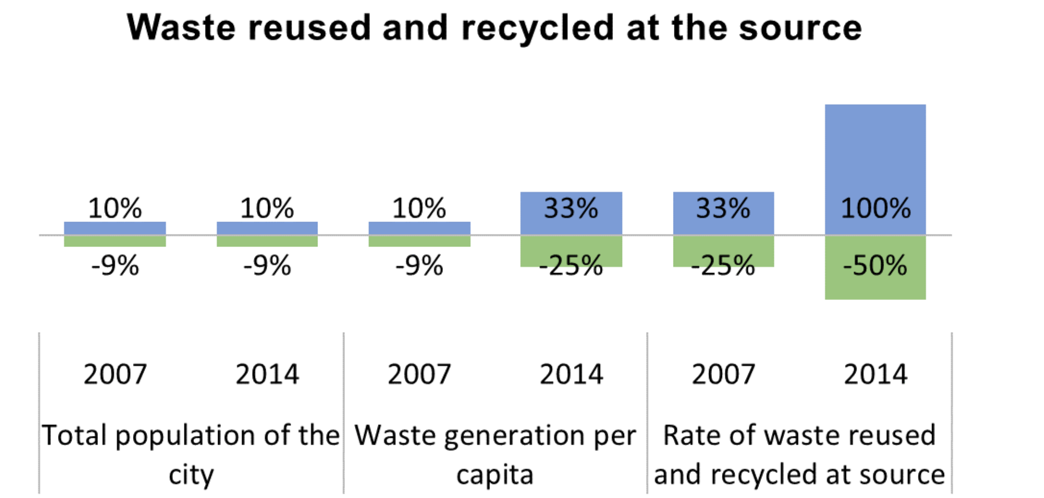
Finally, there was also the case of flows and processes with a considerable level of uncertainty, because despite being qualitatively documented, there was not any prior quantitative assessment, and those were: the *waste generation to waste reused and recycled at source*, which occurs at the household level and the *waste generation to illegal dumping* that includes the depositing of formally collected waste from the inner city and within areas not covered by waste collection services into vacant lots, ravines and ditches, an alleged practice by some private companies that want to evade the disposal fees at the formal Hulene dumpsite. Assessing such flows is also critical to complete a complete waste database, and therefore assist in the development of suitable improvement strategies.

5.3.6. Sensitivity analysis results

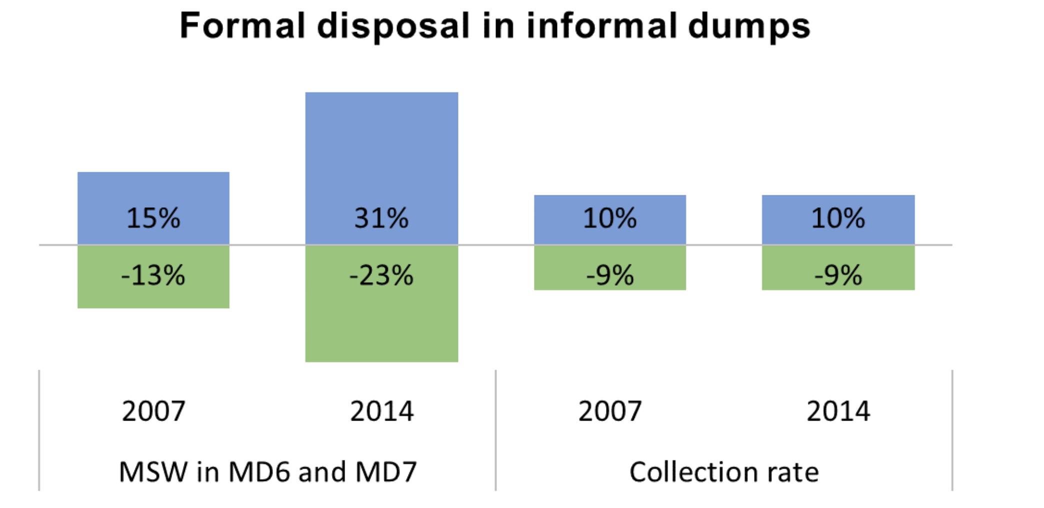
The degree of change for each parameter was determined by the lower and upper bound results, obtained from the Hedbrant and Sörme model. The sensitivity was then calculated as the percentage difference between the results of the MFA study and the values resulting from the parameter change, and the results are presented in **Figure 18**.

The most determining parameters for each flow (from (a) to (f), in **Figure 18**), are the rate of waste reused and recycled at the source, waste processed for recycling, MSW in the inner city, MSW in MD6 and MD7, collection rate, and illegal dumping rate. To reduce the uncertainties of the estimate flows, those are the parameters deserving further investigation, particularly in the instance of limited resources available for data collection. Decision-makers can then structure an effective data collection campaign, in which the accurate assessment of these parameters is prioritised.

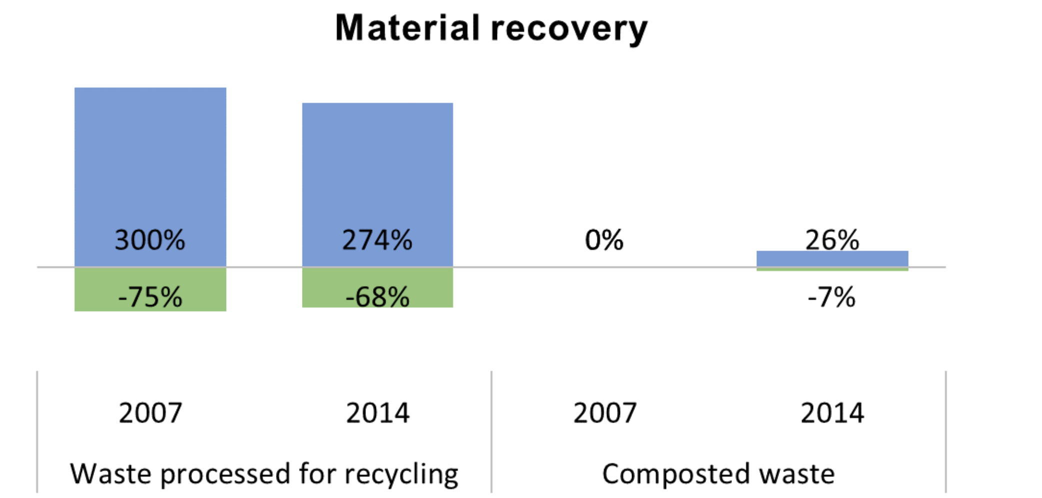
The results also provided an initial perspective on the required strategies for the improvement of the waste flows. For example, it is clear that to increase the quantity of waste reused and recycled at the source in (a), increasing the rate of waste reused and recycled at source will yield the most significant results. However, there were also cases, where parameters from the same flow, exhibited opposite effects on the upper and lower bounds, such as, in the final disposal in Hulene dumpsite (c), and uncollected waste flows (e), which means that an isolated intervention on one of the parameters, would result in the worsening of the other. For instance, in the case of final disposal in Hulene dumpsite, the results suggested that to reduce the quantity of waste finally disposed in the Hulene dumpsite, the MSW generation in the inner city should also be reduced, nonetheless, to reduce illegal dumping, means sending more waste to the Hulene dumpsite, fact that creates a contradictory situation, where solving the illegal dumping problem, aggravates the problem of the unsustainable final disposal method in use. Therefore, those cases highlight how measures aiming at improving a singular flow parameter, may worsen other parameters of the same flow, and subsequently the whole flow, which substantiates the relevance of simultaneously addressing the parameters from the same flow and to apply an integrated approach when devising improvement strategies.



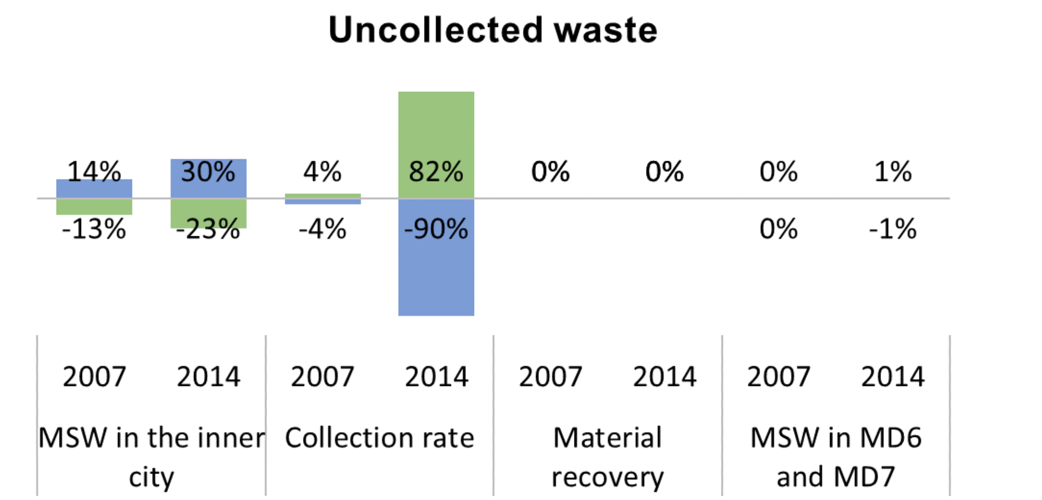
(a)



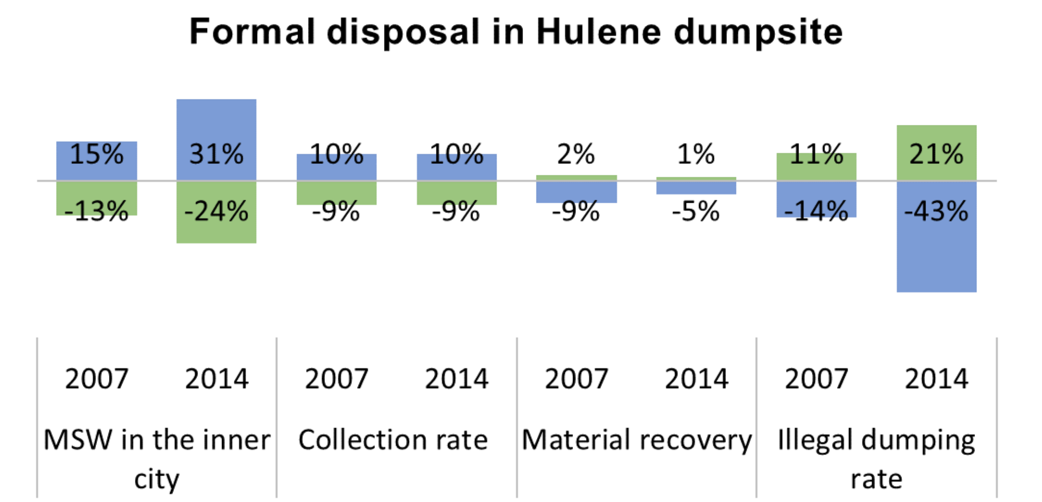
(b)


Material recovery
300%
274%
0%
26%
-75%
-68%
-7%
2007
2014
2007
2014
Waste processed for recycling
Composted waste

(c)


Uncollected waste
14%
30%
4%
82%
0%
0%
0%
1%
-13%
-23%
-4%
-90%
0%
-1%
2007
2014
2007
2014
2007
2014
2007
2014
MSW in the inner city
Collection rate
Material recovery
MSW in MD6 and MD7

(d)


Formal disposal in Hulene dumpsite
15%
31%
10%
10%
2%
1%
11%
21%
-13%
-24%
-9%
-9%
-9%
-5%
-14%
-43%
2007
2014
2007
2014
2007
2014
2007
2014
MSW in the inner city
Collection rate
Material recovery
Illegal dumping rate

(e)

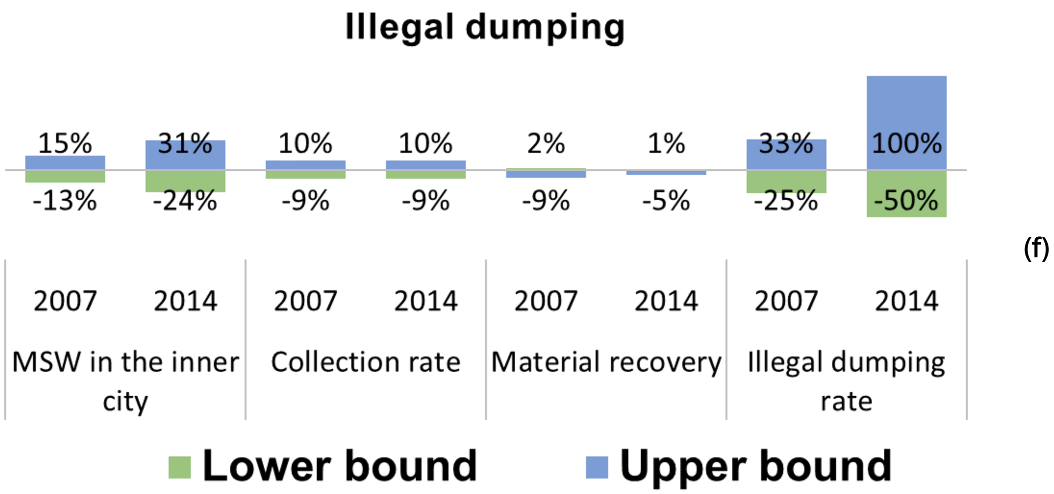


Figure 18 Sensitivity analysis of waste flow parameters

5.4. Conclusions and recommendations

One of the issues that the elements of the waste system's dimension of the ISWM seeks to clarify is what needs to be done when developing or improving a given SWM system. Thus, the past-to-present trends of the main MSW flows and processes within the MSWM system in Maputo City, considering the input data uncertainties, were assessed. In one hand, the MFA tool supported the identification and quantification of the main flows in the system, while on the other hand, data uncertainty analysis was performed with the Hedbrant and Sörme model, followed by a sensitivity analysis, to analysed the input data uncertainty. The main findings are summarised next:

(1) After MSW generation, MSW flows through several routes: reuse and recycled at the source, into the material recovery market, into formal and informal sites, zero flow (no collection) and into illegal dumpsites.

From 2007 to 2014, the MSW generation significantly increased from 397×10³ tonnes to 437×10³ tonnes, along with the material recovery amount, from 3×10³ tonnes and 7×10³ tonnes, and a modest increase of waste reused and recycled at the source, from, 18×10³ tonnes to 19×10³ tonnes. However, the rates of waste processing for recycling and composting are far below their existing potential. In addition, there is a need to verify the possibility to establish fruitful waste handling practices at the source of generation.

On the other hand, in 2014, the total quantity of unaccounted MSW decreased from 2007, from 300×10³ tonnes to 158×10³ tonnes due to the increased coverage of waste collection; however, about three times more waste was disposed of, in unsanitary disposal sites and illegal dumpsites, which unveils the need to upgrade and supervise the final disposals methods, respectively.

(2) The Hedbrant and Sörme model clarified the scale of the variation caused by the input data uncertainty and demonstrated the existence of gaps in the data compilation and consistency. In 2007, the average lower and upper bounds were 29% and 71% respectively, and in 2014, these bounds were raised to 41% and 96%, respectively. Neither established flows, such as waste generation to waste reused and recycled at the source, nor the new and emerging flows, such as waste generation to material recovery and waste generation to illegal dumping, have been appropriately considered and/or documented. Therefore, proper quantification and recognition of the growing complexity of the MSWM system will enhance the updating of priorities.

(3) The sensitivity analysis showed the parameters that mostly influenced each flow: the rate of waste reused and recycled at the source, waste processed for recycling, MSW in the inner city, MSW in MD6 and MD7, collection rate, and illegal dumping rate. The findings validate the necessity for the several integrated interventions, planned and implemented simultaneously.

In sum, the depiction of the past-to-present features of the MSW flow in Maputo City indicated, first, the fundamental need for a detailed and citywide investigation to obtain the actual values for waste data from generation to final disposal. Mandatory and voluntary schemes to sustain a waste database, for instance, can be established to allow data to be available and shared between all relevant stakeholders. Once such requirement is fulfilled, the management strategy must adhere to an integrated approach, to deal with the following proposal matters:

- Customise waste reduction, reuse and recycle plans according to the different characteristics of waste generators within the city and type of waste generated.
- Explore the potential for waste material recovery, with the recognition and integration of scavengers as indispensable stakeholders.
- Achieve whole city waste collection coverage and change the waste final disposal method.
- Recognise and act on seizing illegal waste dumping.
- Incorporate schemes to clarify and continuously reduce the uncertainty aspects within the MSWM system.

6. Life-cycle thinking for environmental and cost assessments of MSW treatment and final disposal options in Maputo City

6.1. Introduction

The increase of greenhouse gas (GHG) content in the atmosphere, caused by human activities in the last decades have been widely recognised, particularly, the contribution from collection and treatment of waste generated in cities, which accounts for 18% of the total anthropogenic methane emissions globally (Barton et al., 2008). Couth and Trois (2011) reported that, according to the United Nations Statistics Division (UNSD) and Carbon Dioxide Information Analysis Center (CDIAC), sub-Saharan countries presented a substantial increase in CO_2 emissions between 1994 and 2004, ranging between 222% and 307%, and those numbers will continue to grow due to the population increase and the urban development. Even so, Couth and Trois (2010) also admitted that “the scarce data on carbon emissions from waste management in Africa is likely to represent a high percentage of carbon emissions in urban areas.” According to Carbon Africa, estimates on emissions from uncontrolled dumpsites in Mozambique, in 2014, reached 76,546 tonne CO_2-eq and, if unchanged, this values is expected to nearly double to 1,369,721 tonne CO_2-eq in 2030. Despite that, due to the lack of country-specific activity data, especially concerning waste generation levels, waste collection rates, and waste treatment practices, uncertainties still exist regarding the GHG estimations (Tas & Belon, 2014). Furthermore, there is an urgency to GHG emissions from waste management activities, given that open dumping and landfilling has been reported as the third highest anthropogenic methane (CH_4) emission source, and particularly, open burning of waste, which is practiced in many cities in low-and-middle income countries, also emits as climate pollutants including black carbon (Menikpura & Sang-Arun, 2013).

