

An Investigation of the Imbalance of a Fast-growing Consumer Culture and Insufficient Waste Management Infrastructure across a Number of Sub-Saharan African Cities



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Abstract

Africa is developing at a fast pace in the 21st century and this is accompanied by continuing urbanization. The economic growth rate, measured in terms of growth in gross domestic product (GDP), has been of the order of 4-5% p.a. for much of the past decade, well above the global average. With these increases in economic wealth and urbanization, people are becoming more affluent and demanding more consumer goods. This implies not just growth in the volumes of materials entering and leaving cities, but also a qualitative shift in what is increasingly called ‘the metabolism’ of the cities where this consumption is taking place, a trend expressing itself by a shift in provisioning from the traditional market to the supermarket. It stands to reason that with these changes in consumption comes an increase in the quantity and variety of waste generated. Past studies already show under-capacity waste management infrastructure and insufficient investment in urban waste management in Africa.

The objectives of this dissertation are to

- 1) Develop and present models of the food material flow profile for a traditional market and supermarket consumer from production to disposal and develop waste flow profiles for both the traditional market and supermarket consumer;
- 2) Analyse the effect of change in food provisioning on the waste generated ; and
- 3) Describe the impact of this effect given the current waste management capacity and structure in African cities.

To better inform waste management planning in African cities undergoing such a metabolic transition, metabolic flow models have been developed to describe the acquisition of food from a traditional market vs. a supermarket. Consumer food flows are formulated based on cultural profiling and quantified via the daily nutritional and energy requirements of a healthy person. The associated waste profiles of these food items are then obtained by reading from packaging and processing data sets.

Results from the model confirm that there is a change in the waste profile associated with a shift in consumption from the market to the supermarket. The model is first applied to three diets: student, working class and vegetarian. The model shows 1) a shift of 14 to 58% of the organic content from the post-consumer waste to the supply chain where this food is processed and 2) a

3-10 fold increase in the inorganics in the post-consumer waste associated with food packaging used in supermarkets. These results are then interpreted for three case study cities: Kisumu in Kenya, Kitwe in Zambia and Harare in Zimbabwe, showing that this shift is being seen in all these cities. The shift in the organic waste is within the same range across all three cities within each income group. The increase in the inorganics however differs, being higher in Kitwe and Harare compared to Kisumu. This shows that the magnitude of changes in food-related waste generation is affected by the type of food consumed.

Results from waste management surveys for the same case study cities show that there is a lack of sufficient capacity to provide adequate service to the people in all three cities. The city councils do not have the resources to collect and dispose of all waste generated in the cities and the private sector only provides services where it makes business sense. There is some effort in all three cities devoted to recycling and to management of organic wastes, but this is also inadequate and likely to be overwhelmed by the continuing metabolic shift.

The findings point to the need for waste management becoming more commercially viable, adaptive and inclusive. There is also need for a sociocultural attitude change among the residents at household level who still look down upon waste management.

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Acronyms

FAO – Food and Agriculture Organisation

FMCG – Fast Moving Consumer Goods

GDP – Gross Domestic Product

GHG – Green House Gasses

MFA – Material Flow Analysis

MSW – Municipal Solid Waste

NLEA – Nutritional Labelling and Education Act

OECD- Organisation for Economic Co-operation and Development

SSA – Sub Saharan Africa

USDA – United Stated Department of Agriculture

WHO – World Health Organisation

1 Introduction

1.1 Subject and Motivation

This dissertation is concerned with a possible imbalance between a fast growing consumer culture in urban Africa and the capacity of the waste management systems in these places to cope with change and growth.

Africa is the least developed continent in the world. However, it is experiencing rapid urbanization and economic growth. This means growth of cities and an increase in the quantity and variety of materials consumed and subsequent wastes generated. Earlier work indicated significant lack of capacity and under-investment into the urban waste management sector e.g. Nissing et al., 2008 in Maseru and Kasozi et al., 2010 in Nairobi. With this fast growth in consumption, one might thus expect the waste management backlog to have widened and to have taken new forms.

Thus through this research, we might have an opportunity to capture and describe the changes in urban lifestyles as they unfold in African towns and cities, and how this manifests in new forms of waste management and waste management backlogs. This information would also be relevant to stake holders and investors in waste management planning and policy implementation.

1.2 Background

1.2.1 Urbanization and Economic Growth

The world population is expected to increase by a further 2.3 billion between 2011 and 2050 and at the same time the urban population is expected to increase by 2.6 billion (United Nations Department of Economic and Social Affairs Population Division, 2012). This means that the urban areas are expected to absorb all the population growth while at the same time taking in some of the rural population. Most of this growth is expected in cities in less developed regions (United Nations Department of Economic and Social Affairs Population Division, 2012).

Africa has only about 40% of its population living in urban areas making it the least urbanized continent (United Nations Department of Economic and Social Affairs, 2014). However, the rate

of urbanization, measured as the average annual rate of change of percentage urban is fastest in developing countries. Africa experiences an annual rate of urbanization of 1.1% making it the second fastest urbanizing continent behind Asia (United Nations Department of Economic and Social Affairs, 2014).

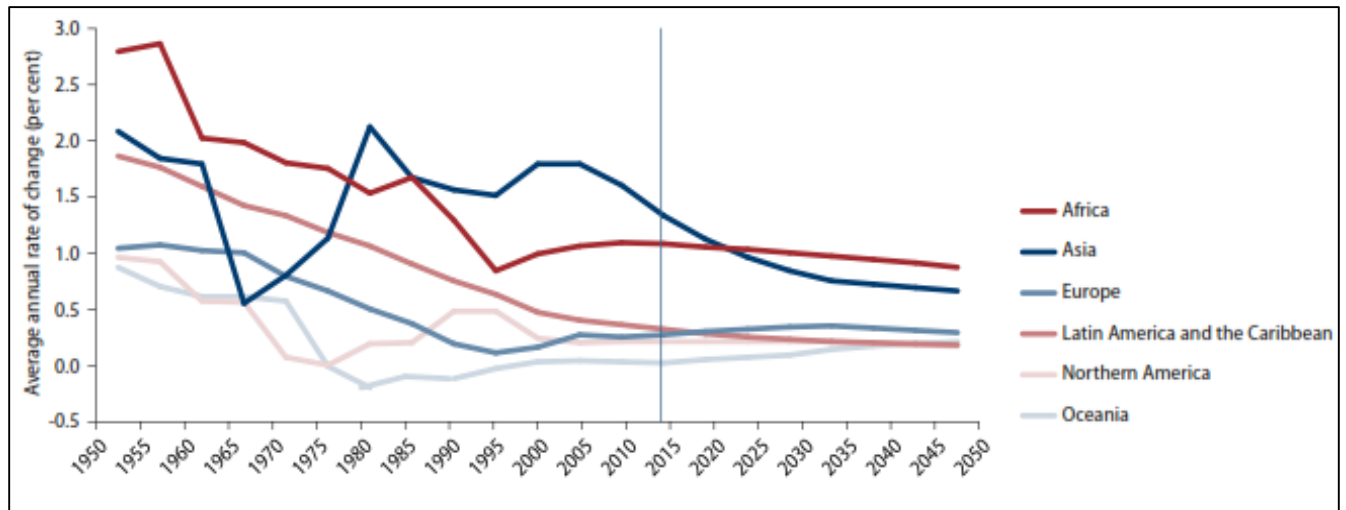


Figure 1: Showing the average annual rate of change of percentage urban in major regions (United Nations Department of Economic and Social Affairs, 2014)

Figure 1 above shows the rate of urbanization in different continents in the world. The rate of urbanization overall has been decreasing. The fluctuation of the rate in Asia is due to the stagnation of urbanization in China in the late 1960s and its subsequent increase. It is noted that Africa is urbanizing at a rate faster than the 1990s and is expected to be the fastest urbanizing continent after 2020.

Accompanying this significant urbanization trend is a high rate of economic growth. The rate of economic growth in Africa, measured in terms of growth in gross domestic product (GDP), was expected to be 4.7% in 2014 up from 4% in 2013 (United Nations, 2014). These figures are well above the average global economic growth rate of 3% in 2014 and 2.1% in 2013. This makes Africa the second fastest growing continent in the world. Since the 1980s there has been a reduction in poverty in African countries. Poverty in Sub-Saharan Africa has reduced rapidly from 40% in 1980 to 30% in 2008 and is expected to fall to 20 percent by 2020 (Hatch, et al., 2011). The proportion of the working population has increased and this has led to an increase in incomes of the people in Africa giving rise to an emerging middle class that will become more demanding as income levels and spending increase. This population is younger and more

educated and has different shopping habits (Mckinsey, 2012). From 2005 to 2008, consumer spending across the continent increased at a compound annual rate of 16 percent (Mckinsey, 2010). With this increase in incomes and subsequent spending power, there is thus growth in demand for consumer goods, a trend that is expressing itself by a shift in provisioning from the traditional market to the supermarket. This is further emphasized by the fast spread of supermarkets occurring in African cities (Reardon, et al., 2003) ; (Neven, et al., 2006). One of the reasons for the fast growth of the supermarkets in Africa is the willingness of the people to adopt the western culture of shopping encouraged by the globalization of the media and advertising (Traill, 2006). Urban consumers are now moving towards the consumption of more highly processed foods and drinks (Kearney, 2010). The urban population lacks time to shop and to prepare meals, have higher incomes and are more mobile (Neven, et al., 2006). Also with urbanization, there is trade liberalization and with the injection of foreign direct investment into developing countries, the number of supermarkets is spreading and the urban population of developing countries is adopting a more western lifestyle.