The Life-Cycle Thinking is a well-established approach with the objective to provide a comprehensive view of all potential impacts from a product or process life cycle, which includes the environmental, social and economic impacts. In turn, Life-Cycle Assessment or Analysis (LCA) is a decision-support tool/ a set of tools, used to quantify these impacts. LCA studies range from comparative assessments of substitutable products delivering similar functions (e.g. glass versus plastic for beverage containers), to comparative assessment of alternative production processes, including comparing waste management strategies, fact that have been demonstrated to offer valuable inputs to identify appropriate solutions for better management of solid waste (Laurent et al. 2014; Morrissey & Browne, 2004; Wilson et al., 2015). LCA for waste management in systems from high-income countries, usually includes a wide range of impact categories, which require detailed knowledge of resource inputs, waste flows and compositions, operational characteristics of facilities and the final destination of recovered materials, energy and residues, and also the evaluated waste scenarios are likely to be complex and cover all flows starting from the household (Barton et al., 2008). However, those aspects limit its application in low-and-middle income contexts, where the lack of baseline data and site-specific coefficients, is usually unavailable (Zurbrügg, et al., 2014). Thus, as suggested by Barton et al. (2008), in cases that it is not appropriate to go to a high level of detail or sophistication and for a non-specific overview of options, a detailed approach is not warranted or necessary, if the goal is to make an initial assessment of ranking options in terms of GHG emissions. Furthermore, it has been concluded that to improve the decision-making process in low-and-middle income countries, not only environmental dimension must be acknowledged, but also the social and economic dimensions must be included, hence the application of LCA, combined other assessment tools, life-cycle costs, value chain, and social analysis (Reich, 2005; Zurbrügg, et al., 2014). For instance, while LCA supports the evaluation the environmental impacts, life-cycle cost helps evaluating the total cost for conduction the same function, and since both tools develop within a system of connected material flows over the whole life cycle, such a combination is encouraged (UNEP/SETAC et al., 2009; Zhao et al., 2011).

In this chapter, following the results of the MFA conducted in the previous chapter, the aim is to identify the less environmentally impactful and the more cost-saving waste treatment and final disposal alternatives for the MSWM system in Maputo City, based on a life-cycle thinking approach. Specifically, the objectives are to:

(1) Estimate the overall GHG emissions; and
(2) The required capital costs, and the operation and maintenance (O&M) costs for the current and alternative waste treatment and final disposal schemes.
(3) Analyse the effect on the GHG emissions, of changes in waste composition, caused by the potential future increase in per capita income, through a sensitivity analysis.

6.2. Material and methods

6.2.1. Goal and scope definition

The goal is to assess and subsequently compare the GHG emissions and costs of different MSW treatment alternatives for Maputo City, based on waste data from the year of 2014. **Figure 19,** depicts the distinctive alternatives within three scenarios, and the description of each scenario is presented next. The estimated amount of MSW generated in 2014 is 437,330 tonnes, and the waste compositions adopted and considered similar throughout all scenarios, are the ones presented in **Table 13.**

Table 13 Composition of household waste in Maputo City (Weight-%)

Waste components	Maputo City average (Urban + Suburban area) (%)
Paper and Cardboard	6.3
Organic fraction	50.4
Plastic	7.5
Glass	5.15
Metal	2
Rags and rubber	2.85
Hygiene items (nappies)	2.3
Other, inert fraction	23.5

Source: Adapted from Stretz, 2012b

Scenario 1 reflects the business-as-usual in Maputo City. Small MSW portions are reused and recycled at the source (4.3%), recovered through recycling related activities (1.4%) or composted (0.2%). The bulk portion is transported and then disposed of in the official dumpsite - *Hulene* (58%), and the remaining portion is either disposed of in smaller dumpsites known or managed by the authorities (1.8%), left uncollected with an unknown final destination (10%) or illegally dumped (25%). Accordingly, key assumptions in this scenario are as follows:

– Hulene dumpsite is assessed as an unmanaged deep landfill (open dump) receiving waste generated in the urban, suburban and semi-urban areas.
– Material recovery and waste reused and recycled at source are considered negligible, thus, the quantities are included in the total amount of MSW final disposed of in Hulene dumpsite.
– The remaining MSW generated in the rural areas, is assessed collectively and as being finally disposed of, in unmanaged shallow landfills (open dump).

The alternative scenarios 2 and 3 are based on the work of Barton et al. (2008) that proposed a number of options for MSWM management, acknowledging the constraints that are likely to be present in low-income countries. In Scenario 2, all MSW is directed to and finally disposed of in a large-scale sanitary landfill. Scenario 3 contains two variants, with material recovery through recycling being the common treatment process. The main assumptions in this scenario are:

– MSW is collected through a selective collection process differentiating the organic fraction from recyclables (paper and cardboard, plastic, glass, and metal) and the other wastes (rags and rubber, hygiene items, inert fraction and other wastes).

- Then, the MSW is directed to an integrated facility where the recyclables go through a material recovery process, in order to be prepared for a subsequent recycling process, while the organic fraction is biologically treated – composted in Scenario 3A or treated via anaerobic digestion in Scenario 3B.
- The other wastes, the rejects, and residues from the recycling and biological treatments are directed to a sanitary landfill.

On the cost assessment, the total cost per year is the sum of the capital costs and the O&M. Capital costs include costs such as the cost of land, design, construction and equipment, whereas, O&M costs include costs such as labour, taxes, administration, indirect costs, fuel, electricity and maintenance cost. The cost per year is calculated according to Equation 8 (Nishtala & Solano-mora, 1997).

$$\text{Annual cost} = \text{CRF} \times \text{Capital cost} + \text{O\&M cost} \qquad \text{(Equation 8)}$$

Where, capital recovery factor (CRF) - units of 1/year, is the capital recovery factor that enables the conversion of the capital costs into annual terms. It is a function of the facility or equipment life (lifetime), and an appropriate interest rate. For a Discount rate ≠ 0, CRF is calculated as showed in Equation 9.

$$\text{CRF} = \frac{Discount\ rate \times (1 + Discount\ rate)^{lifetime}}{(1 + Discount\ rate)^{lifetime} - 1} \qquad \text{(Equation 9)}$$

The cost assessment is based on the following assumptions:

- The interest rate is 10%.
- The lifetime of waste treatment facilities (for material recovery, composting and anaerobic digestion) is 15 years.
- The lifetime for the sanitary landfill is 20 years.
- The lifetime for the unmanaged landfills is 40 years.
- The cost values are converted into the US dollar, corresponding to the market price of 2010 (**Table D.1** from <u>Appendix D</u>).

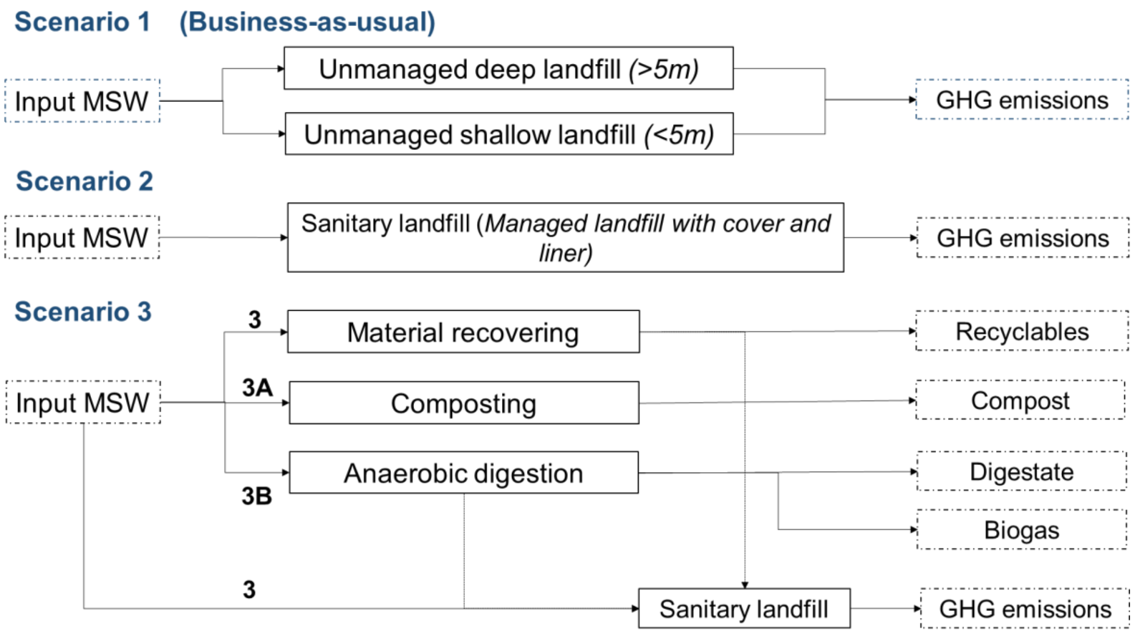


Figure 19 Diagrams of MSW flow of each scenario considered

6.2.2. Inventory analysis

The overall data for the inventory analysis was identified and gathered based on reports, and several relevant kinds of literature. The inventory of material flow and costs for the studied scenarios is summarised in **Table 14** .

The GHG emissions calculations were computed by means of the "Estimation Tool for Greenhouse Gas from Municipal Solid Waste Management in a Life Cycle Perspective", developed by the Institute for Global Environmental Strategies (IGES). According to Menikpura and Sang-Arun (2013), "the IGES estimation tool is a simple spreadsheet simulation to facilitate the estimating of GHG emission from the current waste management practices, to support decision-making process of local governments on selection of appropriate technology for GHG mitigation, to evaluate progress made by adopting suitable waste management approaches, and to contribute to a bottom-up approach for national greenhouse gas inventory report. The adapted life-cycle approach to developing the simulation can be applicable to quantify the GHG emissions from individual treatment technologies as well as from integrated systems." Additionally, once the input of location-specific parameters is concluded, the user is able to assess the results of both direct emissions and GHG savings. The simulation includes the analysis of eight main waste handling and treatment options - transportation, mix waste landfilling, composting, anaerobic digestion, Mechanical Biological Treatment (MBT), recycling, incineration and open burning (Menikpura & Sang-Arun, 2013).

6.2.2.1. *Anaerobic digestion*

The IGES model for this process is based on the Waste Volume of the 2006 Intergovernmental Panel on Climate Change [IPCC] Guidelines for National Greenhouse Gas Inventories, with the usage of recommended average default values. To quantify the overall GHG emissions from anaerobic digestion, users are required to input data on the amount of organic waste used in the process, the fossil fuel and electricity necessary for operational activities, the approximate moisture content of the influent and the type of output (electricity or thermal energy) (Menikpura & Sang-Arun,2013).

The final objective of the anaerobic digestion process in Scenario 3 is assumed to be for biogas production. The operating technology is a dry mesophilic process (30-40ºC) with an electricity consumption of 0.038 MWh per tonne of input waste and a production of 0.69 tonnes of digestate per tonne of input waste (Bjarnadóttir et al., 2002). Fossil fuel consumption is considered null and the resulting digestate to be used in soil conditioning. Cost estimation is based on a French anaerobic digestion facility with a capacity of 72,000 tonnes, being the capital cost $19.1 (EUR 17) per tonne of input waste and O&M cost $59.6 (EUR 53) (Hogg & Eunomia Research & Consulting, 2002).

6.2.2.2. *Composting*

Because of the biogenic origin of the CO_2 emissions from composting, only CH_4 and N_2O emissions are taken into account for the GHG emissions calculation - the emitted CO_2 is regarded to be greenhouse gas neutral (Bjarnadóttir et al., 2002). The average default emission factors recommended by IPCC, used in IGES model are 4 kg CH_4 per tonne of organic waste in wet basis and 0.3 kg N_2O per tonne of organic waste in wet basis (Menikpura & Sang-Arun, 2013). A window process (open string technology) is assumed with 0.5 tonne of pure compost being generated per tonne of input waste (Bjarnadóttir et al., 2002) and it is used for agricultural purposes. Furthermore, the overall fuel consumption demand is 3 litres of diesel per tonne of input waste (Barton et al., 2008). The total cost of composting is set as $12.5 per tonne of compost, of which 24% ($3.0), corresponds to capital costs and the remaining 76% ($ 9.5), corresponds to O&M costs (Dulac, 2001).

6.2.2.3. *Mixed MSW landfilling*

The sanitary landfill option is adopted in all scenarios as the treatment and ultimate MSW disposal method. For landfilling, the IGES model is also adapted from the 2006 IPCC guidelines, where the First Order Decay (FOD) method is strongly suggested, for the reason that it reflects the degradation rate of disposal sites more accurately. To calculate the emissions from a landfill or open dump site, data on the total amount of mixed waste landfilled, and the fossil fuel consumption for operational activities, are required. In addition, it is also required the selection of the landfill type under analysis, that is, if it is a managed landfill, deep unmanaged (MSW heights >5m) or shallow unmanaged (MSW heights <5 m) landfills (IPCC, 2006; Menikpura & Sang-Arun, 2013). In the business-as-usual scenario, the two landfill (open dumps) types were considered: the deep unmanaged landfill that reflects the situation in Hulene dumpsite, where the waste deposited has heights that vary from 5m to 17m; and the shallow unmanaged landfill that corresponds to the portion of waste deposited in scattered locations around the city.

Several default values are required, which the accuracy highly influences the results on the amount of methane generation. Those include the degradable organic carbon (DOC), methane generation rate constant (*k*), methane oxidation on landfill cover (OX) and methane correction factor (MCF) (Menikpura and Sang-Arun, 2013). The operational activities are assumed to yield a diesel consumption of 1 litre per tonne of waste landfilled (Barton et al, 2008).

As for the costs estimation, in the business-as-usual scenario's case, even though it is considered that dumpsites typically do not have capital costs (Scheinberg et al., 2010b), an additional cost corresponding to the negative externalities of pollution and waste - the cost of inaction, was included. Within the *Waste Management Outlook* (2015), several examples of the cost of inaction are presented for similar contexts to the one in Maputo City - the economic costs of largely uncontrolled situations (in lower-income countries), where waste is dumped on land or watercourses, or burned in the open air. In this document, cost of inaction is estimated as being at least between the $20-50 per capita, and it accounts for health impacts (e.g. diarrhoea, gastroenteritis, respiratory diseases and dioxin poisoning, infectious outbreaks and spread of vector-borne diseases, flooding, risks to animals feeding and hazardous substances entering the food chain, and health impacts from uncontrolled hazardous waste disposal), and environmental pollution (e.g. surface, groundwater and marine contamination, greenhouse gas emissions, impacts on fisheries and agriculture, loss of biodiversity and amenity losses to residents and impacts on tourism) (Wilson et al., 2015).

Lastly, the average O&M cost for an open dump is estimated as the $5.0 per tonne of MSW (Wilson et al., 2015). Average costs of sanitary landfill (without landfill gas utilization) for Scenario 2, are assumed based on a Chinese landfill plant in Tianjin City, with for $5.2 (CYN 34.5) per tonne of MSW for capital cost and $1.6 (CYN 10.8) per tonne of MSW for O&M cost (Zhao et al., 2011).

6.2.2.4. *Material recovery*

The paper, cardboard, metals, glass, and plastic within the MSW are sorted by a single-stream process, and forwarded to recycling. The single-stream process flow is designed to retrieve fibre, glass, metals, and plastic from a commingled recyclables stream, assuming a separation efficiency of 90% (Pressley et al., 2015). The basis for the inventory data in the IGES tool is Thailand's specific information, and emissions are calculated based on CO_2 emissions from fossil fuel and utilisation of electricity to operate machines at the sorting process's phase. The required input data include the total amount and the composition of recyclable materials (Menikpura & Sang-Arun, 2013). On the other hand, average costs of a single-stream type material recovery facility (MRF) are $18.1 per tonne of MSW for capital cost and $6.9 per tonne of MSW for O&M cost (Pressley et al., 2015).

Table 14 MSW material flow and cost inventory of waste treatment processes

Scenarios	Waste treatment	Input MSW amount (tonne/year)	Capital cost ($/MSW tonne)	O&M cost ($/MSW tonne)	Cost of inaction - $20 per capita [b]
Scenario 1	Deep unmanaged landfill	278,832	0.0[a]	5.0[b]	Population in the urban, sub-urban and semi-urban areas - 1,198,435 [2014; c]
	Shallow unmanaged landfill	158,498			Population in the Island of Inhaca and the municipal district of KaTembe - 27,432 [2014; c]
Scenario 2	Mixed MSW landfill	437,330	5.2[d]	1.6[d]	N/A
Scenario 3A	Recycling	91,621	18.1[e]	6.9[e]	
	Composting	220,414	3.0[f]	9.5[f]	
	Mixed MSW landfill	244,664	5.2[d]	1.6[d]	
Scenario 3B	Recycling	91,621	18.1[e]	6.9[e]	
	Anaerobic digestion	220,414	19.1[g]	59.6[g]	
	Mixed MSW landfill	202,785	5.2[d]	1.6[d]	

Source: [a] Scheinberg et al., 2010b; [b] Wilson et al. 2015; [c] National Statistics Institute of Mozambique (2015); [d] Zhao et al., 2002; [e] Pressley et al., 2010; [f] Dulac, 2001; [g] Hogg and Eunomia Research & Consulting, 2002

6.3. Results and discussion

6.3.1. Environmental assessment

The results from total GHG emissions and costs for each assessed scenarios are illustrated in **Figure 20.** Scenario 3A represents the best environmental improvement, with a net benefit emission of -296,008 tonnes CO_2-eq per year. Scenario 3B follows with a net benefit of -211,603 tonnes CO_2-eq per year. The main contributors to those negative emissions are the biological treatment options (-333,287 tonne CO_2-eq per year for composting and -223,925 tonne CO_2-eq per year for anaerobic digestion), and the recycling activities (-108,528 tonne CO_2-eq per year), whereas the positive emissions, are caused by final disposal in sanitary landfills.

Changing from open dumping (business-as-usual) to sanitary landfilling (Scenario 2) does not yield environmental benefits with regards to GHG emissions, with an increase from 201,112 tonnes CO_2-eq per year to 260,621 tonnes CO_2-eq per year (30% more). Nevertheless, as previously pointed out, the process of open dumping in Maputo City, is coupled with open burning activities, which in turn, causes massive air pollution and emits black carbon. Scenario 1 presented fewer emissions than Scenario 2, due to the differences during the waste decomposition process under aerobic conditions, which is directly related to the waste final disposal approach and the facility characteristics. Because a larger fraction of waste decomposes aerobically in the top layer of unmanaged waste disposal facilities, it is regarded that CH_4 generation is inherently less than in anaerobic managed disposal facilities such as sanitary landfills. Besides, the same applies in the case of shallow and deep unmanaged facilities, where in deep facilities (and/or facilities with high water table); the fraction of waste that degrades aerobically is smaller than in shallow facilities. Hence, the different MFC default values among those three types of facilities - 0.4 for shallow unmanaged landfills, 0.8 for deep unmanaged landfills and 1.0 for anaerobic sanitary landfills (IPCC, 2006).

Even though throughout all alternative scenarios, sanitary landfilling is the key contributor of GHG emissions to the environment, there is potential for emissions reductions, by ensuring semi-aerated landfill conditions and/or by introducing specific landfill gas management systems to use it as an energy source. For instance, on landfill operation under semi-aerobic conditions, the Fukuoka method is a remarkable example of a system that utilises natural decomposition processes under aerobic conditions, to increase microbial activity, and as a result, faster stabilisation of waste occurs. Is a system where the leachate and gas are constantly removed from the waste mass through leachate collection and gas venting systems, and also, is intrinsically cheaper to operate, comparing with the anaerobic systems (Chong et al., 2005; Ministry of the Environment of Japan, 2012; SPREP & JICA, 2010; Tanaka et al., 2005). In addition, a proposal by Chang (2004), to develop a stove that runs on a landfill gas system for Guatemala City's poor demographics, exemplifies the potential of landfill collection and recovery schemes in low-income contexts, to simultaneously address: air pollution reduction, natural resource conservation public health protection (landfill gas burns cleanly comparing with burning wood), and poverty reduction.

An additional environmental issue that should be considered is the management of the residues and rejects resulting from the biological treatment processes. In this study, these materials were directly added in the quantity of MSW entering the sanitary landfill, however ideally, before final disposal, these should go through treatment processes. This fact might mean that in one hand, fewer quantities of MSW will enter the sanitary landfills, thus, reducing the overall GHG emissions, but in the other hand, the required treatment processes' operations might emit additional GHG. Therefore, further studies focusing on the biological waste treatments should be conducted to assess all the aspects encompassing each alternative.

6.3.2. Cost assessment

Opposite to the GHG emission results, Scenario 2 shows the highest cost-saving, with overall costs under US$ 1 million per year, proceeded by Scenario 3A, which demands little less than US$ 3.5 million per year. Because of both high capital and O&M costs associated with anaerobic digestion, Scenario 3B, presents the second highest costs of about US$ 14.5 million per year. The costly scenario is the business-as-usual scenario, around US$ 27 million per year, in which the cost of inaction alone, contributes with about US$ 24.5 million per year.

These results substantiate the premise that open dumps have low initial cost and high long-term cost while, sanitary landfills have increased initial, O&M costs and moderate long-term cost (UNEP, 2005). Overall, it is certain that if the current scenario in Maputo City is not improved, it will ultimately cost several times more. However, because the available data regarding the cost of inaction per capita is still limited (Wilson et al., 2015), it exposes the need to conduct a thorough investigation on the precise number of impacts and the evidence for cost requirement. In addition, as all alternative scenarios include sanitary landfilling, in order to enable additional cost reduction, the possibility of operating a semi-aerobic facility and/or pursuing landfill gas recovery should be considered and subject to comprehensive assessment. While the capital cost might increase, semi-aerobic landfills are cheaper to operate and manage, as well as costs can be reduced by usage of the locally available or wasted materials (SPREP & JICA, 2010). On the other hand, from the landfill gas recovery schemes, there is a potential to create revenue through the trade and transfer of emission reduction credits (UNEP, 2005; World Bank, 2004). Regarding the high cost of Scenario 3B, because large-scale or centralized facilities require costly mechanization, and also, have limited commercial past performance records for MSW (Barton et al., 2008; Matthews, 2012), to reduce the resulting high costs, an option would be to set-up small-scale and/or localized anaerobic digestion facilities.

6.3.3. Sensitivity to waste composition changes

The physical characteristics of the waste such as density, moisture content and calorific value, are affected by the waste composition, thus, affecting the waste management schemes, i.e., the technology for collection, treatment and the 3Rs (Wilson et al., 2015). Since waste composition changes over time, according to the variations in consumption patterns, an analysis is required, however, that is a costly activity for an authority to carry out (Barton at al., 2008). Given that, this section aims to examine the implications of the changes in waste composition, in relation to the potential future improvement of the socio-economic context in Maputo City. That is, a change from the current context (low-income), to lower-middle-income and subsequently to an upper-middle-income. The average values of waste composition for each income level considered are presented in **Table 15**.

Table 15 Waste composition for different economic contexts

Waste components	*Maputo City – Low-income ($1,045 or less)*[a]	Lower-middle-income (more than $1,046 less than $4,125)[b, c]	Upper-middle-income (more than $4,126 less than $12,735)[b, c]
Paper and Cardboard	*6*	11	19
Organic matter	*50*	53	46
Plastic	*8*	9	12
Metal	*2*	3	4
Glass	*5*	3	5
Other, residue, inert waste	*29*	21	14

Source: [a] Stretz, 2012b; [b] World Bank, 2016; [c] Wilson et al., 2015

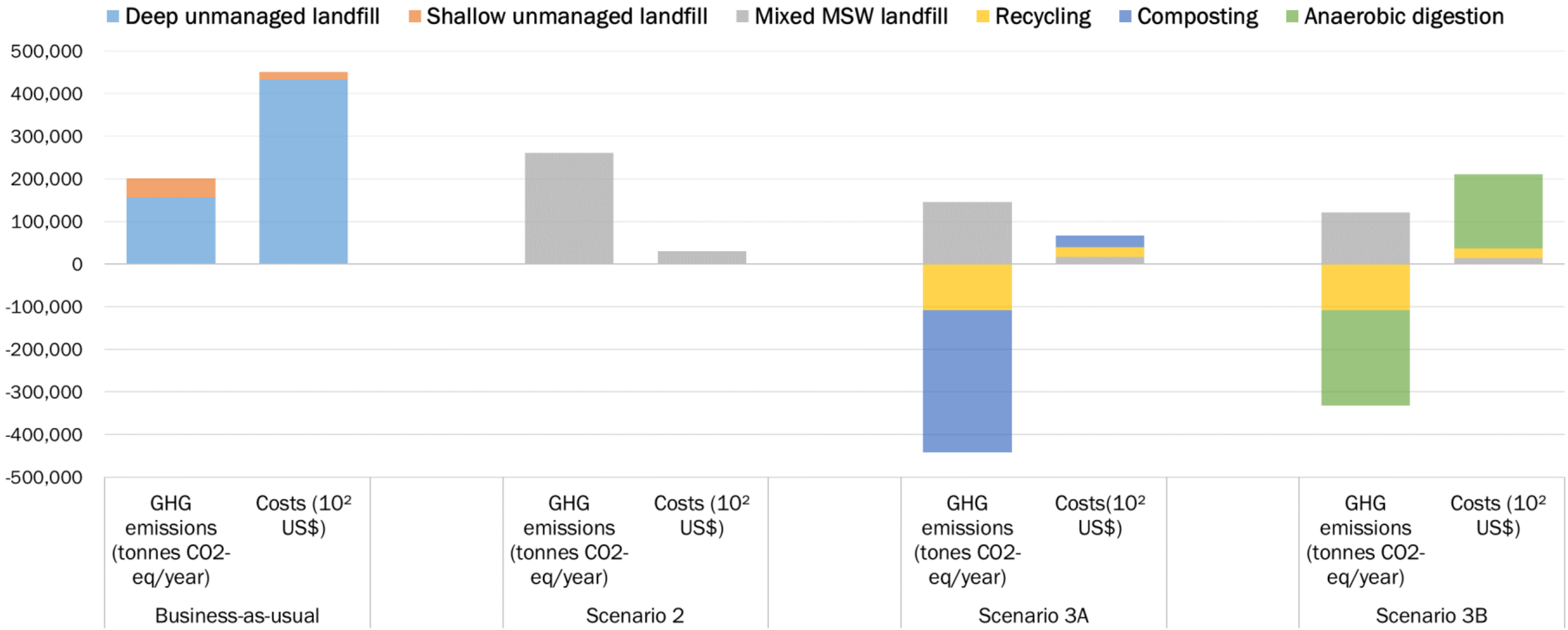


Figure 20 GHG emissions and costs requirement results for each scenario

The sensitivity analysis results are presented in the following **Figure 21**, where the current economic status of Maputo City (low-income) is set at 100% and the other cases are shown relative to it. For the business-as-usual scenario and Scenario 2, there is an increasing trend in total GHG emissions in equal proportion. Increases are due to the lower moisture content (higher fractions of degradable carbon) along the years, mainly caused by the increase of paper and cardboard content, which is reflected in the value of DOC that in the current context is 0.1008, and increasing to 0.1235 for the lower-middle-income and to 0.145 for the upper-middle-income context. Thus, in relation to the actual context, GHG emissions in the business-as-usual scenario and scenario 2, for a lower-middle-income context are 23% higher, and for the upper-middle-income are 44% higher. In Scenarios 3A and 3B, similar behaviour is followed. The low-income context presents negative GHG emissions values, and in the case of lower-middle-income context, those further decrease 42% in Scenario 3A and 30%, in Scenario 3B; for upper-middle-income context GHG reductions are around 58% in Scenario 3A and 54% Scenario 3B. This decrease is mainly prompt by recycling since the portions of recyclable materials increased in both alternative income levels.

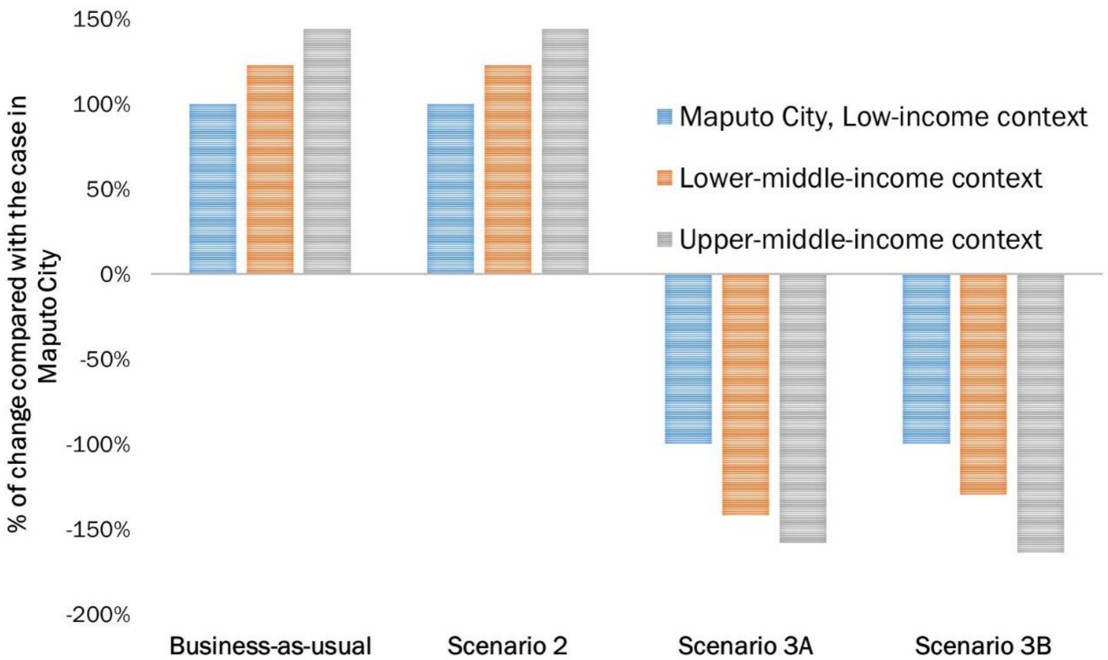


Figure 21 Sensitivity to waste composition on GHG emissions

These results highlight the fact that with an improvement of the current income level, the possibility for GHG emissions increases, because the generated waste will tend to have less organic matter and more packing and low moisture elements, concurrently, it also means that more recyclable materials will be generated. Thus, emphasising on the relevance of investing in waste material recovery schemes to improve the overall performance of the waste treatment and final disposal choices.

6.4. Conclusions and recommendations

An environmental and cost assessment of different MSW treatment scenarios and final disposal alternatives was completed for Maputo City system, through the application of a life-cycle thinking approach. The compared scenarios were three, the Scenario 1 in which MSW is finally disposed through open dumping (business-as-usual), the Scenario 2, with MSW being disposed in a sanitary landfill, and the Scenario 3, with the inclusion of material recovery via recycling, biological treatment (3A - composting or 3B - anaerobic digestion) and sanitary landfilling.

(1) The most environmentally impactful scenarios were Scenario 2 and the business-as-usual scenario (due to the inadequacy that is open dumping), with GHG emissions of 260,621 tonnes CO_2-eq per year and 201,112 tonnes CO_2-eq per year, respectively. Whereas, Scenario 3A and 3B, showed negative GHG emissions, -296,008 tonnes CO_2-eq per year and -211,603 tonnes CO_2-eq per year, respectively. On the other hand, for Scenario 2, the potential to reduce landfill gas emissions from sanitary landfills was acknowledged, providing that it operates in a particular set of conditions to manage and reduce the landfill gas generated.

(2) In the cost requirement, Scenario 2 followed by Scenario 3A presented the least costly alternatives - with US$ 838 thousand per year and US$ 3.5 million per year. Results also showed that the business-as-usual scenario is not only causing negative environmental impacts but also represents the less economically sustainable option, US$ 27 million per year, mostly due to the cost of inaction. Furthermore, due to the high cost associated with the mechanisation of large-scale or centralised facilities and the limited availability of performance records for anaerobic digestion, Scenario 3B, presented the second highest total costs, US$ 14.5 million per year, suggesting the relevance of examining instead, small-scale or localised anaerobic digestion facilities.

(3) Lastly, the sensitivity analysis for changes in the waste composition, clarified that with the potential increase in the income per capita in the future, the GHG emissions will increase in the business-as-usual scenario and Scenario 2. Conversely, in case either Scenario 3A or 3S is in place, the GHG emissions will reduce and the portion of material that can be recycled will considerably increase.

To address the challenges of environmental protection and economic sustainability of the waste treatment and final disposal in Maputo City, the following is proposed:

- An exhaustive assessment of the short-, middle-, and long-term environmental, economic and social effects of the open dumping activities and the adequate closure of all the open dumps in operation.
- Investigate the sustainability, appropriateness and feasibility of the biological waste treatments.
- Consider sanitary landfilling, with semi-aerated landfill conditions and landfill gas management systems, to use it as an energy source, as a cost-effective and environmentally sound option.
- Invest in the waste material recovery schemes that take into account and allow for modification (expansion/reduction), according to future changes in the system.

7. Lessons from Maputo City

MSW generation increase and subsequent mismanagement, contributes to the increasing public health issues and degradation of the environment, thus, being an issue that requires urgent attention and adequate decision-making. While this fact has been widely recognised throughout the nations, in low-income contexts, the burden of providing satisfactory waste management systems is substantial, due to a combination of several multifaceted reasons. Initially, in an attempt to address the MSW problems in those locations, a 'technical fix' that focuses on the technical and financial aspects of waste management was favoured, without success. As a response, the ISWM concept was developed, including a mix between the technical, financial, socio-cultural, environmental, institutional and political aspects, aiming for the waste management systems integration and sustainability.

The dissertation here presented, was set up under the umbrella of the ISWM concept, to understand the process of developing integrated and sustainable MSWM systems in low-income contexts, in a study case conducted for Maputo City, Mozambique. Four main topics were explored, according to the dimensions and the aspects of the ISWM concept, and answering to the specific objectives of the research, that comprise: (**I**) the analysis of the barriers affecting the performance of the MSWM policy in Maputo City; (**II**) the identification of the key stakeholders, their relevance and interactions in the MSWM system in Maputo City; (**III**) an investigation of the past and current flows of MSW in Maputo City; and (**IV**) a discussion of the environmental impacts and cost requirement of the current and alternative MSW treatment and final disposal schemes. To address each objective, different analytical decision-making tools and system analysis methods were applied, allowing for a systematic and comprehensive assessment of the MSWM system, and the proposal of improvement measures. Following, a summary of the four addressed topics, followed by the main contributions and the proposals for future research, are presented.

7.1. MSWM policy

The initial topic was dedicated to access the policy and institutional aspects in Maputo City, by analysing the barriers to the MSWM policy, as it concerns to the necessity for sound institutions and pro-active policies. The study was structured to incorporate a group problem-solving technique, Delphi method, to identify the barriers to the policy; and the structural modelling techniques, ISM and DEMATEL to make sense of the interrelationships and the degree of influence of each barrier.

Firstly, 26 barriers to the MSWM policy in Maputo City were identified, related to seven standard policy instruments - three for legislation and regulation; three for voluntary agreements; four for economic instruments; five for education and influence over behavioural change; four for monitoring, information and performance assessment; four for choice of technology; and three for community linkages. The cause barriers, which influence the most the underperformance of the policy and the severity of the other barriers, are nine and are closely related to the fragile waste management institution and the weak relationships between stakeholders. On the contrary, the remaining 17 barriers are the dependent barriers that are influenced by the cause barriers, which among others, include barriers related to the technology choice and economic instruments.

7.2. Stakeholders

To attend to the issues of inclusivity and participation, the stakeholder's dimension was subjected to analysis, through a combination of the SA method, to identify the stakeholders, their function and significance in the system, and the SNA method, to map and clarify the overall and individual connectivity of stakeholders.

In Maputo City, there are 35 main stakeholders within the MSWM system, and those can be either part of the government, civil society, academia, service users, donors and cooperation agencies, and the private sector. The findings suggest that the most powerful and interested stakeholders are all the government institutions, a donor and cooperation agency, an institution from academia, a private sector institution, and two organisations from civil society. The stakeholders with interest in the system, but with little power, include the remaining stakeholders from academia, a civil society organisation, and three stakeholders from the private sector. The remaining stakeholders, which compose the majority and include service users, have neither power nor interest in the system. Additionally, the social network maps showed an overall lack of connectivity among stakeholders, regarding both cooperation and partnerships, as well as information sharing. Yet, excepting for the service users, at least one stakeholder from each group has a prominent set of connections with other stakeholders, and those can have a relevant role.

7.3. Elements of the system and material flow

To have a clear understanding of the elements of the waste management system in Maputo City, the third topic looked into the past (year 2007), and present (year 2014), MSWM flows, through the application of the MFA method, together with the recognition and discussion of the effects of input data uncertainty, by employing the Hedbrant and Sörme model and the sensitivity analysis, to ultimately categorise and quantify the MSW flows, and identify the bottleneck issues.

In Maputo City MSWM system, five main routes of waste from the generation stage were identified – to reuse and recycled at the source; into the material recovery market; into formal and informal sites; zero flow (no collection); and into illegal dumpsites. MSW generation and the amount of material recovery increased from 397×10^3 tonnes to 437×10^3 tonnes, and from 3×10^3 tonnes and 7×10^3 tonnes, respectively, nevertheless, the rate of material recovery is far below the potential. On the other hand, the total quantity of unaccounted MSW decreased from 300×10^3 tonnes to 158×10^3 tonnes due to the increased coverage of waste collection, however, about three times more waste is disposed of, in unsanitary disposal sites and illegal dumpsites. The study on the uncertainty of input data, demonstrated the existence of gaps in the data compilation and consistency, in both established flows, and new and emerging flows. The averaged variance of results in 2007, were 29% and 71% for the lower and upper bounds respectively, and in 2014, the values increased to 41% and 96%. On the other hand, the sensitivity analysis elucidated the parameters that influence the most each MSW flow, and those include: the rate of waste reused and recycled at the source, waste processed for recycling, MSW in the inner city, MSW in MD6 and MD7, collection rate, and illegal dumping rate.