1.2.2 Waste Management in African Cities

With an increase in urbanization and urban population in cities in Africa, there is an increase in the impact that these cities have on the environment. Urbanization in Africa had already earlier been observed to lead to the following outcomes (Achankeng, 2003);

- Increased incomes leading to changes in life style and consumption patterns
- Increase in waste generation: quantity and variety

Growing rates of urbanization and economic growth have led to many environmental challenges for cities around the world, e.g. the increased generation of waste that arises from increased consumption and use of resources. This is especially evident in developing countries that lack resources and capacity for waste management.

Previous studies show that African countries have poor waste management systems and inadequate waste management infrastructure. Most cities collect only a fraction of the waste generated and still only a fraction of this waste is disposed of properly (Medina, 2006). Despite spending increasing resources on waste management, most cities in Africa still only collect less

than half the total waste generated (Medina, 2010). This is exemplified by the case of Nairobi, shown in Figure 1 below.

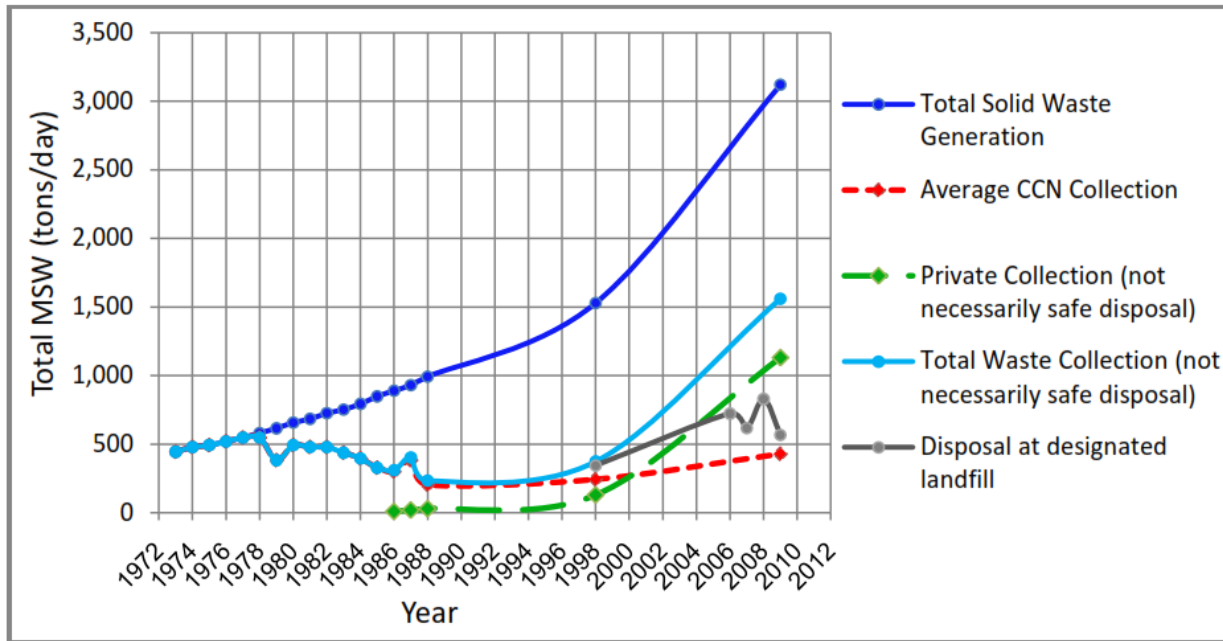


Figure 2: Showing waste generation and collection rates in Nairobi, Kenya adapted from Kasozi et al., 2010

For this case, it can be seen that the rate of waste generation far exceeds the rate at which the waste is collected, which in turn exceeds the capacity of disposal sites. Even the major disposal site of Dandora cannot be classified as “safe”. This shows the under capacity of the waste management system.

With the increasing urbanization and economic growth in African cities, increasing pressure is put on city councils to provide adequate services. Given the fast and vast shifts in consumer patterns and lifestyle discussed above, provision of waste management services is likely to face new challenges. This additional waste, if not followed with immediate adjustment strategies to remove it, will lead to environmental deterioration and health hazards (McMicheal, 2000). Policies to promote better and more efficient waste management systems need to be informed, especially given the fast rate of urbanization in many Sub-Saharan African countries. One way of informing governments, donors and policy makers is to provide efficient information on urban consumption patterns as these directly influence the nature of the waste. Such information helps to identify key leverage points to improve the waste management system.

1.3 Objectives of Research

This research aims to describe the effect of the change in urban consumption lifestyles, particularly changes in the source of food provisioning, on the waste profile of urban residents and how this effect impacts the waste management structure and capacity in African cities.

The objectives of the dissertation are to

- 1) Develop and present models of the food flow profile for a traditional market and supermarket consumer from production to disposal and develop waste flow profiles for both the traditional market and supermarket consumer;
- 2) Analyse the effect of change in food provisioning on the waste generated; and
- 3) Describe the impact of this effect given the current waste management capacity and structure in African cities.

1.4 Scope of Investigation

In this study, a material flow analysis is used to describe metabolic shifts in African urban lifestyles. Metabolic analysis can quantify the material and energy inputs and outputs, however, for this study the focus is on a material analysis and no energy analysis is performed.

The study combines material flow analysis modelling with case analyses. The latter covers urban food consumption in three sub Saharan African cities: Kitwe in Zambia, Harare in Zimbabwe and Kisumu in Kenya. These cases were chosen so as to align with a larger planned study of urban food poverty to be carried out by UCT's African Centre for Cities. The study is also limited to analyzing the waste management capacity in these cities and does not survey the entire waste management system.

1.5 Research Approach

A significant literature exists on food systems and diets in African cities, to be reviewed in chapter 2. Likewise, the concept of an urban metabolism is well established, and some cities have been described to have undergone a metabolic transition. This can be quantitatively described using a material flow analysis, in order to develop an overview of the input and output materials of an urban system. A material flow analysis is a suitable and well established method for deriving the waste profile of a city, linking it to consumption. The fact that mass into the system must be equal to the mass out of and accumulated in the system makes it possible to track the flows from source to disposal.

In this study, food consumption is modelled using various sources of literature on urban African diets. The diets generated in this study are illustrative and are mainly used to elaborate the difference in waste profiles based on the source of provisioning. Waste related to food systems consists of; i) the non-edible portion of produce; ii) packaging and; iii) wastage of bought or prepared food. In the first instance, the choice of fresh vs. processed food purchases will introduce packaging and shift the non-edible portion, so that is modeled first. Waste therefore is associated on the one hand with packaging, on the other hand with the non-edible portion of produce. The model was then extended to include the effect of different levels of food wastage on the waste profile.

The waste management capacity of various African cities has also already been described in reports and surveys; these serve as the main source of information. However, semi-structured interviews were also conducted with selected experts in the case study cities.

1.6 Structure of Thesis

This dissertation consists of eight chapters. This first chapter has set the scene and provided the motivation of carrying out this research by discussing the background and setting the objectives. The literature review, in chapter 2, describes the theory behind the methods used in this research as well as previous work that has been done in this field. The methodology, developed in chapter 3, speaks to how the research was carried out and also outlines the assumptions made when carrying out this research. The findings of the research are then presented in chapters 4, 5 and 6. Chapter 4 describes the characteristics of the cities that are studied in this research while chapters 5 and 6 show the findings of the food and waste systems respectively. Chapter 7 discusses the food and waste systems in each city and compares the results found in each of these cities, showing the relationship between the two systems. The dissertation then ends with a conclusions chapter where the findings of this research are reviewed and synthesized. Recommendations for further work are then made and presented.

2 Literature Review

2.1 Sustainability in Urban Contexts

Urban areas are places where there is large concentration of economic activities, a large population, and large material stock densities leading to high levels of energy and material flows (Niza, et al., 2009). These high levels of material and energy flows have a potential impact on the ecosystem on scales ranging from local to regional to global. With about half the world population living in urban areas, and the concentration of economic activities in cities, a large proportion of the global environmental impacts stems from cities (Bai, 2007). This proportion is likely to become even larger due to the ever increasing urban population (Bai, 2007). Thus it is important to find ways to reduce the environmental impacts of these growing urban areas and to move towards the development of more sustainable urban systems. In order to do this it is important to understand the relationship between human nature and the environment.

Urban areas can be seen as organisms and analysed in this way in order to improve their current environmental performance and long term sustainability (Graedel, 1999). This urban metabolism view proposes that, just as organism takes in food and water from its surrounding and converts it into biomass, energy and waste, cities extract raw materials, fuel and water from the environment and transform them in to the urban built environment, human biomass and waste (Decker, et al., 2000). In order to promote sustainable growth of these cities, it is important to understand these flows. The study and analysis of material and energy flows through cities is key in the strategies towards sustainability in cities (Kennedy & Hoornweg, 2012). The study of such flows includes the quantification of a city's inputs, outputs and storage of energy, materials, nutrients, water and waste. Such flows are inherent in the study of urban metabolism (Kennedy & Hoornweg, 2012). Kennedy *et al* 2007 define urban metabolism as “the sum total of the technical and socioeconomic processes that occur in cities, resulting in growth, production of energy, and elimination of waste” (Kennedy, et al., 2007).

Studies of urban metabolism provide a measure for the material and energy flows in cities and have mainly been used for accounting purposes (Kennedy, et al., 2011). However, such studies are useful beyond this and recent studies have shown how the study of urban metabolism can be

used as a basis for sustainable urban design e.g. (Baccini, 1997; Codoban & Kennedy, 2008; Barles, 2009; Kennedy, et al., 2011).