7.4. Emissions to the environment and costs of MSW treatment and final disposal

The last topic, picked-up from the third topic to estimate the environmental impact by means of GHG emissions, and cost requirements, of the present (business-as-usual), and 2 alternative scenarios for MSW treatment and final disposal, completed within a life-cycle thinking approach. In the business-as-usual scenario, Scenario 1, MSW is finally disposed of through open dumping; in the first alternative scenario, Scenario 2, MSW is disposed of in a sanitary landfill, and in Scenario 3, MSW is recovered via recycling and biological treatment (3A - composting or 3B - anaerobic digestion), and the remaining MSW is disposed of in a sanitary landfill.

Scenario 1 displayed significantly high GHG emissions, 201,112 tonnes CO_2-eq per year, and the highest total cost, US$ 27 million per year, mostly due to the inadequacy that is open dumping and the cost of inaction. Scenario 2 presented the highest GHG emissions, 260,621 tonnes CO_2-eq per year, and Scenario 3A and 3B showed negative GHG emissions, -296,008 tonnes CO_2-eq per year and -211,603 tonnes CO_2-eq per year, respectively. As for the cost estimation for the alternative scenarios, Scenario 3A, with around US$ 3.5 million per year, followed Scenario 2, with less than US$ 1.0 million per year, and Scenario 3B, presented the second highest value, US$ 14.5 million per year, due to the costs associated with large-scale and centralised equipment. An additional analysis of the effect of changes in waste composition, caused by the potential future improvement of the income level, the GHG emissions estimations showed an increase in Scenario 1 and Scenario 2, and the opposite occurred for Scenarios 3A and 3B, coupled with a significant increment of the available material that can be recycled.

7.5. Research contribution

This research has its basis on the recognition that ISWM is a valid concept to address the inherent complexities and a lack of clarity of the issues affecting MSWM systems from low-income contexts, reflected in a study case of Maputo City. Each dimension and aspect that characterise an MSWM system was depicted, in an innovative and resourceful framework. The framework is transferable and includes a combination of several analytical tools and methods that should support decision-makers in the identification, structuring and prioritisation of the issues, in a transparent, cost saving, and a participatory process. Figure 22 presents a proposed roadmap from its application.

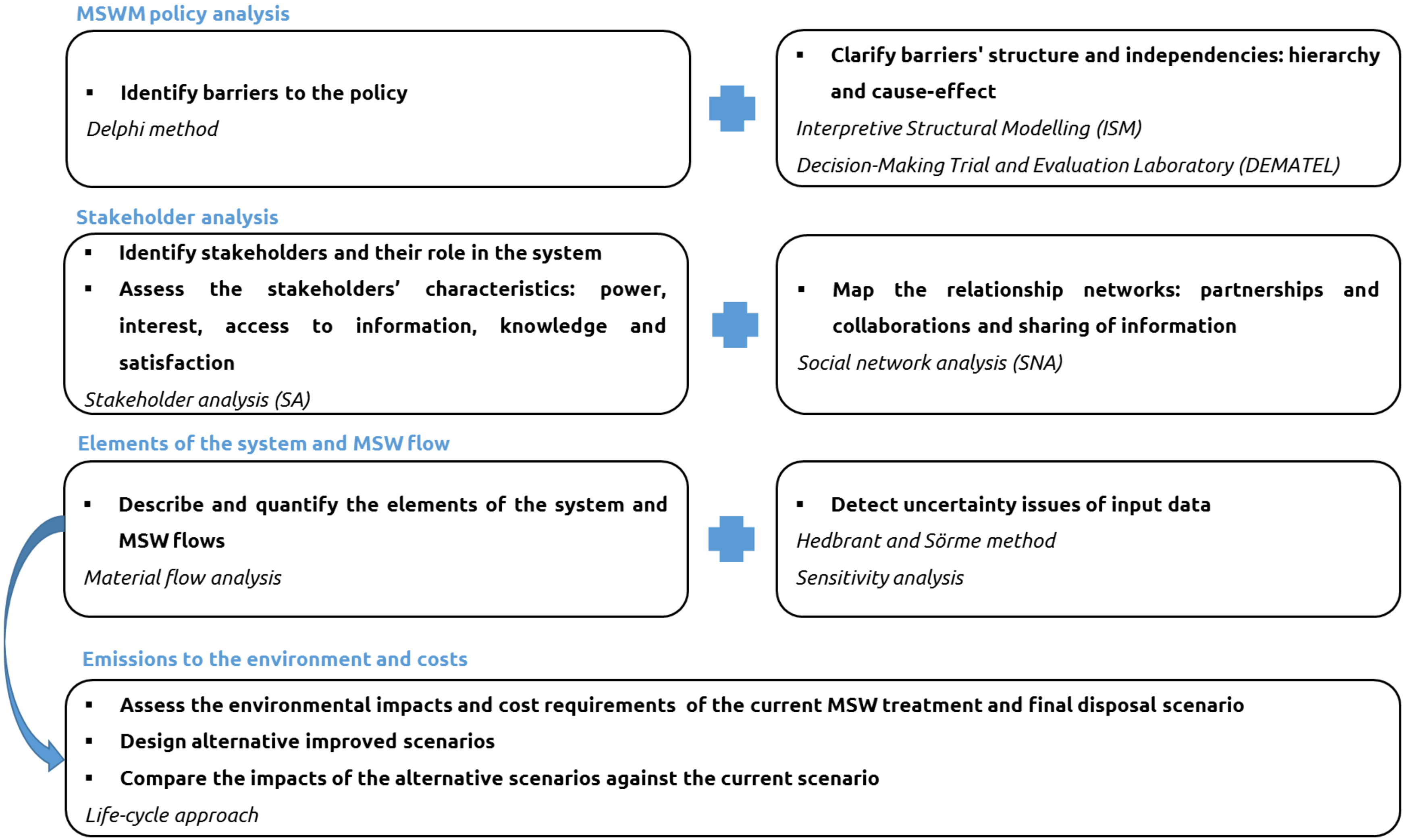


Figure 22 Layout of the framework to support the development of integrated and sustainable MSWM systems

7.6. Future work and limitations

The work completed and the findings of this research provide useful insights and implications for decision-makers and waste practitioners, in developing integrated and sustainable systems, nevertheless, it also exposed the need and the opportunity for follow-up research, which is enumerated bellow, according to each topic addressed.

- On *Topic I*, since it was conducted in a way that different stakeholders' point of view was combined, a complete picture should be obtained by considering each stakeholder group separately and a larger number of participants, to obtain vast, different and comparable perspectives. In addition, to statistically test and validate the results, the application of the Structural Equation Modeling (SEM), is advised, as well as, the application of the Analytical Network Process (ANP) to examine the consistency index and consistency ratio of the results.
- Regarding *Topic II*, due to the limited number of participant stakeholders in the interview process (representative stakeholders from each group), the findings are only sufficient to engage in a broad and preliminary discussion. A more comprehensive study with all stakeholders or at least the vast majority, done with iterative questionnaires surveys, working groups with experts, and public sessions, for example, can provide a full representation of the stakeholders' scenario. The characteristics selected for the SA can be extended to include assess aspects such as, the ability to mobilise resources and the existence of leadership to lead an action for or against the system. Moreover, in-depth studies addressing the subjective questions such as the characterisation of level of knowledge are required. Similarly, the SNA can be extended to include other analytical metrics to provide a more in-depth understanding of the stakeholder's connections, namely, closeness centrality, betweenness centrality, eigenvector centrality. Lastly, the results of this approach can be further enhanced, if combined with principles and techniques of social engineering that can clarify the socio-cultural characteristics of the stakeholders, to help the development of practical measures to influence the attitude and behaviour, as well as, increase the support of the stakeholders to the functioning of the MSWM system.
- The *Topic III* can greatly benefit from an expansion of the boundaries of the MSWM system, to include processes and elements such as MSW transportation; the estimation of landfill gas and leachate generation; extending the MFA to consider different waste sources and materials in each municipal district; and also account for the MSW, both within the urban metabolism and within the interaction with other habitat scales and metabolisms.
- On *Topic IV*, further research can focus on conducting a full LCA study, to include all the

processes of the system and to cover the impact assessments on human health and the environment (non-toxic and toxic impacts, non-renewable resource reduction, and land and freshwater usage), as well as disposal costs, decommissioning costs and sales revenues.

Furthermore, even though the case study allows for a degree of generalisation and forecasting for locations with analogous geographic and socio-economic characteristics, for particular systems analysis, exhaustive data collections must be conducted, to guarantee a match with the targeted location. There is also an opportunity for the academia, in particular, to expand on this research work, to provide practical know-how on planning, implementation and monitoring of integrated and sustainable waste systems, by looking into solidifying the findings of this research and examining the limited outcomes, along with, improving the applied analytical methods, as well as, suggesting additional ones.

References

1. Ackermann, F., & Eden, C. (2011). Strategic Management of Stakeholders: Theory and Practice. *Long Range Planning*, *44*(3), 179–196. http://doi.org/10.1016/j.lrp.2010.08.001

2. African Ministers' Council on Water [AMCOW], African Development Bank, European Union Water Initiative, United Nations Development Programme [UNDP], Water and Sanitation Program-Africa [WSP-AFRICA], & World Bank. (2006). *Getting Africa on track to meet the MDGs on water and Sanitation - A Status Overview of Sixteen African Countries*. Nairobi.

3. Al-Khatib, I. A., Monou, M., Abu Zahra, A. S. F., Shaheen, H. Q., & Kassinos, D. (2010). Solid waste characterization, quantification and management practices in developing countries. a case study: Nablus district - Palestine. *Journal of Environmental Management*, 91(5), 1131–8. http://doi.org/10.1016/j.jenvman.2010.01.003

4. Allen, C., & Jossias, E. (2011). *WIEGO Organizing Brief No.6: Mapping of the Policy Context and Catadores Organizations in Maputo, Mozambique*. Women in Informal Employment: Globalizing and Organizing (WIEGO).

5. Andreasen, P. K., & Sovacool, B. K. (2014). Energy sustainability, stakeholder conflicts, and the future of hydrogen in Denmark. *Renewable and Sustainable Energy Reviews*. http://doi.org/10.1016/j.rser.2014.07.158

6. Anschütz, J., IJgosse, J., & Scheinberg, A. (2004). *Putting Integrated Sustainable Waste Management into Practice*. (A. Scheinberg, Ed.). Gouda, The Netherlands: WASTE. Retrieved from http://www.waste.watsan.net/content/download/561/4346/file/ISWM ass eng screen.pdf

7. Asase, M., Yanful, E. K., Mensah, M., Stanford, J., & Amponsah, S. (2009). Comparison of municipal solid waste management systems in Canada and Ghana: a case study of the cities of London, Ontario, and Kumasi, Ghana. *Waste Management*, 29(10), 2779–86. http://doi.org/10.1016/j.wasman.2009.06.019

8. Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais [ABRELPE] & International Solid Waste Association [ISWA]. (2013). *Solid Waste: guidelines for successful planning*. Sao Paulo.

9. Associação Moçambicana de Reciclagem [AMOR] (2013). *Project catalog*. Maputo, Mozambique.

10. Association of Italian Lay Volunteers [LVIA] & Caritas. (2009). *RECICLA e FERTILIZA: dois exemplos de como transformar o lixo em recurso (Recicla and Fertiliza: Two examples on how to turn waste into a resource)*. Maputo, Mozambique.

11. Attri, R., Dev, N., & Sharma, V. (2013). Interpretive Structural Modelling (ISM) approach: An Overview. *Research Journal of Management Sciences*, *2*(2), 3–8.

12. Baker, J. W., & Lepech, M. D. (2009). Treatment of Uncertainties in Life Cycle Assessment. In *Proceedings of the ICOSSAR 2009—10th International Conference on Structural Safety and Reliability*. Osaka, Japan.
13. Barton, J. R., Issaias, I., & Stentiford, E. I. (2008). Carbon--making the right choice for waste management in developing countries. *Waste Management*, *28*(4), 690–8. http://doi.org/10.1016/j.wasman.2007.09.033
14. BETA Engenharia Gestão e Ambiente Ltd. (2011). *Projecto Maputo/KaTembe/Ponta do Ouro. Estudo de Pré-viabilidade Ambiental e Definição de Âmbito*. Maputo.
15. Bhuiyan, S. H. (2010). A crisis in governance: Urban solid waste management in Bangladesh. *Habitat International*, *34*(1), 125–133. http://doi.org/10.1016/j.habitatint.2009.08.002
16. Bjarnadóttir, H. J., Friðriksson, G. B., Johnsen, T., & Sletsen, H. (2002). *Guidelines for the use of LCA in the waste management sector*. Espoo, Finland. Retrieved from http://www.nordtest.org/register/techn/tlibrary/tec517/tec517.pdf
17. Borgatti, S. P., Everett M. G., Freeman L. C. (2002) *Ucinet 6 for windows: software for social network analysis*. Analytic Technologies, Harvard, MA.
18. Brugha, R., & Varvasovszky, Z. (2000). Stakeholder analysis: a review. *Health Policy and Planning*, 15(3), 239–246. http://doi.org/10.1093/heapol/15.3.239
19. Brunner, P. H., & Rechberger, H. (2004). *Practical Handbook of Material Flow Analysis*. http://doi.org/10.1016/B978-1-85617-809-9.10003-9
20. Bryson, J. M., Cunningham, G. L., & Lokkesmoe, K. J. (2002). What to do when stakeholders matter: The case of problem formulation for the African American men project of Hennepin County, Minnesota. *Public Administration Review*, *62*, 568–584. http://doi.org/10.1177/0734371X9101100307
21. Buenrostro, O., & Bocco, G. (2003). Solid waste management in municipalities in Mexico: goals and perspectives. *Resources, Conservation and Recycling*, 39(3), 251–263. http://doi.org/10.1016/S0921-3449(03)00031-4
22. Buque, L. I. B. (2013). *Overview of Selective Collection in the Municipality of Maputo, Mozambique: Its Contribution to Municipal Solid Waste Management, Challenges and Perspectives* (in Portuguese). Sao Paulo University.
23. Cabinet of ministers. Regulamento sobre a Gestao de Residuos (Regulation on Waste Management), Pub. L. No. 13/2006 (2006). Republic of Mozambique: Boletim da República.
24. Cabinet of ministers. Regulamento Sobre a Gestão e Controlo do Saco de Plástico (Regulation on management and control of plastic bag), Pub. L. No. 16/2015 (2015). Republic of Mozambique: Boletim da República.

25. Caniato, M., Tudor, T., & Vaccari, M. (2015). Understanding the perceptions, roles and interactions of stakeholder networks managing health-care waste: A case study of the Gaza Strip. *Waste Management*, *35*, 255–264. http://doi.org/10.1016/j.wasman.2014.09.018
26. Caniato, M., Vaccari, M., Visvanathan, C., & Zurbrügg, C. (2014). Using social network and stakeholder analysis to help evaluate infectious waste management: A step towards a holistic assessment. *Waste Management*. http://doi.org/10.1016/j.wasman.2014.02.011
27. Challcharoenwattana, A., & Pharino, C. (2015). Co-Benefits of Household Waste Recycling for Local Community's Sustainable Waste Management in Thailand. *Sustainability*, *7*(6), 7417–7437. http://doi.org/10.3390/su7067417
28. Chalmin P. and Gaillochet C. (2009). *From Waste to Resource: World Waste Survey*. Economica Ltd
29. Chandramowli, S., Transue, M., & Felder, F. A. (2011). Analysis of barriers to development in landfill communities using interpretive structural modeling. *Habitat International*, *35*(2), 246–253. http://doi.org/10.1016/j.habitatint.2010.09.005
30. Chang, J. (2004). Guatemala City Landfill Gas Burning Stove. Retrieved from http://www.its.caltech.edu/~kpickar/e105/papers/papers.htm
31. Chen, C. (2012). The application of interpretive structural modeling method to develop verity design solution of case host preference-based products: a case study of Razor. *Journal of Theoretical and Applied Information Technology*, *35*(1), 9–10. Retrieved from http://www.jatit.org/volumes/Vol35No1/11Vol35No1.pdf
32. Chingotuane, E. G. F. (2008). *The impact of civic education in public health: the case of plastic waste recycling in the municipality* (in Portuguese). Eduardo Mondlane University
33. Chiplunkar, A., Seetharam, K., & Tan, C. K. (2012). *Good Practices in urban water management: Decoding good practices for a successful future*. Asian Development Bank, National University of Singapore.
34. Chong, T. L., Matsufuji, Y., & Hassan, M. N. (2005). Implementation of the semi-aerobic landfill system (Fukuoka method) in developing countries: a Malaysia cost analysis. *Waste Management*, *25*(7), 702–11. http://doi.org/10.1016/j.wasman.2005.01.008
35. Chuang, H.-M., Lin, C.-K., Chen, D.-R., & Chen, Y.-S. (2013). Evolving MCDM applications using hybrid expert-based ISM and DEMATEL models: an example of sustainable ecotourism. *The Scientific World Journal*, *2013*, 751728. http://doi.org/10.1155/2013/751728
36. Chung, S. S., & Lo, C. W. H. (2003). Evaluating sustainability in waste management: The case of construction and demolition, chemical and clinical wastes in Hong Kong. *Resources, Conservation and Recycling*, 37(2), 119–145. http://doi.org/10.1016/S0921-3449(02)00075-7

37. Couth, R., & Trois, C. (2010). Carbon emissions reduction strategies in Africa from improved waste management: a review. *Waste Management, 30*(11), 2336–46. http://doi.org/10.1016/j.wasman.2010.04.013
38. Couth, R., & Trois, C. (2011). Waste management activities and carbon emissions in Africa. *Waste Management, 31*(1), 131–7. http://doi.org/10.1016/j.wasman.2010.08.009
39. Dahlman, K. (2009). *Modeling sanitation scenarios in developing countries. A case study in Kumasi, Ghana*. Swedish University of Agricultural Sciences. Retrieved from http://www.w-program.nu/filer/exjobb/Kristina_Dahlman.pdf
40. Danius, L. (2002). *Data uncertainties in material flow analysis: Local case study and literature survey*. Royal Institute of Technology, Stockholm, Sweden. Retrieved from file://c/Documents and Settings/Jack/My Documents/1 Research/EndNote/References.Data/PDF/Data uncertainties in material flow analysis-3982201091/Data uncertainties in material flow analysis.pdf
41. Danius, L., & von Malmborg, F. B. (2002). On the treatment of uncertainty in MFA: a literature survey. Unpublished
42. Daud, C. M. (2002). *A contribution to solid waste management and hazardous substances management in Maputo and Matola cities* (in Portuguese). Eduardo Mondlane University.
43. Deutsche Welle (2016). Um mundo à parte: a lixeira de Hulene (A separate world: the Hulene dumpsite) <http://www.dw.com/pt-002/um-mundo-%C3%A0-parte-a-lixeira-de-hulene/g-18137565> (04 October 2016)
44. Dias, S. (2011). Recycling in Belo Horizonte, Brazil – An Overview of Inclusive Programming Recycling of Materials from Domestic Waste. *WIEGO Policy Brief (Urban Policies) No 3*, *1*(May), 1–8.
45. Doreian, P., & Woodard, K. L. (1992). Fixed list versus snowball selection of social networks. *Social Science Research*, *21*, 216–233.
46. dos Muchangos, L. S. (2012). *A study of MSWM system in Maputo City, Mozambique - Learning experiences of Chongqing, China*. Chongqing University, Chongqing, P.R. China.
47. dos Muchangos, L. S., Liu, Y., & Li, B. (2014). Comparative study on municipal solid waste management systems of Maputo City, Mozambique and Chongqing City, China. *African Journal of Science, Technology, Innovation and Development*, 6(4), 323–331. http://doi.org/10.1080/20421338.2014.966035
48. dos Muchangos, L. S., Tokai, A., & Hanashima, A. (2015a). Application of the Delphi Method to the Identification of Barriers to a Waste Management Policy in Maputo City, Mozambique. *Journal of Sustainable Development*, 8(6), 146–157. http://doi.org/10.5539/jsd.v8n6p146
49. dos Muchangos, L. S., Tokai, A., & Hanashima, A. (2015b). Analyzing the structure of barriers to municipal solid waste management policy planning in Maputo city, Mozambique. *Environmental*

Development, 16, 76–89. http://doi.org/10.1016/j.envdev.2015.07.002

50. dos Muchangos, L. S., Tokai, A., & Hanashima, A. (2016a) Application of material flow analysis to municipal solid waste flows in Maputo City, Mozambique. *Waste Management & Research*, http://doi.org/10.1177/0734242X16678067

51. dos Muchangos, L. S., Tokai, A., & Hanashima, A. (2016b). Data uncertainties in material flow analysis: municipal solid waste management system in Maputo City, Mozambique. *Waste Management & Research*, http://doi.org/10.1177/0734242X16675685.