The urban metabolism study includes information on energy efficiency, material cycling, waste management and infrastructure and these measures are indicative of a city's sustainability (Kennedy, et al., 2011). The parameters used in urban metabolism generally meet the criteria for good sustainability indicators (Kennedy, et al., 2011). Urban metabolism studies can also be used in quantifying the greenhouse gas emissions of cities. By measurement of the energy consumption, material flows and wastes of the urban area, the GHG emissions of the city can be calculated.

Urban metabolism can also be used to simulate future changes in the material and energy stocks and flows of cities. These changes can also be used in an urban design context and provide necessary information required by urban planners.

2.2 Urban Metabolism as a Field of Study

The term urban metabolism was first used by Wolman in 1965. Wolman used the national consumption rates of water, food, fuel and the production rates of sewage, waste and air pollutants to derive per capita flows for a hypothetical American city of one million people (Wolman, 1965). This was during a period when water and air quality in many American cities was declining.

Following the conception of urban metabolism by Wolman in 1965, two main approaches were used to study the metabolism of socio-economic systems. The first approach describes urban metabolism in terms of energy equivalents and the second approach focuses on the material and energy flows in cities (Broto, et al., 2012). A further review of the study of urban metabolism done by Kennedy and colleagues found that there are two related, non-conflicting, schools of urban metabolism: one following Odum describes metabolism in terms of energy equivalents; while the second more broadly expresses a city's flows of water, materials and nutrients in terms of mass fluxes (Kennedy, et al., 2011).

Since the first urban metabolism study by Wolman in 1965, different authors have done studies in various areas around the world using both the energy equivalent approach and the measurement of material and energy flows. The energy approach is however not mainstream

and most studies of urban metabolism in cities have however focused on quantifying flows of various materials and energy (Kennedy, et al., 2011). One of the reasons for the use of material and energy flows is because this is information easy for stake holders and policy makers to understand.

2.3 Material Flow Analysis

Material flow analysis involves taking the stock of the material and energy flows in a defined system.

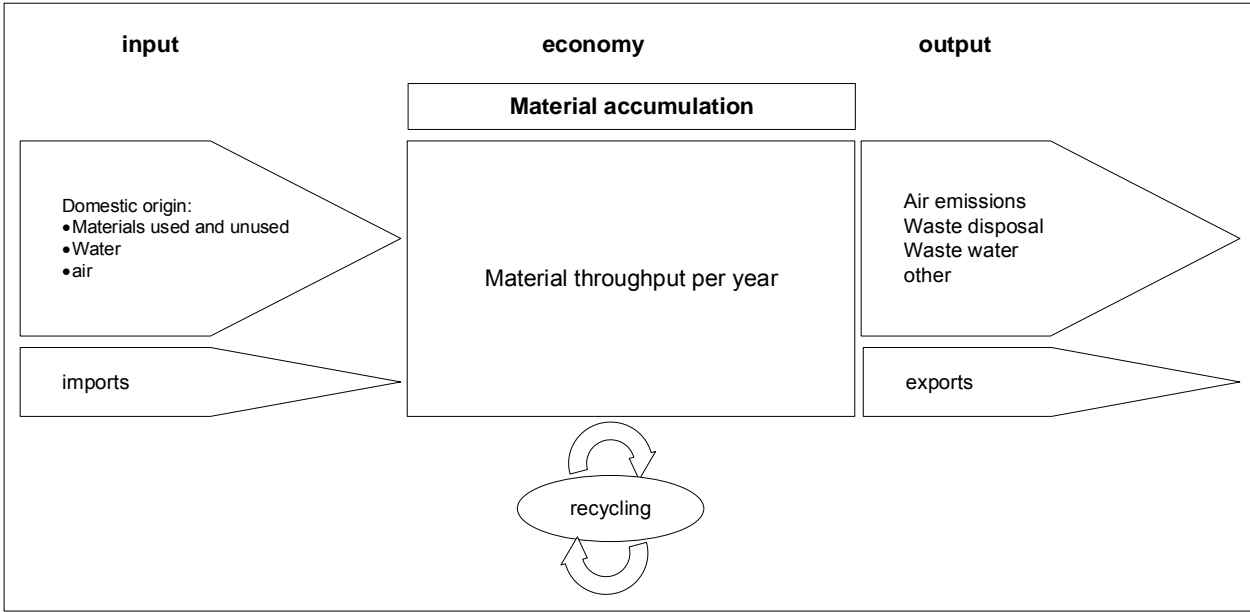


Figure 2-1: Simplified general material balance outline (Eurostat, 2001)

MFA looks to quantify the flow of raw materials, resources and/or intermediate or finished products, in physical units, from the point of extraction, through the processing and manufacturing stages, to their ultimate disposal (Browne, et al., 2011). The system in this case means the boundary over which the flows are measured and this is illustrated in Figure 2-1. The system may be an enterprise, a region, a nation or the entire globe. Material flow analysis can be defined as “an analysis of the throughput of process chains comprising of the extraction or harvest, chemical transformation, manufacturing, consumption, recycling and disposal of materials” (OECD, 2000). Material flow analysis thus looks at social metabolism by accounting for the flows and stocks of materials in a system thus linking sources, pathways and sinks of materials (Broto, et al., 2012). Although this has been mainly done at national level, the 1990s

saw progress in the development of the method of MFA and this included its application to cities (Kennedy, et al., 2011). Material flow analysis is now being widely used although it is yet to pick up in developing countries (Barles, 2009).

The development of material flow analysis initially was driven by two visions (Brunner, 2002). The first was that it would become a standard analytical procedure, like financial accounting, for the assessment of inputs, outputs and stocks of a system. In this way flows and stock of goods and substances could be analyzed in view of sustainable use of these materials i.e. low resource consumption and waste generation. Material flow based approaches can be used to quantify flows in order to enhance resource efficiency and recycling in production (Frohling, et al., 2012). The second goal was that MFA could be used as a tool for analyzing and investigating the metabolism of the anthroposphere i.e. the system consisting of human activities and the corresponding flows of materials energy and information. The tool would be used to describe metabolic processes that have developed over time and hence support the development of sustainable urban systems. MFA can thus be said to explore the metabolism of a region, analyzing the materials needed to satisfy human needs to nourish, clean, reside, work, travel, and communicate (Baccini, 1997).

There is no standard method used in carrying out a material flow analysis and several authors in literature have used different methods to quantify the metabolism of physical economies. However some features do stand out in most methodologies when performing a material flow analysis and these include (Fischer-Kowalski & Huttler, 1999):

- Identification of the system
- System level i.e. global, national, regional or a firm/household
- Material under consideration i.e. bulk flow materials, substances/nutrients, energy and
- The time horizon i.e. a single point in time vs. long time periods

Later research also classifies different methods of material flow analysis based on other dimensions that are similar to the ones stated above and these include; the system boundary identification for material flow sources, extents, and the key socio-institutional entities containing relevant driving forces, as well as the nature and detailing of system components and

flow interconnections, and the comprehensiveness and types of flows and materials covered (Daniels & Moore, 2002).

2.3.1 *MFA Studies*

Different urban metabolism studies, using material flow analysis, have been done over the last decade. Some of the studies done include Paris (Barles, 2009), Lisbon (Niza, et al., 2009), Toronto (Sahely, et al., 2003) and Cape Town (Basson, 2002). A review of the metabolism of cities has also been done (Kennedy, et al., 2007). In these studies, the method in which the MFA has been done may differ, but the concepts and underlying principles have been the same.

In the Paris study, the material flow analysis was done for three regions; Paris, Paris and its suburbs, and the entire region. The system is shown in Figure 2-2 below.

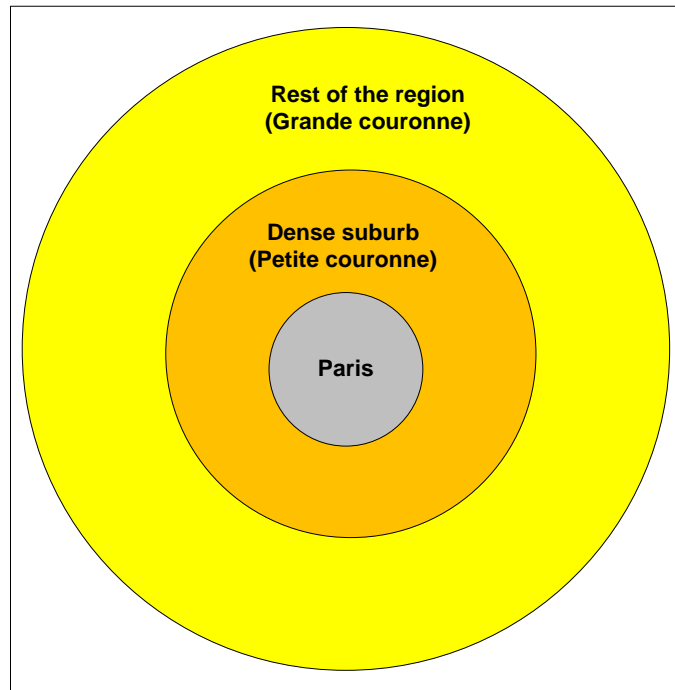


Figure 2-2: Showing the system boundaries for urban metabolism of Paris and its regions (Barles, 2009)

In this study, the entire area was divided into three regions and a material flow analysis was done for each region. The materials considered in this study were bulk flow materials. Bulk flow materials include biomass, fossil fuels, construction materials and minerals. Any materials crossing the boundaries between regions were considered as exports or imports of that region. In this study the metabolism of each region was compared. In this study, it was found that the urban

city center had the highest food consumption and exported all its wastes to other parts of the region while the agricultural and urban sprawl area consumed high levels of construction materials and fuel. The study in Paris shows how urban metabolism is strongly impacted by density and the distribution of activities: Urban areas consume a lot of resources and generate a wider variety of wastes.