52. dos Muchangos, L. S., Tokai, A., & Hanashima, A. (unpublished manuscript). Stakeholder analysis and social network analysis to evaluate the stakeholders of a MSWM system – A pilot study of Maputo City

53. dos Muchangos, L. S., Tokai, A., & Hanashima, A. (unpublished manuscript). Life-cycle thinking for environmental and cost assessments of MSW treatment and final disposal options in Maputo City.

54. Dulac, N. (2001). *The Organic Waste Flow in Integrated Sustainable Waste Management*. (A. Scheinberg, Ed.) *Tools for Decision-markers, experiences from the urban waste expertise programme (1995-2001)*. Gouda, Netherlands.

55. Falatoonitoosi, E., Ahmed, S., & Sorooshian, S. (2014). Expanded DEMATEL for determining cause and effect group in bidirectional relations. *The Scientific World Journal*, *2014*, 103846. http://doi.org/10.1155/2014/103846

56. Fehringer, R., Brandt, B., Brunner, P. H., Daxbeck, H., Neumayer, S., Smutny, R., … Steinbach, D. (2000). *MFA-Manual Guidelines for the use of MFA for MSWM*.

57. Ferrão, D. A. G. (2006). *Avaliação da Remoção e Eliminação dos Resíduos Sólidos na Cidade de Maputo, Moçambique* (in Portuguese). University of Cape Town.

58. Fukushi, K., & Narita, Y. (2002). Study on function and failure analysis of snow melting machines. *The Japan Society of Mechanical Engineering*, *68*(675), 3447–3455.

59. Ghali, M. R., Frayret, J.-M., & Robert, J.-M. (2016). Green social networking: concept and potential applications to initiate industrial synergies. *Journal of Cleaner Production*, *115*, 23–35. http://doi.org/10.1016/j.jclepro.2015.12.028

60. Google earth V 7.1.7.2600 (October 06, 2016). Hulene B, Maputo City, Mozambique. 25° 54’ 02.41” S, 32° 35’ 48.81” E, Eye alt 4.09 km. DigitalGlobe 2016.

61. Grandjean, M. (2015). *GEPHI – Introduction to network analysis and visualization*. Retrieved from http://www.martingrandjean.ch/gephi-introduction/

62. Gubbins, C., & Garavan, T. (2016). Social Capital Effects on the Career and Development Outcomes of HR Professionals. *Human Resource Management*, 55(2), 241–260. http://doi.org/10.1002/hrm.21727

63. Guerrero, L. A., Maas, G., & Hogland, W. (2013). Solid waste management challenges for cities in developing countries. *Waste Management*, *33*(1), 220–32. http://doi.org/10.1016/j.wasman.2012.09.008

64. Gunsilius, E., Chaturvedi, B., Scheinberg, A., Coad, A., & Cortes, S. G. (2011). The Economics of the Informal Sector in Solid Waste Management. CWG - Collaborative Working Group on Solid Waste Management in Low- and Middle-income Countries GIZ - Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

65. Hedrick-Wong, Y., & Angelopulo, G. (2011). *The Challenges of Urbanization in Sub-Saharan Africa: A Tale of Three Cities.*

66. Heidrich, O., Harvey, J., & Tollin, N. (2009). Stakeholder analysis for industrial waste management systems. *Waste Management*, *29*(2), 965–973. http://doi.org/10.1016/j.wasman.2008.04.013

67. Hogg, D., & Eunomia Research & Consulting. (2002). *Costs for Municipal Waste Management in the EU. Final Report to Directorate General Environment, European Commission*. Retrieved from http://ec.europa.eu/environment/waste/studies/eucostwaste_management.htm

68. Holland, J. (2007). *Tools for Institutional, Political and Social Analysis of Policy Reform: A Sourcebook for Development Practitioners. Social Analysis*. Washington, DC: The International Bank for Reconstruction and Development/The World Bank. http://doi.org/10.1596/978-0-8213-6890-9

69. Hoornweg, D., & Bhada-Tata, P. (2012). What a waste. A global review of solid waste management. World Bank

70. Hou, J., & Zhou, D. (2011). Study on influence factors of distributed energy system based on DEMATEL and ISM. *International Journal of Nonlinear Science*, *12*(1), 36–41.

71. Hsu, C.-W., Kuo, T.-C., Chen, S.-H., & Hu, A. H. (2013). Using DEMATEL to develop a carbon management model of supplier selection in green supply chain management. *Journal of Cleaner Production*, *56*, 164–172. http://doi.org/10.1016/j.jclepro.2011.09.012

72. Hyman, M., Turner, B., & Carpintero, A. (2013). *Guidelines for National Waste Management Strategies: Moving from Challenges to Opportunities*. (T. Cieux, Ed.). United Nations Environment Programme (UNEP).

73. International Solid Waste Association (ISWA), Waste-to-energy research and technology council (WTERT), Regional Solid Waste Exchange of Information and Expertise Network (SWEEPNET), University of Leeds, & Solid Waste Management in Asia and Pacific Islands (SWAPI). (2014). *Waste Atlas. The world`s 50 biggest dumpsites. 2014 Report*.

74. Jacob, P., Kashyap, P., Suparat, T., & Visvanathan, C. (2014). Dealing with emerging waste streams: Used tyre assessment in Thailand using material flow analysis. *Waste Management & Research*, *32*(9), 918–926. http://doi.org/10.1177/0734242X14543554

75. Japan International Cooperation Agency (JICA) & Government of The Republic of Mozambique. (2013). *Project for Promotion of Sustainable 3R Activities in Maputo in the Republic of Mozambique WORK PLAN [First Year]*.
76. Japan Ministry of the Environment. (2011). *Japan Annual Report on the Environment, the Sound Material-Cycle Society and the Biodiversity 2011*. Retrieved from http://www.env.go.jp/en/wpaper/2011/
77. Jenkins, P. (2000). City profile: Maputo. *Cities*, *17*(3), 207–218. http://doi.org/10.1016/S0264-2751(00)00002-0
78. Kauko, K., & Palmroos, P. (2014). The Delphi method in forecasting financial markets— An experimental study. *International Journal of Forecasting*, *30*(2), 313–327. http://doi.org/10.1016/j.ijforecast.2013.09.007
79. Kautto, P., & Melanen, M. (2004). How does industry respond to waste policy instruments—Finnish experiences. *Journal of Cleaner Production*, *12*(1), 1–11. http://doi.org/10.1016/S0959-6526(02)00023-9
80. Klundert, A. Van De, & Anschütz, J. (1999). Integrated Sustainable Waste Management: the selection of appropriate technologies and the design of sustainable systems is not (only) a technical issue. In *CEDARE/IETC Inter-Regional Workshop on Technologies for Sustainable Waste Management*. Alexandria, Egypt.
81. Klundert, A. Van De, & Anschiitz, J. (2000). *The Sustainability of Alliances Between Stakeholders in Waste Management - using the concept of integrated Sustainable Waste Management. Working paper for UWEP/CWG, 30 May 2000.*
82. Klundert, A. Van De, & Anschütz, J. (2001). *Integrated Sustainable Waste Management - the Concept*. (A. Scheinberg, Ed.) *Tools for Decision-makers. Experiences from the Urban Waste Expertise Programme (1995-2001)*. Gouda, Netherlands: WASTE. Retrieved from www.waste.nl
83. Konteh, F. H. (2009). Urban sanitation and health in the developing world: reminiscing the nineteenth century industrial nations. *Health & Place*, *15*(1), 69–78. http://doi.org/10.1016/j.healthplace.2008.02.003
84. Kreakie, B. J., Hychka, K. C., Belaire, J. A., Minor, E., & Walker, H. A. (2016). Internet-Based Approaches to Building Stakeholder Networks for Conservation and Natural Resource Management. *Environmental Management*, *57*(2), 345–354. http://doi.org/10.1007/s00267-015-0624-8
85. Laner, D., Feketitsch, J., Rechberger, H., & Fellner, J. (2015). A Novel Approach to Characterize Data Uncertainty in Material Flow Analysis and its Application to Plastics Flows in Austria. *Journal of Industrial Ecology*, *0*(0), n/a-n/a. http://doi.org/10.1111/jiec.12326

86. Laner, D., Rechberger, H., & Astrup, T. (2014). Systematic Evaluation of Uncertainty in Material Flow Analysis. *Journal of Industrial Ecology*, *18*(6), 859–870. http://doi.org/10.1111/jiec.12143

87. Laurent, A., Bakas, I., Clavreul, J., Bernstad, A., Niero, M., Gentil, E., ... Christensen, T. H. (2014). Review of LCA studies of solid waste management systems - Part I: Lessons learned and perspectives. *Waste Management, 34*(3), 573–588. http://doi.org/10.1016/j.wasman.2013.10.045

88. Lederer, J., Ongatai, A., Odeda, D., Rashid, H., Otim, S., & Nabaasa, M. (2015). The generation of stakeholder's knowledge for solid waste management planning through action research: A case study from Busia, Uganda. *Habitat International*, *50*, 99–109. http://doi.org/10.1016/j.habitatint.2015.08.015

89. Li, M., Xia, J., Chen, C., Yin, B., Wang, K., 2012. A new system structure analysis arithmetic with reachable effect factor. Transaction of Beijing Institute of Technology 32(2):135-140 · February

90. Liao, C.-H., & Chiu, A. S. F. (2011, January). Evaluate municipal solid waste management problems using hierarchical framework. *Procedia - Social and Behavioral Sciences*. Elsevier B.V. http://doi.org/10.1016/j.sbspro.2011.10.554

91. Lienert, J., Schnetzer, F., & Ingold, K. (2013). Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes. *Journal of Environmental Management*, *125*, 134–148. http://doi.org/10.1016/j.jenvman.2013.03.052

92. Lura Consulting. (2004). Solid Waste as a Resource - Review of Waste Policies. In CaretScript (Ed.), *Solid Waste as a Resource - Workbook for Sustainable Communities* (Vol. 4, pp. 59–138). Guide for Sustainable Communities, Ottawa, Ontario: Federation of Canadian Municipalities (FCM). Retrieved from https://www.fcm.ca/home.htm

93. Macuácua, E., (2002). *The municipality, the private enterprise and the citizenship in the management of public services. The case of waste collection and treatment in Maputo City* (in Portuguese). Eduardo Mondlane University.

94. Mahajan, V. B., Jadhav, J. R., Kalamkar, V. R., & Narkhede, B. E. (2013). Interpretive Structural Modelling for Challenging Issues in JIT Supply Chain: Product Variety Perspective. *International Journal of Supply Chain Management*, *2*(4), 50–63.

95. Manga, V. E., Forton, O. T., & Read, A. D. (2008). Waste management in Cameroon: A new policy perspective? *Resources, Conservation and Recycling*, 52(4), 592–600. http://doi.org/10.1016/j.resconrec.2007.07.003

96. Maputo City Municipal Assembly. *Postura da Limpeza de Resíduos Sólidos Urbanos do Municipio de Maputo (Positions for municipal solid waste cleaning in Maputo City)*, Pub. L. No.

86/AM/2008 (2008). Republic of Mozambique.

97. Maputo Municipal Council (2008a*). Plano de estrutura urbana do município de Maputo: I Análise da situação actual do município de Maputo (Urban Structure Plan for the Municipality of Maputo: I Analysis of the current City of Maputo situation).* Maputo, Mozambique.

98. Maputo Municipal Council. (2008b). *Plano Director - Gestão de resíduos sólidos urbanos na Cidade de Maputo (Master plan of municipal solid waste management in Maputo City)*. Master Plan, Maputo, Mozambique: Conselho Municipal da Cidade de Maputo.

99. Marshall, R. E., & Farahbakhsh, K. (2013). Systems approaches to integrated solid waste management in developing countries. *Waste Management*, *33*(4), 988–1003. http://doi.org/10.1016/j.wasman.2012.12.023

100. Martin, N., Evans, M., Rice, J., Lodhia, S., & Gibbons, P. (2016). Using offsets to mitigate environmental impacts of major projects: A stakeholder analysis. *Journal of Environmental Management*, *179*, 58–65. http://doi.org/10.1016/j.jenvman.2016.04.054

101. Masood, M., Barlow, C. Y., & Wilson, D. C. (2014). An assessment of the current municipal solid waste management system in Lahore, Pakistan. *Waste Management & Research*, *32*(9), 834–847. http://doi.org/10.1177/0734242X14545373

102. Matthews, E. (2012). *Good News From the Dump Methane Emissions from Solid Waste: Current Conditions and Future Prospects*. Boston.

103. Mbiba, B. (2014). Urban solid waste characteristics and household appetite for separation at source in Eastern and Southern Africa. *Habitat International*, *43*, 1–11. http://doi.org/10.1016/j.habitatint.2014.02.001

104. Menikpura, N., & Sang-Arun, J. (n.d.). *User Manual Estimation Tool for Greenhouse Gas (GHG) Emissions from Municipal Solid Waste (MSW) Management in a Life Cycle Perspective*.

105. Mertanen, S. T., Langa, J. M., & Ferrari, K. (2013). *Catadores de Lixo de Maputo. Quem são e como trabalham (Maputo waste collectors - Who are they and how do they work?).* Retrieved from
http://www.lvia.it/sites/default/files/materiale/catadores_lixo_LVIA_mo%C3%A7ambique.pdf

106. Ministry of Coordination for Environmental Action [MICOA]. (2008). *Plano de acção das necessidade de capacitação resultantes da auto-avaliação nacional (Action plan for capacity buling needs, resulting from national self-evaluation)*.

107. Ministry of Coordination for Environmental Action. (2012). *Estratégia de Gestão Integrada de Resíduos Sólidos Urbanos em Moçambique (Strategy for Integrated Municipal Solid Waste Management in Mozambique)*. Maputo.

108. Ministry of the Environment of Japan. (2012). *Solid Waste Management and Recycling Technology of Japan. - Toward a Sustainable Society*.

109. Montangero, A. (2007). *Material Flow Analysis A tool to assess material flows for environmental sanitation in developing countries*.
110. Morone, P., Tartiu, V. E., & Falcone, P. (2015). Assessing the potential of biowaste for bioplastics production through social network analysis. *Journal of Cleaner Production*, *90*, 43–54. http://doi.org/10.1016/j.jclepro.2014.11.069
111. Morrissey, A. J., & Browne, J. (2004). Waste management models and their application to sustainable waste management. *Waste Management*, *24*(3), 297–308. http://doi.org/10.1016/j.wasman.2003.09.005
112. Mozambique National Cleaner Production Centre. (2007). *Programme Document for Sustainable Consumption and Production in Maputo and Matola Cities*. Maputo.
113. National Statistics Institute [INE] of Mozambique (2014). *Anuário Estatístico Cidade de Maputo 2008 – 2012 (Statistical Yearbook City of Maputo 2008 - 2012)*. Maputo.
114. National Statistics Institute [INE] of Mozambique (2015). *Population projections for 2007 to 2014. Government of Mozambique*. Retrieved from http://www.ine.gov.mz/estatisticas/estatisticas-demograficas-e-indicadores-sociais/projeccoes-da-populacao/populacao-projectada-por-distritos-maputo-cidade-2007_2040.xls/view (13 Jun 2015).
115. Newspaper Opaís – Editorial staff (2014, December 11). Malária mata 53 pessoas na cidade de Maputo (Malaria kills 53 in Maputo City). *Jornal O País*. Retrieved from http://opais.sapo.mz/index.php/sociedade/45-sociedade/32787-malaria-mata-53-pessoas-na-cidade-de-maputo.html
116. Newspaper Opaís – Editorial staff (2015a, March 05). Maputo regista mais de 400 casos de doenças diarreicas em duas semanas (Maputo registers more than 400 cases of diarrheal diseases in two weeks). *Jornal O País*. Retrieved from http://opais.sapo.mz/index.php/sociedade/45-sociedade/34739-maputo-regista-mais-de-400-casos-de-doencas-diarreicas-em-duas-semanas-.html
117. Newspaper Opaís – Editorial staff (2015b, August 13). Maputo e Matola terão aterro sanitário para acabar com lixeiras a céu aberto (Maputo and Matola will have a sanitary landfill to end with the open dumps). *Jornal O País.* Retrieved from http://opais.sapo.mz/index.php/sociedade/45-sociedade/37362-maputo-e-matola-terao-aterro-sanitario-para-acabar-com-lixeiras-a-ceu-aberto.html
118. Nhacolo, A. Q. (1999). *An approach on the sanitation problems and their effects on the residents of the neighbourhood Xipamanine* (in Portuguese). Eduardo Mondlane University.
119. Nishtala, S., & Solano-mora, E. (1997). Description of the Material Recovery Facilities Process Model Design, Cost, and Life-Cycle Inventory.
120. Notícias – Editorial staff (2015, January 08). Muro da lixeira volta a desabar (The open dump

wall collapses again). *Jornal Notícias*. Retrieved from http://www.jornalnoticias.co.mz/index.php/capital/29673-muro-da-lixeira-volta-a-desabar

121. Otte, E., & Rousseau, R. (2002). Social Network Analysis: A Powerful Strategy, Also for the Information Sciences. *Journal of Information Science*, *28*(6), 441–453. http://doi.org/10.1177/016555150202800601

122. PagaLata (2008) *No title*. Retrieved from http://slideplayer.com.br/slide/3166987/ (09 September 2015)

123. Park, S., Lee, S.-J., & Jun, S. (2015). A Network Analysis Model for Selecting Sustainable Technology. *Sustainability*, *7*(10), 13126–13141. http://doi.org/10.3390/su71013126

124. Prell, C., Hubacek, K., & Reed, M. (2009). Stakeholder Analysis and Social Network Analysis in Natural Resource Management. *Society & Natural Resources : An International Journal*, *22*(6), 501–518. http://doi.org/10.1080/08941920802199202

125. Pressley, P. N., Levis, J. W., Damgaard, A., Barlaz, M. A., & DeCarolis, J. F. (2015). Analysis of material recovery facilities for use in life-cycle assessment. *Waste Management*, *35*, 307–317. http://doi.org/10.1016/j.wasman.2014.09.012

126. Rădulescu, C., Ştefan, O., Rădulescu, G., Rădulescu, A., & Rădulescu, M. (2016). Management of Stakeholders in Urban Regeneration Projects. Case Study: Baia-Mare, Transylvania. *Sustainability*, 8(3), 238. http://doi.org/10.3390/su8030238

127. Raeesi, R., Dastrang, M., Mohammadi, S., & Rasouli, E. (2013). Understanding the Interactions among the Barriers to Entrepreneurship Using Interpretive Structural Modeling. *International Journal of Business and Management*, *8*(13), 56–72. http://doi.org/10.5539/ijbm.v8n13p56

128. Ravi, V., & Shankar, R. (2005). Analysis of interactions among the barriers of reverse logistics. *Technological Forecasting and Social Change*, *72*(8), 1011–1029. http://doi.org/10.1016/j.techfore.2004.07.002

129. Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C. H. Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*, 90(5), 1933–1949. http://doi.org/10.1016/j.jenvman.2009.01.001

130. Reich, M. C. (2005). Economic assessment of municipal waste management systems - Case studies using a combination of life cycle assessment (LCA) and life cycle costing (LCC). *Journal of Cleaner Production*, *13*(3), 253–263. http://doi.org/10.1016/j.jclepro.2004.02.015

131. Risti, G. (2005). Basic indicators of integrated solid waste management. *Series: Working and Living Environmental Protection Vol.*, *2*(5), 383–392.

132. Sankoh, F. P., & Yan, X. (2013). Problems of Solid Waste Management in Developing Urban Cities: A Case Study of Freetown, Sierra Leone. *American Journal of Environmental Protection*, *2*(5), 113. http://doi.org/10.11648/j.ajep.20130205.11

133. Scheinberg, A., Wilson, D. C., & Rodic-Wiersma, L. (2010). *Solid waste management in the world's cities. Water and Sanitation in the World's Cities 2010* (Vol. 50). London; Washington DC: Earthscan for UN-HABITAT. http://doi.org/10.1002/9780470999677

134. Schmeer, K. (1999). *Guidelines for Conducting a Stakeholder Analysis*. *MD: Partnerships for Health Reform*. Bethesda.

135. Seadon, J. K. (2006). Integrated waste management--looking beyond the solid waste horizon. *Waste Management (New York, N.Y.)*, *26*(12), 1327–36. http://doi.org/10.1016/j.wasman.2006.04.009

136. Secretariat of the Pacific Regional Environment Programme (SPREP)., & Japan International Cooperation Agency (JICA). (2010). *A Practical Guide to Landfill Management in Pacific Island Countries and Territories*.

137. Segala, K., Opressa, I., & Palalane, J. (2008). *Urbanization and municipal development in Mozambique. Chapter: Solid waste management* (in Portuguese). Instituto Brasileiro de Administração Municipal Area de Desenvolvimento Urbano e Meio Ambiente

138. Sharma, B., Singh, M., & Neha. (2012). Modeling the Knowledge Sharing Barriers using an ISM approach. *International Proceedings of Computer Science & Information*, *45*(ICIKM), 233–238.

139. Sharma, H. D., Gupta, A. D., & Shushil. (1995). The Objectives of Waste Management in India: A Futures Inquiry. *Technological Forecasting and Social Change*, *48*, 285–309.

140. Shekdar, A. V. (2009). Sustainable solid waste management: an integrated approach for Asian countries. *Waste Management*, 29(4), 1438–48. http://doi.org/10.1016/j.wasman.2008.08.025

141. Shieh, J.-I., Wu, H.-H., & Huang, K.-K. (2010). A DEMATEL method in identifying key success factors of hospital service quality. *Knowledge-Based Systems*, *23*(3), 277–282. http://doi.org/10.1016/j.knosys.2010.01.013

142. Singh, M. D., & Kant, R. (2008). Knowledge management barriers: An interpretive structural modeling approach. *International Journal of Management Science and Engineering Management*, *3*(2), 141–150.

143. Skulmoski, G. J., Hartman, F. T., & Krahn, J. (2007). The Delphi Method for Graduate Research. *Journal of Information Technology Education*, *6*.

144. Snel, M., & Ali, M. (1999). *Stakeholder analysis in local solid waste management schemes*. Retrieved from http://www.lboro.ac.uk/well/

145. Stanisavljevic, N., Vujovic, S., Zivancev, M., Batinic, B., Tot, B., & Ubavin, D. (2015). Application of MFA as a decision support tool for waste management in small municipalities – case study of Serbia. *Waste Management & Research*, *33*(6), 550–560. http://doi.org/10.1177/0734242x15587735

146. Stretz, J. (2012a). *Economic Instruments in Solid Waste Management. Case Study Maputo,*

Mozambique. (E. Gunsilius & GIZ, Eds.). Maputo: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH Concepts for Sustainable Waste Management.

147. Stretz, J. (2012b). *Operator Models. Respecting Diversity Annex 7 - Maputo Case Study*. Retrieved from http://www.giz.de/solid-waste-management
148. Tanaka, N., Tojo, Y., & Matsuto, T. (2005). Past, present, and future of MSW landfills in Japan. *Journal of Material Cycles and Waste Management*, *7*(2), 104–111. http://doi.org/10.1007/s10163-005-0133-6
149. Tang, J., & Brunner, P. H. (2014). Globalising MFA - Decision Support for Waste Management in Cities Based on the Software STAN. *Resources and Waste Management*, 1–41.
150. Tas, A., & Belon, A. (2014). *A Comprehensive Review of the Municipal Solid Waste Sector in Mozambique: Background Documentation for the Formulation of Nationally Appropriate Mitigation Actions in the Waste Sector in Mozambique*. Nairobi, Kenya; Maputo, Mozambique. Retrieved from www.carbonafrica.co.ke
151. Teo, M. M. M., & Loosemore, M. (2010). Community-based protest against construction projects: The social determinants of protest movement continuity. *International Journal of Managing Projects in Business*, 3(2), 216–235. http://doi.org/10.1108/17538371011036554
152. The Intergovernmental Panel on Climate Change (IPCC). (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 5. Waste*. (S. Eggleston, L. Buendia, K. Miwa, T. Ngara, & K. Tanabe, Eds.) (Vol. 5). Hayama, Japan: Institute for Global Environmental Strategies (IGES) on behalf of the IPCC. Retrieved from http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html
153. Tojo, N., Neubauer, A., & Bräuer, I. and. (2006). *Waste management policies and policy instruments in Europe- An overview*.
154. Tseng, M., & Lin, Y. H. (2011). Modeling a hierarchical structure of municipal solid waste management using interpretive structural modeling. *WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT*, *7*(11), 337–348.
155. UNEP/SETAC Life Cycle Initiative at UNEP, CIRAIG, & Development, F. and the B. F. P. P. S. S. (2009). Guidelines for Social Life Cycle Assessment of Products. (G. U. Catherine Benoît, UQAM/CIRAIG, and Bernard Mazijn, Ed.) United Nations Environment Programme (UNEP).
156. United Nations Environment Programme [UNEP]. (2002). *Waste Management Planning: An Environmentally Sound Approach for Sustainable Urban Waste Management*. Retrieved from http://www.gdrc.org/uem/waste/waste-planning.html
157. United Nations Environment Programme [UNEP]. (2005). *Solid Waste Management*. UNEP.
158. United Nations Human Settlements Programme [UN-HABITAT]. (2007). *Perfil do Sector Urbano em Moçambique*.
159. United Nations Human Settlements Programme [UN-HABITAT]. (2010). *Mozambique Cities*

Profile. Maputo, Nacala and Manica. Nairobi, Kenya.

160. Vance-Borland, K., & Holley, J. (2011). Conservation stakeholder network mapping, analysis, and weaving. *Conservation Letters*, *4*(4), 278–288. http://doi.org/10.1111/j.1755-263X.2011.00176.x
161. Varvasovszky, Z., & Brugha, R. (2000). How to do (or not to do) … A stakeholder analysis. *Health Policy and Planning*, 15(3), 338–345. http://doi.org/10.1093/heapol/15.3.338
162. Wakefield, R., & Watson, T. (2014). A reappraisal of Delphi 2.0 for public relations research. *Public Relations Review*, *40*(3), 577–584. http://doi.org/10.1016/j.pubrev.2013.12.004
163. Walker, W. E., Harremoës, P., Rotmans, J., van der Sluijs, J. P., van Asselt, M. B. A., Janssen, P., & Krayer von Krauss, M. P. (2003). Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision Support. *Integrated Assessment*, *4*(1), 5–17. http://doi.org/10.1076/iaij.4.1.5.16466
164. Wang, G., Wang, Y., & Zhao, T. (2008). Analysis of interactions among the barriers to energy saving in China. *Energy Policy*, *36*(6), 1879–1889. http://doi.org/10.1016/j.enpol.2008.02.006
165. Wang, W.-C., Lin, Y.-H., Lin, C.-L., Chung, C.-H., & Lee, M.-T. (2012). DEMATEL-based model to improve the performance in a matrix organization. *Expert Systems with Applications*, *39*(5), 4978–4986. http://doi.org/10.1016/j.eswa.2011.10.016
166. WASTE (2015) Retrieved from http://www.waste.nl/en/our-approach (13 Jan 2016)
167. Wikimedia Commons (2015). *File: Mozambique in Africa.svg*. Retrieved from https://commons.wikimedia.org/wiki/File:Mozambique_in_Africa.svg (14 September 2016)
168. Wilson, D. C., Araba, A. O., Chinwah, K., & Cheeseman, C. R. (2009). Building recycling rates through the informal sector. *Waste Management*, *29*(2), 629–635. http://doi.org/10.1016/j.wasman.2008.06.016
169. Wilson, D. C., Rodic, L., Scheinberg, A., Velis, C., & Alabaster, G. (2012). Comparative analysis of solid waste management in 20 cities. *Waste Management & Research, 30*(3), 237–254. http://doi.org/10.1177/0734242X12437569
170. Wilson, D. C., Velis, C. A., & Rodic, L. (2013). Integrated sustainable waste management in developing countries. *Proceedings of the ICE - Waste and Resource Management*, *166*(2), 52–68. http://doi.org/10.1680/warm.12.00005
171. Wilson, D. C., Velis, C., & Cheeseman, C. (2006). Role of informal sector recycling in waste management in developing countries. *Habitat International*, 30(4), 797–808. http://doi.org/10.1016/j.habitatint.2005.09.005
172. Wilson, D., Rodic, L., Modak, P., Soos, R., Rogero, A. C., Velis, C., Iyer M. & Simonett, O. (2015). *Global Waste Management Outlook*. (T. Cannon, Ed.). United Nations Environment Programme (UNEP). Retrieved from http://www.unep.org/ietc/Portals/136/Publications/Waste

Management/GWMO report/GWMO full report.pdf

173. Wu, B., Xu, H., & Dai, T. (2010). Identifying safety factors on expressway work zone based on DEMATEL and ISM. *Journal of Transportation Systems Engineering and Information Technology 10*(05), 130–136.

174. Wu, K., Zheng, M., Lu, S., & Wu, Y. (2013). Applying DEMATEL method to the study on sustainable management of low-carbon tourism for Cultural heritage conservation. In *Recent Advances in Energy, Environment, Economics and Technological Innovation Applying* (pp. 96–102). Paris.

175. Yin, S., Wang, C., Teng, L., & Hsing, Y. M. (2012). Application of DEMATEL, ISM, and ANP for key success factor (KSF) complexity analysis in R&D alliance. *Scientific Research and Essays*, *7*(19), 1872–1890. http://doi.org/10.5897/SRE11.2252

176. Zhao, W., Huppes, G., & van der Voet, E. (2011). Eco-efficiency for greenhouse gas emissions mitigation of municipal solid waste management: A case study of Tianjin, China. *Waste Management*, *31*(6), 1407–1415. http://doi.org/10.1016/j.wasman.2011.01.013

177. Zhou, D., & Zhang, L. (2008). Establishing hierarchy structure in complex systems based on the integration of DEMATEL and ISM. *Journal of Management Sciences in China 11*(02), 20–26.

178. Zhou, D., Wang, Z., Lassoie, J., Wang, X., & Sun, L. (2014). Changing stakeholder relationships in nature reserve management: A case study on Snake Island-Laotie mountain national nature reserve, Liaoning, China. *Journal of Environmental Management*, 146, 292–302. http://doi.org/10.1016/j.jenvman.2014.07.018

179. Zurbrügg, C., Caniato, M., & Vaccari, M. (2014). How Assessment Methods Can Support Solid Waste Management in Developing Countries—A Critical Review. *Sustainability*, *6*, 545–570. http://doi.org/10.3390/su6020545

Appendices

Appendix A

Table A.1 Structural self-interaction matrix

Barriers	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	V	O	O	V	O	O	V	O	V	X	O	O	O	O	O	O	X	O	V	O	O	O	O	O	O
2		A	O	A	O	O	O	O	O	X	V	X	X	O	O	O	X	O	A	O	O	O	O	A	O
3			V	X	X	O	V	V	O	X	O	V	O	O	V	O	X	O	X	O	O	O	O	O	V
4				A	O	V	O	O	V	X	X	X	V	O	O	O	A	V	O	O	O	O	X	A	X
5					X	O	O	A	O	O	X	X	X	O	O	O	O	V	X	V	O	V	X	V	V
6						O	V	X	O	O	A	A	A	O	O	O	A	X	A	A	O	O	A	X	X
7							V	V	A	A	O	O	A	O	A	A	A	O	A	A	O	V	O	O	A
8								O	O	A	O	V	O	O	X	A	A	O	X	A	V	V	O	O	O
9									A	A	V	V	V	O	O	O	A	O	A	O	O	O	V	O	O
10										A	A	O	O	O	O	O	O	O	A	A	O	O	O	O	O
11											V	V	V	V	V	O	X	V	V	O	V	O	A	V	A
12												X	A	O	A	O	A	O	O	A	O	O	X	A	A
13													X	O	V	O	O	O	O	O	O	O	O	O	O
14														O	O	O	O	O	O	O	O	O	V	A	A
15															O	O	A	O	A	O	A	V	O	O	O
16																X	A	O	V	V	O	V	O	O	A
17																	O	O	A	O	O	O	O	O	O
18																		O	V	O	V	O	O	V	O
19																			A	O	O	O	V	O	O
20																				X	X	V	O	O	O
21																					V	O	O	O	O
22																						V	O	O	O
23																							O	O	O
24																								A	V
25																									X

Table A.2 Final reachability matrix

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Driving power
1	1	1	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
2	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
3	0	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	23
4	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
5	0	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	23
6	0	0	0	0	0	1	0	1	1	0	0	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	16
7	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0	1	1	0	0	1	1	1	1	1	0	1	14
8	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1	1	0	0	1	1	1	1	0	0	0	9
9	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	1	1	0	0	1	1	1	1	1	0	1	12
10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
11	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
12	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0	1	1	1	1	1	0	1	11
13	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	1	1	1	1	0	0	0	8
14	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	1	1	1	1	0	0	0	8
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	6
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	6
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	0	1	0	9
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	3
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	4
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	4
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	4
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
Dependence power	1	4	2	3	2	3	1	6	5	2	6	10	13	13	8	16	16	7	8	19	19	19	21	13	9	13	

Table A.3 Partitioning the reachability matrix for all levels of barriers

Barrier	Reachability set	Antecedent Set	Intersection Set	Level
1	1, 2, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26,	1	1	VIII
2	2, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26	1,2,3,5	2	VII
3	2, 3, 4, 5, 6, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26	3,5	3, 5	VIII
4	4, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26	3,4,5	4	VII
5	2, 3, 4, 5, 6, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26	3,5	3, 5	VIII
6	6, 8, 9, 12, 13, 14, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26	3,5,6	6	VII
7	7, 8, 9, 12, 13, 14, 16, 17, 20, 21, 22, 23, 24, 26	7	7	VII
8	8, 13, 14, 16, 17, 20, 21, 22, 23	1, 3, 5, 6, 7, 8	8	V
9	9, 12, 13, 14, 16, 17, 20, 21, 22, 23, 24, 26	3, 5, 6, 7, 9	9	VI
10	10	1,10	10	I
11	10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26	1, 2, 3, 4, 5, 11	11	VI
12	12, 13, 14, 16, 17, 20, 21, 22, 23, 24, 26	1, 2, 3, 4, 5, 6, 7, 9, 11,12	12	V
13	13, 14, 16, 17, 20, 21, 22, 23,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12,13,14	13, 14	IV
14	13, 14, 16, 17, 20, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14	13, 14	IV
15	15, 23	1, 2, 3, 4, 5, 11, 15,18	15	II
16	16, 17, 20, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 16, 17, 18	16, 17	III
17	16, 17, 20, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 16, 17, 18	16, 17	III
18	15, 16, 17, 18, 20, 21, 22, 23, 25	1, 2, 3, 4, 5, 11,18	18	IV
19	19, 24, 26	1, 2, 3, 4, 5, 6, 11,19	19	II
20	20, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 16, 17, 18, 20, 21, 22	20, 21, 22	II
21	20, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 16, 17, 18, 20, 21,22	20, 21, 22	II

Barrier	Reachability set	Antecedent Set	Intersection Set	Level
22	20, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 16, 17, 18, 20, 21, 22	20, 21, 22	II
23	23	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23	23	I
24	24, 26	1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 19, 24, 26	24, 26	I
25	25	1, 2, 3, 4, 5, 6, 11, 18, 25	25	I
26	24,26	1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 19, 24, 26	24,26	I

A.