Another urban metabolism study was done in Toronto at the neighborhood scale (Codoban & Kennedy, 2008). This study looked at the metabolism for 4 different Toronto neighborhoods for the year 2000 and the methodology used is shown below.

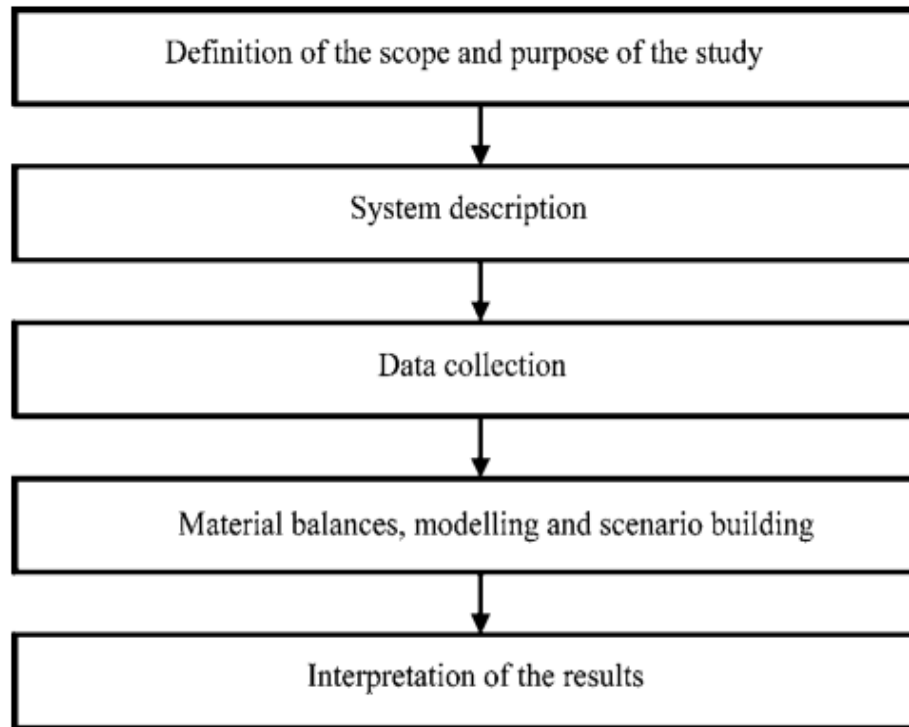


Figure 2-3: Showing methodology at neighborhood level in Toronto urban metabolism study (Codoban & Kennedy, 2008)

The most difficult step in the methodology was the description of the system. This is because it is difficult to describe a system that would be adequately represented with the available data. Obtaining sufficient and reliable data is also difficult and in this study data for previous years had to be used as well as data from different cities that were considered to have a similar

metabolism to that of Toronto e.g. part of the food waste data used in this study was obtained from Ontario residential waste data.

This study looked at the metabolism of four different neighborhoods in Toronto. It considered three metabolic processes within the neighborhoods; operation of buildings; preparation and consumption of meals and beverages; and transportation. The findings suggest ways to make the city more sustainable.

The MFA done in Toronto has enabled implementation of sustainable waste management practices like applying compost from the green bin program as well as further diversion of wastes from landfills through recycling. Various composting and recycling programs have been implemented from the information gathered from the metabolic study (Codoban & Kennedy, 2008).

2.4 Trends in Urban Metabolism

2.4.1 Global Trends

The term “metabolic transition” has been used to describe the fundamental changes in socioeconomic energy and material use that occur during industrialization (Haberl, et al., 2011). The change from an agriculturally based economy to an industrial one leads to a rise in the metabolic rates, i.e. increased material and energy flows per capita per year. Coupled to population increase this leads to a rise in the metabolic scale, i.e. the size of extraction and trade flows (Krausmann, et al., 2011). However, not only do the flows of material and energy increase, but there is also a shift in the composition of the materials consumed from biomass to more of minerals and fossil materials.

Different studies have been done to show the changes in metabolism at national scale, city scale as well as the neighbourhood scale. Depending on the availability of data, the studies have been done over several decades or just a few years. However it can be deduced that with changing socio-economic metabolisms around the globe, there is an increase in the metabolic rates, largely driven by a shift from agrarian based societies to more industrialized societies.

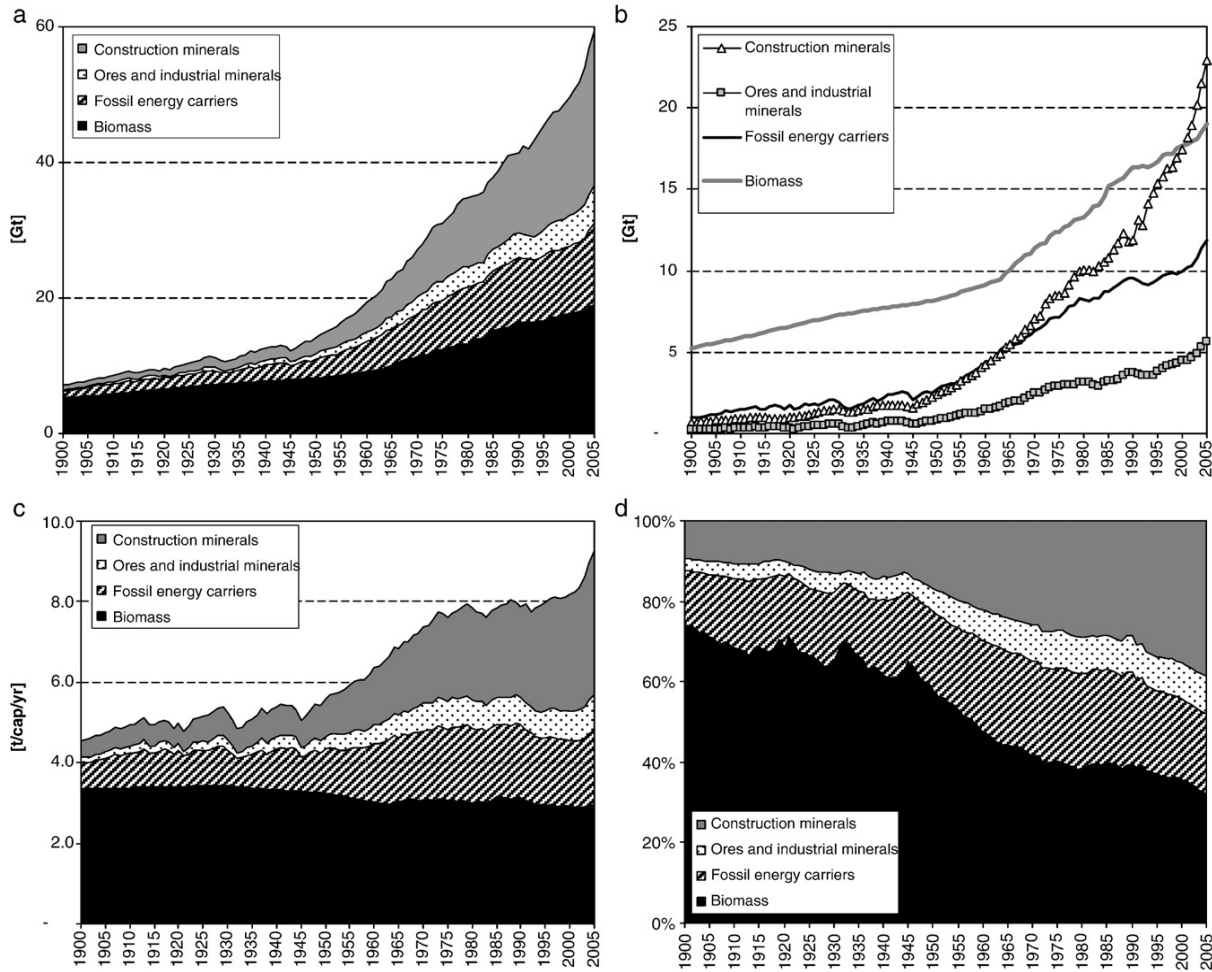


Figure 2-4: Showing global trends in material use from 1900 to 2005 (Krausmann, et al., 2009)

Over the last century there has been a 10-fold increase in the materials consumed globally. Figures 2-4a and 2-4b show an increase in the flows of the material flows since 1900. Interesting to note is that in the late 1990s the consumption of construction materials surpasses the consumption of biomass and this is seen in Figure 2-4b. Figure 2-4c shows a decrease in the metabolic rate of biomass but an increase in the rates of the other material groups and this shows the shift to a more industrialized society. This shift is further illustrated in Figure 2-4d where there is a reduction in the percentage of biomass in the total material use and an increase in the use of minerals and fossil energy carriers. The Figure 2-4 above shows the change in material use at a global level for the last century, however other studies have been done at national and city level.

Past urban metabolism studies that describe metabolic transitions, i.e. changes in urban metabolism, have been done over long periods of time e.g. decades, and have mainly shown a transition from the agrarian economy to the industrial economy. From this perspective industrialization has been looked at as a transition from the agrarian to industrial regime (Krausmann, et al., 2008).

By comparison, the study done by Warren-Rhodes and Koenig (2001) on the city of Hong Kong is a detailed study and focusses on specific material groups. This study is a continuation of the work done by Newcombe and colleagues in 1978. This study shows the changes in the per capita resource inputs and waste outputs for the period from 1971 to 1997.

Hong Kong underwent transformation from an intermediary center of trade and transshipment in the 1960s to a light industry center in the 1970s and to a service based economy in the 1990s. This transition was accompanied by large economic growth with a per capita GDP rise of more than 10% annually. The city of Hong Kong also grew in size and population from a city of 3.94 million in 1971 to 7 million people in 1997. In order to cope with the increase in population size, more land had to be reclaimed. Hong Kong is one of the most densely populated cities in the world. All this led to an increase in both the quantity and variety of materials flowing through the city. Table 2-2 below shows changes in the resource input and waste output flows from 1971 to 1997.

Table 2-1: Showing material inputs and waste outputs in Hong Kong for 1971 and 1997

Inputs (tons/day)				Wastes (tons/day)		
Material	1971	1997	% increase	1971	1997	% increase
Glass	270	363	34	152	240	58
Plastic	680	3390	399	184	1160	530
Wood	1889	2095	11	637	100	-84
Iron and Steel	1878	7240	286	65	240	269
Paper	1015	2768	173	691	1740	152
Human Food	5985	12101	102	393	2050	422
Cement	3572	9822	175	-	-	-

From 1971 to 1997 there was an increase in the flow rates of all the material inputs and waste outputs in Hong Kong except for wood waste. The largest increases occurred in the plastic (399%) and iron and steel (286%) inputs. There was also an increase in the consumption of paper of 173%, whilst the amount of food consumed doubled. The increases in the material inputs often far exceed the population growth for the same period which was 78%. However, economic growth far outpaced these growth rates and was at approximately 1100% from 1971-1997. The large jump in the plastic inputs was mainly due to an increase in consumer packaging. With the huge economic growth, the people of Hong Kong became more affluent and the demand for appliances, electronic goods and other consumer items increased and packaging of these goods also contributed to growth in plastic inputs. The percentage of plastics in the waste outputs also increased and this increased at a higher rate than the inputs, indicating the fastest increase in short-lived uses of plastic. The same trend was observed for paper and human food. This was because of the “throw-away” mentality in Hong Kong and this was further exemplified by the daily use of 1 million styrofoam lunch boxes, which were dumped in landfills at the rate of 120 tons/day.

As a result, wastes in Hong Kong increased greatly between 1971 and 1997. Domestic wastes formed the second largest portion of wastes generated after construction and demolition wastes. It was found that food, plastics and paper were the main components of the domestic waste and this showed the “throw-away” mentality adopted over the 26 years. Hong Kong has a high annual waste generation per unit area and was expected to run out of landfill space by the year 2015. Steps were however taken to address the solid waste problem mainly through recycling. 33% of the municipal solid waste was recycled which included a few plastics, mostly post-consumer packaging. The government also looked into the construction of new incinerators with a combined annual capacity of 2 Mt of municipal waste.

The 26 year study in Hong Kong showed a 78% increase in population and an 1100% increase in the economic growth. These increases came along with an increase in resource consumption and waste generation habits. Consumption skyrocketed because of increase in affluence and changes in consumer life styles. Waste generated far exceeded population growth, with an 80% increase in per capita waste generation showing an increase in wastage linked to growth in affluence. These changes have caused major environmental concerns for the city of Hong Kong.

2.4.2 *Transition in the African Context*

Urban metabolism studies in the African context are few in literature. The metabolic transition in African cities today could in a way be expected to be similar to that experienced in Hong Kong. Although the city of Hong Kong was at a much later stage of the metabolic transition, the changing metabolism in African cities shows some similarities to those experienced in Hong Kong. The African economy is growing at a fast rate and this means that the incomes of the people in Africa are increasing. Although low per capita incomes have been recorded in most African cities, average incomes are increasing giving rise to an emerging middle class that will become more demanding as income levels and spending increases (Hatch, et al., 2011). This gives rise to an increase in demand. With a population growth of 2.2% per annum and high rates of urbanization and GDP growth, Africa's market for consumer goods is growing and doing so in real terms (Vengesai & Matsika, 2012). Large multinational companies like Unilever and Nestle have been making significant investments in sub-Saharan Africa and expanding their operations and now other large FMCG retailers like YUM Brands and Walmart are seeking a slice of the SSA consumer cake (Vengesai & Matsika, 2012). An analysis shows that by 2020 nine countries will account for three-quarters of the total consumer spending in SSA. These countries are shown in Table 2-3 below along with changes in their spending between 2010 and 2020.

Table 2-2: Showing countries in SSA with highest contribution to consumer spending (Hatch, et al., 2011)

Country	Population (millions)	2010 (\$ billion)	2020 (\$ billion)	% increase
Kenya	40	23	37	61
Ethiopia	83	20	43	115
Uganda	33	15	30	100
Nigeria	151	115	167	45
Ghana	24	15	29	93
Senegal	13	10	16	60
South Africa	49	215	315	47
Angola	19	14	18	29
Zambia	13	10	23	130

From Table 2-3 above it can be seen that Zambia, Ethiopia and Uganda are predicted to experience fastest growth in consumer spending.

2.4.2.1 *Emergence of Supermarkets*

The rise of supermarkets in developing countries has been happening since the mid-1990s and there has been a rapid rise in the number of supermarkets especially in developing countries. Supermarketization has been described in reference to developing countries as the rapid spread of supermarkets (Reardon, et al., 2005), and thus the emergence of supermarkets in this section is described in reference to developing countries. One of the reasons this rise has been increasing GDP and distribution of incomes (Traill, 2006). Initially, supermarkets were a place where only the rich people shopped, however, over the past decade or so they have spread from the wealthy suburbs of cities to the poorer areas and now cater for the urban poor (Weatherspoon & Reardon, 2003). Opportunities to offer cheaper and wider variety of foods have also favored the growth of the supermarkets in Africa (D'Haese & Huylenbroeck, 2005).

In Africa, supermarkets are growing at a fast pace, especially in eastern and southern Africa (Reardon, et al., 2003). South Africa has seen a rapid rise in the number of supermarkets since 1994 and Kenya and other countries are following suit (Traill, 2006). The rapid rise has been made possible by increasing urbanization and the rise of the middle class (Weatherspoon & Reardon, 2003). This increase has been made possible by growth in GDP and distribution of incomes (Traill, 2006). This process is also taking place in North African Mediterranean countries like Morocco and Tunisia (Codron, et al., 2004). The projected rise in the market share of supermarkets for Kenya and South Africa is shown below.

Table 2-3: Showing change in market share of supermarkets based on changes in urbanization and income per capita

Country	Kenya		South Africa	
	2002	2015	2002	2015
Year				
Income per capita (US\$)	393	497	2299	3340
Urbanization (%)	38.2	51.8	56.5	62.7
Market share (%)	10	15	55	65

The increase in the incomes and urbanization leads to an increase in the market share of supermarkets as can be seen in Table 2-4 above. From the table it can be seen that from 2002 supermarkets are expected to have grown by 5% by 2015. The growth of supermarkets in African countries shows a similar trend to that experienced in other developing countries in Latin America and Asia (Reardon & Berdegue, 2002; Weatherspoon & Reardon, 2003).

Table 2-4: Showing Supermarkets' Customer Base by Incomes in Nairobi 2003 (Neven, et al., 2006)

Income Class	%of the Pop.	% of Class Shopping in Supermarket	% of Class		% of HH	
			Buying Fresh Produce in Supermarket	FFV Expenditure Spend in Supermarkets	% of Supermarket Customers	% of Supermarket sales
Poor	30	60	<1	<1	20	12
Low	35	85	15	5	36	24
Lower middle	20	93	5	5	22	20
Upper middle	9	93	15	15	11	19
High	6	>99	40	40	12	25

Table 2-5 above shows that almost all the middle to high income earners shop from the supermarkets. Expenditure in supermarkets also increases with income group and upper middle to high income group account for 44% of supermarket sales and yet these only make up 15% and 23% of the population and supermarket customer base respectively. Most studies on the growth of supermarkets have looked at competition between supermarkets and existing food actors (Neven, et al., 2006; Reardon, et al., 2009), the impact on small farms and small processing/distribution firms (Louw, et al., 2008), as well as the impacts on domestic market development, local employment, and economic growth (Shepherd, 2005; Emongor & Kirsten, 2009). However few studies look at how the expansion of supermarkets has affected consumer outlet choice. Unfortunately, many developing countries do not have the resources to conduct consumer surveys about food consumption and diet (Kearney, 2010).

2.4.2.2 Transition in Food and Nutrition

Increase in globalization, urbanization and economic growth have led to shifts in diets in developing countries around the world. Evidence from previous studies has shown that economic development leads to major transitions in dietary intake and this has been termed as the nutrition transition (Hawkesworth, et al., 2010). This nutrition transition involves a shift in diet away from a diet containing mainly carbohydrates, fibre and low amounts of sugar to energy dense diets composed predominantly of saturated fats, sugar and highly processed foodstuffs common to much of the developed world today (Drewnowski & Popkin, 1997; Popkin, 2004; Popkin, 2006); . These changes in diet have been driven by a number of factors such as increased production, availability and marketing of processed foods and the effects of urbanization (Popkin, 2006).