Table A.4 Barriers' average matrix A

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	*SUM*
1	0	2.00	1.00	0.25	0.50	0.00	0.25	1.00	0.00	0.75	0.75	0.75	0.75	0.25	0.25	1.50	0.25	1.75	0.00	1.00	1.00	1.00	0.00	0.00	0.50	1.00	17
2	1.50	0	1.00	0.25	1.00	1.00	0.25	0.75	0.00	0.00	0.75	1.50	1.50	1.50	1.00	1.25	0.00	2.50	0.00	0.75	0.25	0.50	0.00	0.50	0.25	0.25	18
3	1.25	1.75	0	1.00	1.00	0.75	1.00	0.25	0.25	0.00	2.75	0.75	0.75	0.25	0.25	1.50	0.00	2.75	0.75	1.75	0.75	1.50	0.75	0.75	0.75	0.50	24
4	0.50	0.50	0.25	0	2.33	1.00	1.67	0.00	1.00	1.00	1.33	2.00	0.67	1.67	0.67	0.33	1.00	1.67	1.67	1.00	1.33	0.33	0.33	1.33	1.00	1.00	26
5	0.75	1.00	1.50	2.33	0	2.67	0.00	0.00	0.33	0.67	0.00	1.33	0.33	1.33	0.00	0.33	0.67	0.67	0.67	1.00	1.33	0.00	1.00	2.67	1.67	1.67	24
6	0.00	0.50	0.75	0.67	2.00	0	0.00	1.00	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.33	1.00	1.00	0.33	0.33	0.33	0.00	2.00	0.67	1.33	15
7	0.00	0.00	0.00	0.00	0.00	0.00	0	1.33	1.33	0.00	0.33	0.67	0.67	0.00	0.00	0.33	0.67	0.33	0.00	0.33	0.67	1.00	2.67	0.33	0.00	0.67	11
8	0.00	0.00	0.00	0.00	0.00	0.33	1.67	0	1.00	0.00	0.33	0.67	1.00	0.00	0.33	1.67	1.33	0.33	0.00	1.67	1.00	1.67	2.33	0.00	0.00	0.00	15
9	0.00	0.00	0.00	0.33	0.33	1.33	1.00	0.33	0	1.00	0.33	1.33	1.00	2.33	0.67	0.33	0.00	0.33	0.33	0.33	0.67	0.33	0.00	1.33	0.33	0.00	14
10	0.25	0.00	0.00	0.67	0.33	0.33	0.67	0.00	1.67	0	0.33	0.33	0.00	0.00	1.00	0.00	0.00	0.33	0.33	1.00	1.67	0.00	0.00	0.00	0.00	0.00	9
11	2.75	3.00	2.00	2.67	1.00	0.67	1.67	2.00	1.67	1.00	0	1.50	1.00	1.75	1.50	1.75	0.50	2.75	2.25	1.25	0.50	1.00	1.00	1.00	2.50	1.50	40
12	0.50	0.75	0.75	1.67	2.33	1.33	0.00	0.33	0.67	1.33	0.25	0	2.25	2.25	0.50	0.75	0.00	0.75	0.25	0.25	0.75	0.00	0.25	1.75	1.50	1.25	22
13	0.75	1.75	0.25	1.00	1.67	1.33	0.00	0.67	0.67	0.00	0.25	1.75	0	1.75	0.75	1.50	0.50	0.75	0.25	0.75	0.75	0.75	0.00	1.75	0.75	0.50	21
14	0.50	1.75	0.00	0.67	1.33	1.33	1.00	0.00	1.33	0.00	0.25	1.00	2.00	0	0.00	0.25	0.50	1.00	0.25	0.25	0.50	0.00	0.00	2.50	0.75	1.25	18
15	0.00	0.00	0.00	0.00	0.00	0.33	1.00	0.67	0.00	0.33	0.25	0.25	0.25	0.00	0	0.00	0.00	0.75	0.00	0.75	1.25	1.25	1.50	0.25	0.00	0.00	9
16	0.75	1.00	0.25	0.67	0.67	0.33	1.33	2.00	0.67	0.00	0.25	0.75	1.25	0.75	0.50	0	2.25	1.25	1.50	1.50	1.00	1.50	1.75	0.00	1.00	0.50	23
17	0.00	0.00	0.00	0.00	0.33	1.00	1.33	1.67	0.33	0.33	0.00	0.00	0.00	1.00	0.00	1.25	0	1.25	0.50	1.25	0.25	0.75	0.50	0.00	0.25	0.25	12
18	1.75	1.75	1.75	2.00	0.33	1.33	1.00	1.67	1.33	0.67	2.75	1.25	1.25	1.00	1.50	1.75	1.75	0	1.25	1.25	0.50	1.50	1.25	0.50	1.00	1.00	33
19	0.00	0.00	0.75	1.00	2.00	1.67	0.00	0.00	0.67	0.67	0.25	0.50	0.50	0.50	0.00	1.00	0.75	0.75	0	1.25	0.75	0.50	0.75	0.25	0.00	0.50	15
20	0.50	0.50	1.25	0.33	0.67	1.00	1.67	2.00	1.67	1.33	0.50	0.75	0.25	0.75	0.75	1.50	1.50	1.25	1.25	0	1.25	1.50	1.50	0.50	0.75	0.50	25
21	0.25	0.50	0.75	0.33	0.33	0.33	1.00	1.33	0.67	2.33	0.00	0.75	0.50	0.50	1.75	0.25	0.50	0.25	0.75	1.50	0	2.00	1.00	0.00	0.00	0.00	18
22	0.00	0.25	1.00	0.00	0.00	0.67	0.33	0.67	0.67	0.00	0.50	0.00	0.50	0.00	1.75	0.25	0.00	1.00	0.50	1.00	0.50	0	1.75	0.25	0.00	0.00	12
23	0.00	0.00	0.75	0.00	0.67	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.25	0.00	0.25	0.50	0.75	0.25	0.50	0	0.25	0.00	0.00	5
24	0.00	0.00	0.75	1.00	2.33	2.33	1.00	0.00	0.00	0.00	1.00	1.75	0.50	0.75	0.25	0.00	0.25	0.50	0.25	0.50	0.50	0.25	0.25	0	2.25	2.50	19
25	0.50	0.75	0.75	1.33	2.00	2.00	0.33	0.33	1.00	0.00	0.25	2.25	0.50	2.25	0.25	0.25	0.25	0.25	0.00	0.00	0.00	0.00	0.00	2.00	0	2.25	20

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	*SUM*
26	1.00	1.25	0.75	1.33	2.00	1.67	1.00	0.33	0.00	0.00	2.00	1.50	0.50	1.75	0.00	0.75	0.50	0.75	0.25	0.50	0.25	0.00	0.00	1.50	2.75	0	22
SUM	14	19	16	20	25	25	20	19	19	11	15	23	18	22	14	19	14	25	15	22	18	18	19	21	19	18	

Table A.5 Barriers' direct influence matrix D

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	SUM
1	0.000	0.050	0.025	0.006	0.013	0.000	0.006	0.025	0.000	0.019	0.019	0.019	0.019	0.006	0.006	0.038	0.006	0.044	0.000	0.025	0.025	0.025	0.000	0.000	0.013	0.025	0.41
2	0.038	0.000	0.025	0.006	0.025	0.025	0.006	0.019	0.000	0.000	0.019	0.038	0.038	0.038	0.025	0.031	0.000	0.063	0.000	0.019	0.006	0.013	0.000	0.013	0.006	0.006	0.46
3	0.031	0.044	0.000	0.025	0.025	0.019	0.025	0.006	0.006	0.000	0.069	0.019	0.019	0.006	0.006	0.038	0.000	0.069	0.019	0.044	0.019	0.038	0.019	0.019	0.019	0.013	0.59
4	0.013	0.013	0.006	0.000	0.058	0.025	0.042	0.000	0.025	0.025	0.033	0.050	0.017	0.042	0.017	0.008	0.025	0.042	0.042	0.025	0.033	0.008	0.008	0.033	0.025	0.025	0.64
5	0.019	0.025	0.038	0.058	0.000	0.067	0.000	0.000	0.008	0.017	0.000	0.033	0.008	0.033	0.000	0.008	0.017	0.017	0.017	0.025	0.033	0.000	0.025	0.067	0.042	0.042	0.60
6	0.000	0.013	0.019	0.017	0.050	0.000	0.000	0.025	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.008	0.025	0.025	0.008	0.008	0.008	0.000	0.050	0.017	0.033	0.36
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.033	0.033	0.000	0.008	0.017	0.017	0.000	0.000	0.008	0.017	0.008	0.000	0.008	0.017	0.025	0.067	0.008	0.000	0.017	0.28
8	0.000	0.000	0.000	0.000	0.000	0.008	0.042	0.000	0.025	0.000	0.008	0.017	0.025	0.000	0.008	0.042	0.033	0.008	0.000	0.042	0.025	0.042	0.058	0.000	0.000	0.000	0.38
9	0.000	0.000	0.000	0.008	0.008	0.033	0.025	0.008	0.000	0.025	0.008	0.033	0.025	0.058	0.017	0.008	0.000	0.008	0.008	0.008	0.017	0.008	0.000	0.033	0.008	0.000	0.35
10	0.006	0.000	0.000	0.017	0.008	0.008	0.017	0.000	0.042	0.000	0.008	0.008	0.000	0.000	0.025	0.000	0.000	0.008	0.008	0.025	0.042	0.000	0.000	0.000	0.000	0.000	0.22
11	0.069	0.075	0.050	0.067	0.025	0.017	0.042	0.050	0.042	0.025	0.000	0.038	0.025	0.044	0.038	0.044	0.013	0.069	0.056	0.031	0.013	0.025	0.025	0.025	0.063	0.038	1.00
12	0.013	0.019	0.019	0.042	0.058	0.033	0.000	0.008	0.017	0.033	0.006	0.000	0.056	0.056	0.013	0.019	0.000	0.019	0.006	0.006	0.019	0.000	0.006	0.044	0.038	0.031	0.56
13	0.019	0.044	0.006	0.025	0.042	0.033	0.000	0.017	0.017	0.000	0.006	0.044	0.000	0.044	0.019	0.038	0.013	0.019	0.006	0.019	0.019	0.019	0.000	0.044	0.019	0.013	0.52
14	0.013	0.044	0.000	0.017	0.033	0.033	0.025	0.000	0.033	0.000	0.006	0.025	0.050	0.000	0.000	0.006	0.013	0.025	0.006	0.006	0.013	0.000	0.000	0.063	0.019	0.031	0.46
15	0.000	0.000	0.000	0.000	0.000	0.008	0.025	0.017	0.000	0.008	0.006	0.006	0.006	0.000	0.000	0.000	0.000	0.019	0.000	0.019	0.031	0.031	0.038	0.006	0.000	0.000	0.22
16	0.019	0.025	0.006	0.017	0.017	0.008	0.033	0.050	0.017	0.000	0.006	0.019	0.031	0.019	0.013	0.000	0.056	0.031	0.038	0.038	0.025	0.038	0.044	0.000	0.025	0.013	0.59
17	0.000	0.000	0.000	0.000	0.008	0.025	0.033	0.042	0.008	0.008	0.000	0.000	0.000	0.025	0.000	0.031	0.000	0.031	0.013	0.031	0.006	0.019	0.013	0.000	0.006	0.006	0.31
18	0.044	0.044	0.044	0.050	0.008	0.033	0.025	0.042	0.033	0.017	0.069	0.031	0.031	0.025	0.038	0.044	0.044	0.000	0.031	0.031	0.013	0.038	0.031	0.013	0.025	0.025	0.83
19	0.000	0.000	0.019	0.025	0.050	0.042	0.000	0.000	0.017	0.017	0.006	0.013	0.013	0.013	0.000	0.025	0.019	0.019	0.000	0.031	0.019	0.013	0.019	0.006	0.000	0.013	0.38
20	0.013	0.013	0.031	0.008	0.017	0.025	0.042	0.050	0.042	0.033	0.013	0.019	0.006	0.019	0.019	0.038	0.038	0.031	0.031	0.000	0.031	0.038	0.038	0.013	0.019	0.013	0.64
21	0.006	0.013	0.019	0.008	0.008	0.008	0.025	0.033	0.017	0.058	0.000	0.019	0.013	0.013	0.044	0.006	0.013	0.006	0.019	0.038	0.000	0.050	0.025	0.000	0.000	0.000	0.44
22	0.000	0.006	0.025	0.000	0.000	0.017	0.008	0.017	0.017	0.000	0.013	0.000	0.013	0.000	0.044	0.006	0.000	0.025	0.013	0.025	0.013	0.000	0.044	0.006	0.000	0.000	0.29
23	0.000	0.000	0.019	0.000	0.017	0.000	0.008	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.006	0.000	0.006	0.013	0.019	0.006	0.013	0.000	0.006	0.000	0.000	0.13
24	0.000	0.000	0.019	0.025	0.058	0.058	0.025	0.000	0.000	0.000	0.025	0.044	0.013	0.019	0.006	0.000	0.006	0.013	0.006	0.013	0.013	0.006	0.006	0.000	0.056	0.063	0.47
25	0.013	0.019	0.019	0.033	0.050	0.050	0.008	0.008	0.025	0.000	0.006	0.056	0.013	0.056	0.006	0.006	0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.050	0.000	0.056	0.49
26	0.025	0.031	0.019	0.033	0.050	0.042	0.025	0.008	0.000	0.000	0.050	0.038	0.013	0.044	0.000	0.019	0.013	0.019	0.006	0.013	0.006	0.000	0.000	0.038	0.069	0.000	0.56
SUM	0.34	0.48	0.41	0.49	0.63	0.62	0.49	0.47	0.46	0.29	0.39	0.58	0.45	0.56	0.35	0.49	0.34	0.63	0.36	0.55	0.45	0.45	0.46	0.54	0.47	0.46	

Table A.6 Barriers' total influence matrix T

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Sum (d)
1	0.586	2.682	1.596	0.944	1.260	0.804	0.920	1.697	0.633	1.123	1.360	1.542	1.419	1.021	0.816	2.208	0.789	2.618	0.528	1.756	1.568	1.667	0.684	0.668	1.140	1.551	33.579
2	2.089	0.906	1.667	1.101	1.933	1.932	0.945	1.490	0.723	0.421	1.419	2.369	2.262	2.321	1.525	2.043	0.602	3.416	0.586	1.544	0.920	1.213	0.704	1.398	1.042	1.032	37.602
3	2.106	2.834	1.008	2.096	2.197	1.954	1.949	1.330	1.226	0.608	3.562	1.953	1.697	1.407	1.067	2.542	0.794	4.037	1.610	2.795	1.583	2.427	1.729	1.785	1.778	1.489	49.564
4	1.187	1.463	1.126	1.148	3.626	2.378	2.514	0.880	1.951	1.619	2.044	3.158	1.597	2.836	1.307	1.230	1.658	2.767	2.361	1.964	2.175	1.114	1.192	2.570	2.044	2.062	49.970
5	1.344	1.854	2.253	3.271	1.501	3.916	0.860	0.725	1.179	1.182	0.818	2.494	1.155	2.424	0.560	1.136	1.247	1.798	1.353	1.870	2.066	0.690	1.586	3.824	2.687	2.725	46.520
6	0.389	0.996	1.251	1.329	2.774	0.923	0.566	1.422	2.110	0.319	0.532	0.788	0.515	0.749	0.348	1.177	0.762	1.636	1.406	0.940	0.831	0.783	0.501	2.696	1.349	1.962	29.054
7	0.193	0.276	0.298	0.295	0.408	0.415	0.382	1.669	1.622	0.214	0.566	1.032	0.982	0.412	0.308	0.689	0.904	0.698	0.262	0.750	0.959	1.351	3.024	0.684	0.310	0.905	19.608
8	0.259	0.376	0.400	0.359	0.492	0.835	2.165	0.637	1.483	0.311	0.609	1.120	1.406	0.500	0.756	2.120	1.724	0.887	0.414	2.208	1.431	2.205	2.956	0.432	0.360	0.338	26.784
9	0.297	0.491	0.374	0.868	1.088	2.010	1.440	0.737	0.557	1.268	0.655	1.923	1.515	2.858	0.982	0.736	0.332	0.880	0.672	0.795	1.119	0.711	0.424	2.028	0.860	0.593	26.215
10	0.421	0.243	0.253	0.933	0.668	0.700	1.008	0.338	1.971	0.320	0.536	0.697	0.281	0.379	1.266	0.270	0.222	0.672	0.588	1.324	1.965	0.352	0.344	0.335	0.248	0.244	16.579
11	3.793	4.436	3.225	4.121	2.968	2.593	3.074	3.310	3.014	1.813	1.343	3.367	2.490	3.495	2.506	3.241	1.605	4.630	3.274	2.841	1.844	2.337	2.355	2.678	3.867	2.951	77.172
12	1.114	1.664	1.452	2.650	3.613	2.623	0.780	0.965	1.472	1.765	0.946	1.211	3.016	3.318	1.030	1.486	0.591	1.768	0.873	1.099	1.524	0.622	0.837	2.995	2.477	2.256	44.148
13	1.295	2.501	0.942	1.846	2.783	2.453	0.745	1.356	1.377	0.461	0.852	2.727	0.840	2.709	1.266	2.199	1.070	1.747	0.832	1.542	1.442	1.382	0.669	2.768	1.622	1.400	40.828
14	1.009	2.424	0.632	1.481	2.423	2.414	1.583	0.601	1.925	0.379	0.838	1.996	2.652	0.994	0.453	0.919	0.957	1.833	0.726	0.909	1.076	0.523	0.504	3.444	1.609	2.091	36.395
15	0.157	0.214	0.271	0.221	0.268	0.603	1.279	0.991	0.312	0.530	0.448	0.511	0.478	0.223	0.295	0.274	0.215	1.029	0.228	1.083	1.489	1.576	1.883	0.471	0.192	0.200	15.442
16	1.228	1.675	0.921	1.366	1.606	1.333	2.120	2.802	1.437	0.477	0.827	1.632	1.963	1.627	1.086	0.876	2.838	2.187	2.047	2.398	1.693	2.288	2.613	0.835	1.626	1.174	42.675
17	0.254	0.366	0.350	0.378	0.785	1.477	1.788	2.138	0.842	0.549	0.323	0.450	0.417	1.371	0.309	1.683	0.435	1.694	0.839	1.724	0.650	1.215	1.080	0.442	0.593	0.618	22.771
18	2.648	2.989	2.757	3.179	1.913	2.783	2.252	2.872	2.484	1.359	3.670	2.683	2.404	2.415	2.369	3.015	2.597	1.719	2.220	2.611	1.603	2.638	2.416	1.832	2.183	2.130	63.740
19	0.389	0.550	1.256	1.618	2.725	2.423	0.554	0.546	1.238	1.029	0.688	1.148	0.969	1.150	0.393	1.517	1.188	1.441	0.515	1.856	1.283	0.987	1.250	0.996	0.608	1.071	29.387
20	1.017	1.224	1.905	1.121	1.639	2.010	2.522	2.825	2.495	1.804	1.153	1.668	1.048	1.632	1.383	2.319	2.123	2.245	1.867	1.019	2.021	2.344	2.443	1.361	1.449	1.223	45.863
21	0.533	0.885	1.151	0.757	0.888	0.934	1.557	1.840	1.251	2.626	0.391	1.262	0.965	0.974	2.192	0.767	0.862	0.904	1.119	2.127	0.607	2.531	1.663	0.504	0.365	0.373	30.029
22	0.274	0.602	1.338	0.355	0.430	1.086	0.757	1.088	1.030	0.239	0.837	0.410	0.822	0.365	2.049	0.670	0.294	1.482	0.818	1.460	0.867	0.476	2.199	0.614	0.314	0.301	21.175
23	0.126	0.169	0.923	0.193	0.863	0.255	0.532	0.526	0.185	0.122	0.177	0.205	0.160	0.169	0.638	0.448	0.163	0.499	0.652	0.984	0.449	0.720	0.268	0.435	0.171	0.171	10.203
24	0.580	0.828	1.453	1.973	3.517	3.450	1.621	0.613	0.748	0.422	1.611	2.732	1.183	1.777	0.663	0.678	0.738	1.400	0.825	1.180	1.110	0.750	0.818	1.210	3.190	3.420	38.489
25	1.036	1.553	1.386	2.250	3.249	3.173	1.002	0.857	1.661	0.403	0.906	3.244	1.303	3.252	0.636	0.906	0.720	1.196	0.536	0.689	0.653	0.468	0.488	3.193	1.039	3.189	38.988
26	1.728	2.267	1.591	2.439	3.358	2.968	1.807	1.129	0.907	0.496	2.678	2.730	1.417	2.929	0.558	1.609	1.121	1.945	0.957	1.367	1.002	0.681	0.712	2.782	3.785	1.194	46.158
Sum (r)	26.054	36.470	31.780	38.293	48.978	48.445	36.723	35.384	35.834	21.860	29.790	45.054	34.954	43.306	26.760	36.758	26.552	47.129	28.107	40.835	33.933	34.049	35.343	42.981	36.906	36.661	