Rapid urbanization and economic growth has led to a dramatic shift in the Asian diets away from staples towards livestock and dairy products, fruit and vegetables, and fats and oils (Pingali, 2006). Food consumption patterns are showing signs of convergence towards the western diet and the rapid spread of global supermarket chains and fast food restaurants is reinforcing the above trends (Pingali, 2006). The diet transformation in Asia can be seen as involving income-induced diet diversification and diet globalization and westernization (Pingali, 2006). Growth in incomes leads to changes in food consumption not only in quantity but also across the different food types. The process of urbanization and globalization leads to changes in general lifestyles and dietary needs (Popkin, 1999). As incomes increase, people are willing to pay more for convenience and this frees up more time for other activities and with smaller families in urban areas, this lifestyle becomes affordable (Pingali, 2006). The demand for processed foods which have less preparation time rises and this has been typically seen as more women enter the work force (Kennedy & Reardon, 1994). This trend in food consumption pattern is being experienced by many Asian countries in economic and demographic transition (Shetty, 2002). It is thus expected to see a higher consumption of processed foods and ready-made meals and this avoids the long preparation time of traditional meals. The diet transition has also been witnessed in smaller and poorer households, especially with increased reliance on street foods (Ruel, et al., 1998); (FAO, 2002). Purchase of street foods frees up time for other income-earning activities.

Most research that has looked at nutrition transition and change in food consumption patterns have done so mainly focusing on the impact on diet, health and nutrition, but studies on the effect of the change in food consumption patterns on waste profile have been few and limited.

2.5 Urban Solid Waste Management

Urban areas generate a variety of waste and this is likely to increase with the growing proportion of urbanized people. Cities today have been described as mainly linear systems and have a huge dependence on the hinterland i.e. their metabolism involves the use of imported resources and exportation of all emissions and final wastes to the *hinterland* (Brunner, 2007). It is thus necessary to find sustainable ways to deal with the increasing amount of waste and minimize the impact on the environment. Increasing population growth and urbanisation has put increased pressure on the waste resources and thus stake holders are under pressure to find ways to deal with these phenomena.

Waste management in urban areas is mainly provided as a service by the municipality. However in recent times, municipalities have been unable to cope with the increasing pressure on existing resources and cannot provide adequate services for urban areas on their own. The private sector is now involved in provision of waste management services as they usually have the capacity to cope with changes in waste structure. In developing countries, a number of voluntary organizations have also been involved in order to ease the burden of waste management on the urban municipal councils.

2.5.1 Waste Generation and Composition

Municipal solid waste generation varies across regions in both volume/quantity and composition as shown in Figures 2-5 and 2-6. According to (Hoornweg & Bhada-Tata, 2012);

- MSW generation levels are expected to double by 2025.
- The higher the income level and rate of urbanization, the greater the amount of solid waste produced.
- OECD countries produce almost half of the world's waste, while Africa and South Asia produce the least waste as shown in Figure 2-5.

The source of waste comes from different activities that occur. Municipal solid waste includes waste generated by households and the commercial sector while industrial waste includes waste generated by big companies e.g. mining companies and manufacturing plants. Household waste makes up the larger percentage of municipal solid waste.

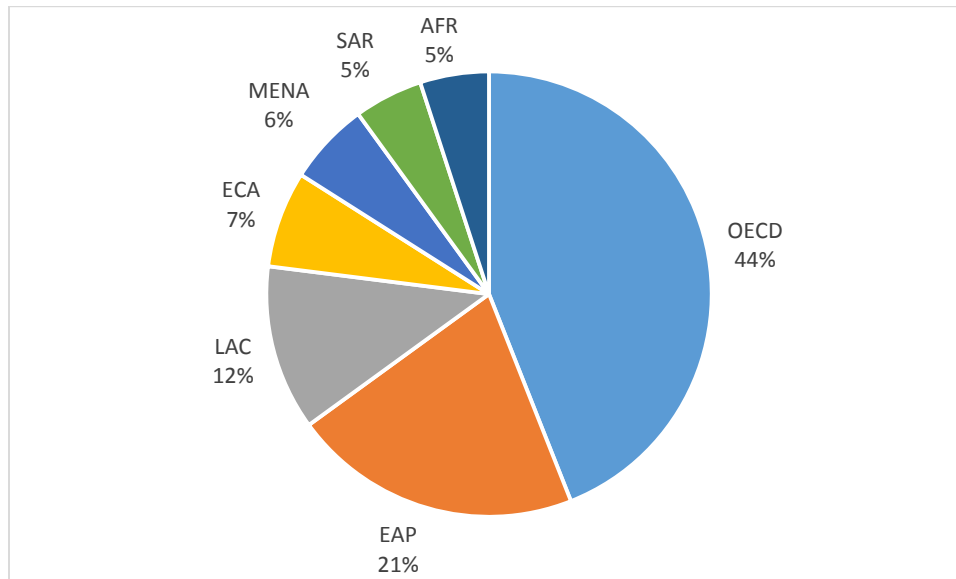


Figure 2-5: Global waste generation by region (Hoornweg & Bhada-Tata, 2012) OECD- Organisation for Economic Co-operation and Development, EAP- East Asia and Pacific, LAC-Latin America and Caribbean, ECA- Europe and Central Asia, MENA- Middle East and North Africa, SAR- South Asia region AFR- Africa

The characteristics of waste generated in developed world differ from those of waste developed in developing countries. The rate of municipal solid waste generation is affected by economic development, the degree of industrialization, public habits, and local climate and generally the higher the economic development and rate of urbanization, the greater the waste produced (Hoornweg & Bhada-Tata, 2012). In sub-Saharan Africa, per capita waste generation spans a wide range from 0.09 to 3 kg/capita/day, with an average of 0.65 kg/capita/day and this is low compared to high income countries that generate an average of 2.2 kg/capita/day (Hoornweg & Bhada-Tata, 2012).

Waste composition also varies across regions and is influenced by factors such as culture and economic development. Lower income countries have a higher percentage of organic waste than higher income countries. In low-income countries, organics make up as much as 64% of the waste stream while in high-income countries they make up as little as 28% (Hoornweg & Bhada-

Tata, 2012). Paper, plastics and other inorganic content make up the highest portion of the waste in high-income countries.

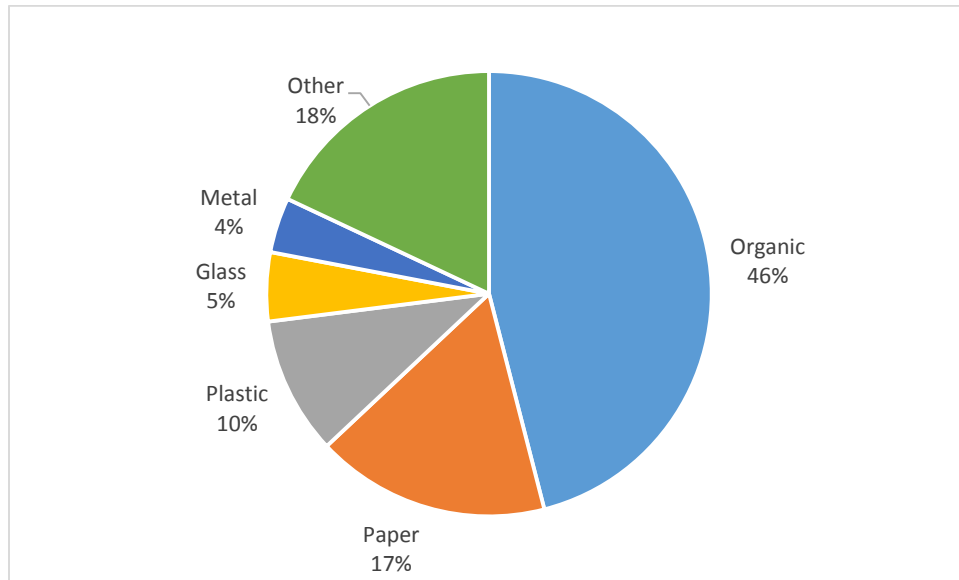


Figure 2-6: Global solid waste composition (Hoornweg & Bhada-Tata, 2012)

Figure 2-6 above shows the global solid waste composition. Waste volumes and compositions vary from place to place around the world and many factors contribute to this difference. The main indicators used to analyse waste generation and composition are socio-economic factors. Factors that affect the volumes and composition of waste include; income level, level of education, population and household size, cultural beliefs, lifestyles and eating habits.

A lot of studies have been done to study which of these factors influence waste generation and composition. There is no one answer to this question as each region is different and studies have shown that some factors apply to certain areas and others do not. Waste management studies have been done to analyse the effect of the different socio-economic factors on waste generation and composition. A thorough review of these studies can be found in Beigl, et al., 2008. Most studies have looked at the influence of population growth and economic growth on waste.

The effect consumption lifestyle, in terms of food choice provisioning, on household waste production has also been studied to some extent. Thogersen (1996) showed that the increase in waste in industrialized countries can be satisfactorily explained by increase in consumption. However this study also found that the changes in consumption lifestyle associated with increased purchase of processed food has sometimes accelerated and other times decelerated

generation of household waste (Thogersen, 1996). The effects of the “modernization of the food base” are complex and would be better understood through analysis of the whole production and consumption cycle. The comparison between waste generated by the USA and Mexican households showed that the former generated less waste. The US households however discarded twice as much packaging waste by weight than the Mexican households and it was found that the Mexicans discarded twice as much food waste as they did packaging. This was because the Mexicans bought a lot of inedible organic waste with their fresh food. Most of this matter has been removed from the processed foods that families in the United States buy more frequently. Thus most of the inedible food waste in the US became industrial waste. The amount of food waste in household waste also varied among industrialized countries. In 1980 food waste was 8% in the USA and 22% in Denmark. And some authors explained the differences in the composition of the household waste on grounds of different degrees of industrialization of the food base (Thogersen, 1996).

Most studies have focused on the effect of socio-economic factors on waste generation and composition e.g. (Achankeng, 2003; Beigl, et al., 2008; Scheinberg & Mol, 2010; Scheinberg, et al., 2010; Thogersen, 1996). Studies looking at income and economic growth have focused on change in waste based on change in income earned. However, studies comparing the effect of choice of provisioning on waste and waste capacity are lacking.