Table A.7 Barriers' net influence matrix N

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26
B1																										
B2	-0.593																									
B3	0.511	1.167																								
B4	0.244	0.362	-0.970																							
B5	0.084	-0.079	0.056	-0.355																						
B6	-0.415	-0.936	-0.703	-1.049	-1.142																					
B7	-0.727	-0.669	-1.652	-2.219	-0.451	-0.151																				
B8	-1.439	-1.114	-0.930	-0.521	-0.233	-0.586	0.496																			
B9	-0.335	-0.232	-0.852	-1.083	-0.091	-0.100	-0.181	-0.746																		
B10	-0.701	-0.178	-0.355	-0.686	-0.515	0.381	0.794	0.027	0.703																	
B11	2.433	3.017	-0.336	2.078	2.150	2.061	2.507	2.701	2.359	1.277																
B12	-0.428	-0.704	-0.501	-0.508	1.119	1.835	-0.252	-0.155	-0.451	1.067	-2.421															
B13	-0.124	0.239	-0.754	0.249	1.629	1.938	-0.236	-0.050	-0.138	0.180	-1.637	-0.289														
B14	-0.011	0.103	-0.775	-1.355	-0.002	1.666	1.171	0.101	-0.932	0.000	-2.657	-1.323	-0.057													
B15	-0.659	-1.310	-0.796	-1.086	-0.292	0.256	0.972	0.235	-0.670	-0.736	-2.058	-0.519	-0.788	-0.231												
B16	-0.980	-0.367	-1.621	0.136	0.470	0.157	1.431	0.682	0.700	0.207	-2.415	0.146	-0.237	0.708	0.812											
B17	-0.535	-0.237	-0.444	-1.281	-0.461	0.715	0.884	0.414	0.511	0.326	-1.282	-0.141	-0.653	0.414	0.094	-1.155										
B18	0.030	-0.426	-1.280	0.412	0.114	1.147	1.553	1.984	1.604	0.687	-0.960	0.915	0.657	0.582	1.340	0.828	0.902									
B19	-0.139	-0.036	-0.354	-0.742	1.372	1.017	0.291	0.132	0.566	0.441	-2.586	0.274	0.137	0.424	0.165	-0.530	0.349	-0.778								
B20	-0.738	-0.321	-0.890	-0.843	-0.231	1.070	1.772	0.617	1.700	0.480	-1.688	0.570	-0.494	0.723	0.300	-0.079	0.399	-0.366	0.012							
B21	-1.035	-0.035	-0.432	-1.417	-1.178	0.103	0.598	0.408	0.132	0.661	-1.453	-0.262	-0.477	-0.101	0.704	-0.926	0.212	-0.699	-0.164	0.106						
B22	-1.394	-0.611	-1.089	-0.759	-0.259	0.303	-0.594	-1.117	0.320	-0.113	-1.500	-0.212	-0.560	-0.158	0.472	-1.617	-0.921	-1.156	-0.169	-0.885	-1.664					
B23	-0.558	-0.534	-0.806	-0.998	-0.723	-0.247	-2.491	-2.430	-0.239	-0.222	-2.178	-0.632	-0.509	-0.335	-1.245	-2.166	-0.918	-1.916	-0.598	-1.459	-1.215	-1.479				
B24	-0.088	-0.570	-0.332	-0.597	-0.307	0.754	0.937	0.181	-1.280	0.087	-1.067	-0.263	-1.585	-1.667	0.192	-0.158	0.296	-0.432	-0.171	-0.181	0.606	0.136	0.383			
B25	-0.104	0.512	-0.392	0.206	0.562	1.824	0.692	0.497	0.801	0.155	-2.961	0.767	-0.319	1.643	0.444	-0.720	0.127	-0.987	-0.072	-0.760	0.289	0.154	0.053	0.003		
B26	0.178	1.235	0.102	0.377	0.632	1.006	0.903	0.792	0.314	0.252	-0.273	0.474	0.017	0.839	0.359	0.435	0.504	-0.186	-0.114	0.144	0.629	0.380	0.541	-0.638	0.595	

Appendix B

Sample of Questionnaire to stakeholders

Date: ___/___/_____

Institution: ____________________

Name of interviewee (undisclosed information): __________________________

Introduction

We are researchers from Osaka University (Japan), conducting an academic study to explore the opinions of several important stakeholders who are interested in a successful and sustainable municipal solid waste management (hereinafter MSWM) system in Maputo City, Mozambique. As a stakeholder in this area, it is crucial for to obtain your opinion and that of your organisation.

We plan to conduct questionnaires to produce a general report about the MSWM system stakeholders in Maputo City. The information obtained through these questionnaires will be for the direct use in the study, and will be processed maintaining the anonymity of respondents.

Following, we would like to ask you questions about your views and the views of your organisation regarding the MSWM system in Maputo City and its stakeholders.

1. Personal information.
   Name; Institution (if applies); Physical address; Email address.

A. About your knowledge and involvement in the MSWM system of Maputo City

2. Have you heard about municipal solid waste management (MSWM) system?

3. If so, what do you know about it? Please try to describe it.

4. In your opinion, is the MSWM system in Maputo City clear? Please justify.

5. How well do you understand the system? Please rank your knowledge on a scale from 1 to 5.

1 = very poor knowledge	2 = poor knowledge	3 = fair knowledge	4 = good knowledge	5 = very good knowledge

6. How are you involved with the MSWM of Maputo City?

7. Since when?

B. About the role of your organisation

8. What is the role of your organisation within the MSWM system in Maputo City?

9. Does your organisation have the power to influence the MSWM system in Maputo City? Please classify in a scale from 1 to 5.

1 = very little power	2 = little power	3 = moderate power	4 = significant power	5 = very significant power

9.1. Please explain.

10. What is the level of interest that your organisation has towards the MSWM system in Maputo City? Please classify in a scale from 1 to 5.

1 = very little interest	2 = little interest	3 = moderate interest	4 = significant interest	5 = very significant interest

10.1. Please explain.

11. What is the position of your organisation in relation to the current structure and functioning of MSWM system in Maputo City?

1 = very satisfied	2 = somewhat satisfied	3 = neither satisfied nor dissatisfied	4 = somewhat dissatisfied	5 = very dissatisfied	6 = I don't know	7 = no opinion

C. Other stakeholders and your organisation's relationship with them

12. Please fill in the information regarding <u>**other stakeholders within the MSMW system in Maputo City.**</u> Below is a preliminary list of stakeholders, please add the missing stakeholders in the blank spaces and in case it is required add rows and proceed as follows:

i. Regarding "*Knowledge of existence*", answer if you know about the institution existence and intervention in the MSWM sector in Maputo City. **YES** if you know about its existence and intervention; **NO** if you don't know about its existence and intervention: **NOT APPLICABLE** if you know for a fact that the organisation do not/no longer intervene in the system.

ii. Regarding "*Power and interest level*", answer according to the stakeholder power to influence the system and their interest in the system on a scale 1 to 5.

1 = very little power	2 = little power	3 = moderate power	4 = significant power	5 = very significant power

1 = very little interest	2 = little interest	3 = moderate interest	4 = significant interest	5 = very significant interest

iii. Regarding "*Position in relation to the current MSWM system*", answer how do you think the stakeholder stands regarding the current structure and functioning of the MSWM system.

1 = very satisfied	2 = somewhat satisfied	3 = neither satisfied nor dissatisfied	4 = somewhat dissatisfied	5 = very dissatisfied

Name of the stakeholder	*Knowledge of existence*	*Level of power*	*Level of In*	*position in relation to the current MSWM system*
Ministry of the Environment				
Fund for the Environment				
⋮ .				
Limetal				

13. From the list above, is missing any interested party? If yes, list and characterise following the directions from question 12.

14. How do you classify the access to information about the MSWM system in Maputo City? Please answer on a scale 1 to 5.

1 = very hard to access	2 = hard to access	3 = fair to access	4 = easy to access	5 = very easy to access

14.1. Please explain.

15. Please fill in the information regarding **<u>your relationship with other stakeholders of the MSMW system in Maputo City</u>** – the partnerships and/or cooperation and the information sharing. Please add the missing stakeholders in the blank spaces and in case it is required add rows, and proceed as follows:

i. Regarding "*Partnership and/or Cooperation*", classify the type of relationship with the other stakeholder in a scale of 1 to 5.

0 = none	1 = very weak	2 = weak	3 = moderate	4 = strong	5 = very strong

ii. Regarding "*Information sharing*", describe how do you share information with other stakeholders, according to:

Means	For example: through meetings, reports, and/or media
Frequency	Regularly; Occasionally; or Rarely.

Appendix C

Table C.1 Characteristics of Maputo and Lusaka cities

Characteristics	Maputo City - Capital of Mozambique	Lusaka City - Capital of Zambia [d]
Total area	308 km^2 [a]	375 km^2
Population	1.2 million [a]	1.5 million
Average household size	5.5[b]	5.5
MSW generation per capita	197 kg $year^{-1}$ [c]	201 kg $year^{-1}$

Source: [a]Stretz, J. (2012a). *Economic Instruments in Solid Waste Management. Case Study Maputo, Mozambique*. (E. Gunsilius & GIZ, Eds.). Maputo: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH Concepts for Sustainable Waste Management; [b]Stretz, J. (2012). *Economic Instruments in Solid Waste Management. Case Study Maputo, Mozambique*. (E. Gunsilius & GIZ, Eds.). Maputo: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH Concepts for Sustainable Waste Management; [c]Maputo Municipal Council. (2008). Plano Director - Gestão de resíduos sólidos urbanos na Cidade de Maputo (Master plan of municipal solid waste management in Maputo City); [d]Scheinberg, A., Wilson, D. C., & Rodic-Wiersma, L. (2010). *Solid waste management in the world's cities. Water and Sanitation in the World's Cities 2010* (Vol. 50). London; Washington,DC: Earthscan for UN-HABITAT. http://doi.org/10.1002/9780470999677

Table C.2 Details of waste generation and reuse and recycling at the source process

	Name of element	Description	Value / Method of Estimation	Source
Input	Maputo City population and total population per municipal district	The total population of Maputo City of 2007 and 2014.	Figures of Mozambican statistics' authority	National Institute of Statistics, 2015
	Waste generation per capita	Average household waste (HHW) generation per capita in Maputo city.	Based on Maputo City municipal authority's data = 197 kg $capita^{-1}$ $year^{-1}$.	Maputo Municipal Council, 2008
	Rate of waste reused and recycled at source	The rate of the waste reused and recycled at source (household level).	Assumption based on the figure for Lusaka City, Zambia (2007) = 8% of HHW.	Scheinberg et al., 2010
Output	HHW generation	The overall quantity of waste generated in the households or similar settings.	Multiplication of waste generation per capita and total population.	Calculated
	Waste reused and recycled at source	The quantity of waste reused and recycled in various forms at generation point.	Multiplication of HHW and rate of waste reused and recycled at the source.	
	Total municipal solid waste (MSW) generation	The overall quantity of MSW generated in Maputo City.	The sum of all types of waste generated in Maputo City and the waste reused and recycled at the source.	
	Total MSW generated in the inner city	The overall quantity of MSW generated in municipal districts	Calculated by authors. A portion of MSW generated in the municipal districts n.1 to 5	

Name of element	Description	Value / Method of Estimation	Source
	n. 1 to 5.	(excluding quantity of waste reused and recycled at source).	
Total MSW generated in municipal districts six (MD6) and seven (MD7)	The overall quantity of MSW generated in MD6 and MD7.	Calculated by authors. A portion of MSW generated in the MD6 and MD7 (excluding quantity of waste reused and recycled at source).	
MSW generation per waste type			
Commercial waste	Wastes generated by the commercial sector and private and public institutions.	30% of HHW.	Calculated, based on figures reported by Maputo Municipal Council, 2008
Non-hazardous industrial waste	Wastes generated by the industry sector without the hazardous properties and with similar characteristics as HHW and commercial wastes.	10% of HHW.	
Waste from wet markets and fairs	Wastes generated in the wet markets and fairs.	15% of HHW.	
Green waste	Greenery wastes from parks and gardens.	5% of HHW.	
Bulky household waste	Waste with similar characteristics as HHW	2% of HHW.	

Name of element	Description	Value / Method of Estimation	Source
	commercial and non-hazardous industrial wastes, which is designated by the authorities as too big/large/voluminous.		
Waste from sweeping	Waste from public sweeping.	3% of HHW.	
Construction and demolition debris	Wastes resultant from construction and demolition activities.	8% of HHW.	

Table C.3 Details of the waste collection process

	Name of element	Description	Value / Method of Estimation	Source
Input	Total MSW generation Total MSW generated in the inner city Total MSW generated in MD6 and MD7			
	Collection rate	Percentage of the official waste collection - by the local authority and/or licensed companies.	Based on figures from reports published by the German International Cooperation Agency (GIZ) = 30% for 2007; 90% for 2014.	Stretz, 2012a; 2012b
	MSW processed for recycling	The quantity of recyclables available in the market.	Based on reported figures from various sources = 3100 tonnes/year in 2007; 6250 tonnes/year in 2014.	AMOR, 2011; LVIA & Caritas, 2009; Buque, 2013; Tas & Belon, 2014
	MSW composted	The quantity of compost available in the market.	Estimate based on reported figures from various sources = Zero in 2007; 600 tonnes/year in 2014.	
Outputs	Official MSW collection in the inner city	Waste officially collected in the inner city.	Total MSW generated in the inner city multiplied by collection rate minus waste processed for recycling and quantity of compost.	Calculated
	Official MSW collection in MD6	Waste officially collected in	Total MSW generated in MD6 and	

Name of element	Description	Value / Method of Estimation	Source
and MD7	MD6 and MD7.	MD7 multiplied by collection rate.	
Uncollected waste	The quantity of waste that is not covered by the formal waste collection.	Total MSW generation minus waste officially collected in the whole city.	

Table C.4 Details of waste processing, treatment, and final disposal process

	Name of element	Description	Value / Method of Estimation	Source
Input	Total MSW generation			
	Total MSW generated in the inner city			
	Official MSW collection in the inner city			
	Official MSW collection in MD6 and MD7			
	MSW processed for recycling			
	MSW composted			
	Rate of illegal dumping	Percentage of waste that after formal collection in the inner city is illegally disposed of.	Assumption based on the figure for Lusaka City, Zambia (2007) = 30%, multiplied by value of official collection in the inner city	Scheinberg et al., 2010
Outputs	Illegal dumping	Waste that after formal collection is illegally dumped.	Official MSW collected in the inner city multiplied by the rate of illegal dumping.	Calculated
	Processing for recycling rate	Percentage of waste that it is processed and prepared for recycling.	Corresponding percentages of waste recovered from the total MSW generated in the inner city.	
	Composting rate	Percentage of waste that it is composted.		

Name of element	Description	Value / Method of Estimation	Source
Formal open dumping	Waste that after formal collection is formally dumped in the city final disposal site - Hulene site.	Official MSW collected in the inner city minus illegal dumping.	
Informal open dumping	Waste officially collected in MD6 and MD7 that is dumped in informal open dumps.	The sum of MSW collected in MD6 and MD7.	
Material recovered	Materials recovered through processing for recycling and composting activities.	The sum of quantities of MSW processed for recycling and MSW composted.	
Waste unaccounted for	The overall quantity of waste that is informally and illegally dumped and the waste that is not formally collected.	The sum of uncollected waste, waste illegally dumped and waste informally dumped.	

Appendix D

Table D.1 Currency conversion applied

Country	Currency	Amount for $1 US dollar
P.R. China	Yuan - CNY	0.1522
European Zone	Euro - EUR	1.125

Values as of 1 January 2010
Source: http://www.oanda.com/currency/historical-rates/