In traditional markets, factors influencing the waste generation include the incomes of people and the level of recycling in the market. Other factors may include time and season.

2.5.2 Waste Management Practices

With increasing urbanization and economic growth in the world today, it is expected that the variety and quantity of waste generated will increase. It is thus important to quantify the volumes of waste as well as their compositions before a waste management strategy can be developed (Sakai, et al., 1996). The volume of waste should be known so that optimal ways of handling the waste can be identified e.g. effective transportation of the waste. It is also important to get the composition of the waste especially if dealing with hazardous material or materials for recycling.

2.5.2.1 Waste Reduction, Reuse and Recycling

Waste management is key in the industrial sector and efforts to minimize waste are usually driven through government and industrial regulations. The minimization and prevention of wastes is key for industries not only for the environmental benefits but also avoidance of the costs that come with handling or managing wastes. Industries now look into optimization of processes and manufacturing techniques which includes use of less raw materials and thus generation of less waste and also minimizing weight and volume of packaging while still maintaining product integrity during transportation (Sakai, et al., 1996). Apart from waste minimization, there are also efforts to reduce quantities of hazardous wastes in the waste streams.

Another way to manage the amounts of wastes generation is through recycling and re-using of some of the waste materials. These terms have been used interchangeably in some instances, but recycling can be better defined as the use of waste material as raw material for the manufacture of a new or similar type of product (Sakai, et al., 1996). Recycling reduces the amount of waste generated by taking out the valuable waste material which can be reused in production processes. The use of recycled material reduces the use of virgin raw materials and reduces the environmental burden from the extraction of virgin resources. The use of secondary resources has also been known to reduce the energy consumption and the attendant environmental burden particularly in the metals industry (Gaustad, et al., 2010). Different methods to promote recycling have been developed both at local, regional and global levels. One of the ways is the notion that one man's trash is another man's treasure which has been emphasized in the field of industrial ecology. In this way one industries waste or discarded material becomes another industry's raw material and in this way innovative pathways can be discovered for turning wastes into economically valuable resources. Economic, environmental, and social benefits are realized through industrial ecology by discovering ways to divert discarded products or materials from the waste stream and recover their residual value through reuse, recycling, and remanufacturing (Cimren, et al., 2011).

However, there are several problems that have been associated with recycling. The lack of incentives for people to recycle and the poor and inefficient methods associated with waste sorting and the collection of recyclables makes this difficult. Morgan and Hughes (2006) showed in their study of the Aluminium sector that recycling is more readily practiced at the corporate

level because of the obvious magnitude of the savings generated, however, at the individual consumer level, the benefits may not be apparent or motivating. One person may feel his single effect on the environment is insignificant or not find the savings worth it at a household level (Morgan & Hughes, 2006). Thus it is important to find more incentives to encourage people to recycle. Changes in composition of scrap or end of life material also makes it difficult to incorporate secondary materials in manufacturing processes while maintaining product output quality as well as production efficiency.

Recycling is more of a common practice with the higher income class and here more advanced methods of collection are used i.e. with the employment of collection service agents and use of material handling and sorting facilities although informal recycling still exists e.g. aluminium can collection (Hoornweg & Bhada-Tata, 2012). In the lower income classes, collection and sorting is mainly done by the informal sector and waste picking and the recycling markets are unregulated with a large number of middle men. Recycling rates are thus higher in developed countries with rates of about 30% in the US and 18% in the European Union and can even go as high as 41% (Troschinetz & Mihelcic, 2008). Recycling rates for packaging wastes in the UK were as high as 27% by 2006/07 (Defra, 2007) and as high as 50% in some countries (Eurostat, 2008). Most recycling programs in the US and Europe were started with the recycling markets close to the source but, recycling has now moved from a local to global business e.g. most of the waste recycled in Buenos Aires is shipped to China and the price paid per ton of waste paper in New York City is often based on what the purchase price is in China (Hoornweg & Bhada-Tata, 2012).

2.5.2.2 Incineration

Incineration is one of the ways in which waste can be disposed of. Incineration of MSW is one of the most effective ways as it can reduce the volume of waste required for landfilling by 80 to 95% (Rand, et al., 2000). The use of incineration for waste management also requires for there to be an advanced waste management system. Waste incineration can be done with or without energy recovery. The energy recovered can be used for heating or power generation. However this is very dependent on the calorific value of the waste and thus the composition of the waste is key. In the EU in 2011, 6% of the waste generated was incinerated, 4% with energy recovery and 2% without (Eurostat:, 2013). Incineration with energy recovery is high in some countries like

Denmark, 24% and Belgium, 16%. However this method of waste disposal is very expensive as it requires advanced technology and highly skilled labor to manage operation of the plant. It is thus mainly done in highly developed countries that have the resources to build the plants and expertise to run them. It has been unsuccessful in developing countries due to the high capital and operational costs. The disposal of incineration waste after the process is also key. The waste includes the ash that remains after combustion of the waste and the greenhouse gases generated during the combustion process.

2.5.2.3 Landfilling

Globally, landfilling is the most popular way in which waste is disposed. However percentages vary from more than 90% in developing countries to less 40% in developed countries (Hoornweg & Bhada-Tata, 2012). It is a method where waste is disposed of in open or closed dumpsites and forms a significant part of the waste management system for developing countries. Landfilling is most common in developing countries as it is a cheap way to dispose of waste.

2.5.2.4 Integrated Solid Waste Management

Integrated solid waste management is an effective strategy that enables sustainable solid waste management by considering waste prevention, alternative usage and proper disposal. In the development of waste management strategies an internationally accepted hierarchy is followed in waste management as shown in Figure 2-7 below.

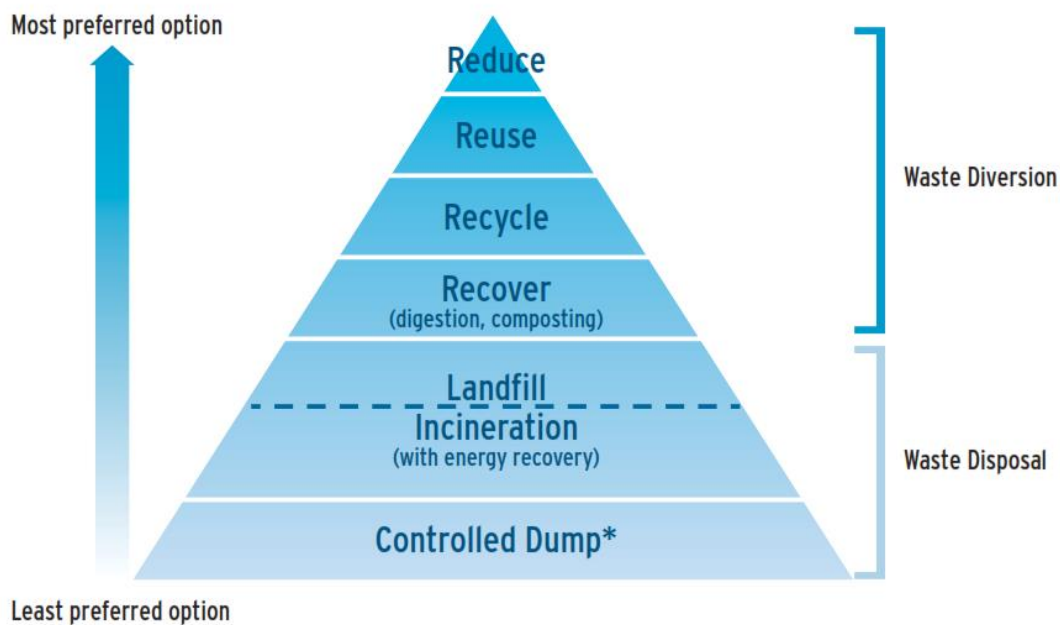


Figure 2-7: Showing waste management hierarchy (Hoornweg & Bhada-Tata, 2012)

The preferred method used in a given region varies depending on a number of factors which include; topography, population density, transportation infrastructures, socioeconomics, environmental regulations, composition of the waste and the availability and way in which waste data are collected (Sakai, et al., 1996).

2.6 Waste Management in Africa

2.6.1 Generation and Trends

Solid waste management is one of the biggest problems faced by governments in African cities. Municipal waste management deals with the collection, transfer, resource recovery, recycling, treatment and final disposal. Although the per capita waste generation in Africa is low compared to other continents, with an average of 0.65 kg/capita/day (Hoornweg & Bhada-Tata, 2012), waste management takes up a large portion of the budget and yet a small percentage of this waste is collected.

The waste generated in African cities is influenced by the population, time of the year (season), local culture, traditions and personal income (Imam, et al., 2008; Parrot, et al., 2009). The waste

generated in Africa is high in organics, forming 57 % of the waste (Hoornweg & Bhada-Tata, 2012).

Collection of municipal solid waste is a public service that impacts the public health and appearance of towns and cities. The waste is collected in garbage bins at domestic waste depots and allocated dumpsites. Collection vehicles also perform house to house garbage collection but this is mainly done in high income areas. Collection rates also vary depending on the time of the year and the location and this is due to poor infrastructure and the lack of all-weather roads. Collection rates may also be low because of the use of poor or not fit for purpose equipment. In several cases collection vehicles and containers have been purchased but have been ineffective because of corruption or the assumption that the equipment will work for all types of waste. Resource recovery and recycling are very low in African cities. This is because of the limited knowledge on technologies and good practices for waste management, lack of equipment for the collection of sorted materials and the absence of decision makers interested in environmental issues (Guerrero, et al., 2013). Few cities in Africa also have transfer stations or material sorting facilities. Municipal waste management has been used as a means to create employment in developing countries. However this has led to a large number of workers and low efficiency. A more efficient way to create jobs would be to promote recycling by the private sector (Coad, 2011). Due to the inefficiencies associated with waste management by the public entities, some of these services are now being provided by the private sector. Provision of efficient waste management services in Africa is hindered by many problems which include insufficient funds, poor technology and infrastructure and lack of organization by the parties involved.

With urbanisation and change in consumption lifestyles, there has been a change in the quantity and composition of the waste generated. Transition countries are starting to face challenges from the practical impacts of these changes. An area where this is felt is in waste management. A study done in Bulgaria showed that the municipalities had to deal with impacts of the transition from socialism affecting their solid waste systems and the existing waste infrastructure and practices had to cater for both increased quantities and types of waste (Scheinberg & Mol, 2010).

Table 2-5: Showing income levels, population and municipal solid waste generation in different cities (Scheinberg, et al., 2010)

City	GDP per capita US\$	Population	kg/cap/ year	Paper %	Plastic %	Glass %	Metal %	Organic %	Other %
Rotterdam, Netherlands	46750	582949	528	27	17	8	3	26	19
San Francisco, USA	45592	835364	609	24	11	3	4	34	24
Adelaide, Australia	39066	1089728	490	7	5	5	5	26	52
Curepipe, Mauritius	5383	83750	284	23	16	2	4	48	7
Varna, Bulgaria	5163	313983	435	13	15	15	10	24	23
Sousse, Tunisia	3425	173047	394	9	9	3	2	65	12
Lusaka, Zambia	953	1500000	210	3	7	2	1	39	48
Nairobi, Kenya	645	4000000	219	6	12	2	1	65	15
Bamako, Mali	556	1809106	256	4	2	1	4	21	52
Moshi, Tanzania	400	183520	338	9	9	3	2	65	12
Ghorahi, Nepal	367	59156	167	6	5	2	0	79	7

It is difficult to obtain data on waste generated in cities. Different cities measure waste generated differently and this also makes comparisons across cities difficult. Waste generated differs within and across cities. Factors that affect the waste generated include the number of people living in the city as well as the wealth (GDP) of the city as shown in Table 2-5 above. From Table 2-6

above, it is seen that organics form a big percentage of waste generated in cities around the world. However, the lower income cities generally have a higher organic fraction in their waste than the high income countries.

2.7 Waste Management Practices and Infrastructure in Africa

Collection, transport and storage form the larger portion of the waste management service costs and yet collection rates are only 46 % (Hoorweg & Bhada-Tata, 2012). With the increased urbanization rates and growth of cities in Africa, there has been an increase in the wastes generated in urban areas. These quantities are not only increasing, but also variety is changing as a consequence of increasing urbanization, incomes, and changing consumption habits (Achankeng, 2003). In developing countries, many urban administrations are failing to deal with the ever-increasing waste quantities and this challenge is made harder by the diversity of materials in the waste, which is no longer mainly food waste and ash, but includes more and more plastic packaging, paper and discarded electronic equipment (Coad, 2011). The amount of waste generated in African cities has grown and yet there has been a further decline in the capacity to collect and safely dispose of this waste (Henry, et al., 2006; Parrot, et al., 2009).

Solid waste generation in Africa varies from city to city and reliable data is difficult to come by. This is due to poor record keeping as well as inefficient waste collection and management practices in most African cities. The municipal waste management services are usually provided as a public service by the municipality and responsible government department. Although recently, due to the inefficiencies associated with waste management by the public entities, some of these services are now being provided by the private sector.

Conventional waste management practices in developing countries do not consider the profound differences between low and middle/high income waste compositions. This results in less than optimal outcomes of solutions put forward by waste management practitioners and stakeholders (Medina, 2006).

2.7.1 Recycling in Developing Countries

Recycling in developing countries focuses more on the practical, direct factors influencing the institutions and elements associated with waste management. Developing countries rely on the informal sector (Troschinetz & Mihelcic, 2008; Wilson, et al., 2009). In developing countries the informal sector accounts for majority of the recycled waste collected and is more active in waste recovery (Scheinberg, et al., 2010). This recycling sector is funded entirely from the sale of the recovered materials and participation in the informal sector is done by (Wilson, et al., 2009);

- Itinerant waste buyers
- Street waste picking
- Municipal waste collection crew
- Waste picking from dumps by scavengers mainly in communities that live on or near dumpsites (Rouse, 2006)

The participation of the informal sector in the recycling sector is creating savings for the formal sector by reducing the amount of waste required for collection and transportation and thus there is potential for a win-win situation through the cooperation of both sectors (Wilson, et al., 2009).

The main barriers to recycling in developing countries are level of personnel education, availability of waste collection and segregation services, and availability of government finances. Housing economics is not a big limiting factor to recycling in developing nations (Troschinetz & Mihelcic, 2008).

2.8 Summary of Literature

Africa is developing at a fast pace with high rates of economic growth and urbanization. With an increase in economic growth and urbanization, people become more affluent, consumer lifestyles change and there is an increase in consumption. This implies fast and vast shifts in the metabolism of those countries, and in particularly their towns and cities, where these new ways of consumption are taking hold.

These shifts in metabolism can be quantified by the study of urban metabolism. This also helps to describe the relationship between urban systems and the environment. Various urban metabolism studies have been done, and most make use of material flow analysis, a tool developed in order to quantify the flows of materials in and out of the economy at national scales. There is no consistent method to carry out material flow analyses at urban scales, but the development of the economy-wide material flow accounting method by the statistics office of European communities, which has been a first step towards harmonization of methods used, is seen to hold promise also for studies at the urban scale.

Metabolic studies have been done over different time periods ranging from a year to several decades. Studies done over time have shown the metabolic transition of most regions from agrarian to industrial regimes. All the studies have shown an increase in resource consumption and wastes generated. In Hong Kong the growth in material use and wastes generated far exceeded population growth over a 26 year period, yet was less than the economic growth over the same period. Consumer life styles changed as people became more affluent and were able to afford more consumer items. This was shown by a 400% jump in plastic consumption, mostly consumer packaging. There was also an 80% increase in per capita waste generated.

A change in consumption patterns in Africa is likely to cause a transition from pre-mall to mall consumption and an increase in demand for consumer items. This describes the metabolic shift in African cities. Thus the waste generated not only increases in quantity, but also in variety. This poses a challenge on the already poor waste management system in Africa. Past studies show that waste management infrastructure in Africa is under capacity and there is insufficient investment in urban waste management. Thus this change in metabolism in African cities is likely to put further strain on waste management systems.

3 Approach and Methodology

This chapter develops the theory on which this dissertation is based and the methodology used to conduct this research. The chapter begins by outlining the key questions and hypotheses that direct this research, based on information drawn from literature. Following this is an explanation of the approach used to conduct this research and justification of why it is used. It then goes on to describe step by step the methods used to carry out this research based on information drawn from theory.

3.1 Key Questions and Hypotheses

Based on the analysis of literature, the following key questions are formulated to guide this research:

- What is the effect of a shift in consumption from a traditional market to a supermarket on the quantity and quality of waste generated?
- Are there systems in the waste management structure to identify and cope with these effects in African cities?
- How can the change in waste quantity and composition be incorporated into waste management planning?

From the key questions above, the following hypotheses are formed for this research:

- The shift from market-based to supermarket-based provisioning doubles the waste generated per capita, as a) better organic waste utilisation resulting from supply chain optimisation is outpaced by increased consumption by supermarket consumers and b) packaging waste material equals the organic waste in weight;
- The growth in waste quantity is relatively easy to incorporate into waste management planning, but change of waste composition is usually overlooked.

3.2 Appropriate Research Methods

This dissertation makes use of two different approaches to develop answers to the proposed research questions. Firstly, the magnitude of changes in urban waste profiles resulting from metabolic transitions is developed using a systems modelling approach. This method generates evidence based on physical laws (specifically, the conservation of mass) and requires input data which can either be primary or drawn from already assembled data sets. Secondly, to answer the question whether there is an imbalance between changing consumption behavior and urban waste management capacity, evidence is gathered from real urban systems, using case studies.

The case study method is one of several ways of doing research and obtaining information about a system. The system could be a person, household, organization, group, industry, city or country. Other methods of doing research include experiments, surveys and analysis of past information.

Case studies are generally preferred when investigating a particular current phenomenon within some real-life context in order to answer questions such as “why and how” (Yin, n.d.). Case studies can be done using either qualitative or quantitative data. These data may come from different sources, such as fieldwork, archival records, verbal reports, observations, or a combination of these (Yin, 1981) (Eisenhardt, 1989).

There are different types of case studies that could be used to carry out research and these can be exploratory, explanatory or descriptive.

In conducting case study research, it is of importance to present the right type of questions and hypotheses to be used to guide this research.

In the context of this research, the case study approach will be used to answer the question of how the shift or change in choice of consumer provisioning affects the waste profile and how this affects the waste management practices. The question as to why this phenomenon is happening is supported from information based on both past and present events found in literature.

3.3 Methodology for Study

The purpose of the methodology used in this study is twofold: first to illustrate the effect of choice of consumption provisioning on the waste profile of a consumer and secondly to show how this effect manifests further downstream in the waste management system. A material flow analysis approach is used to track the flows from the choice of provisioning up to the disposal by the consumer. In this study, metabolic flow models are developed to describe the acquisition of food from a traditional market vs. a supermarket. In order to develop these models, consumer food flows are formulated and the amount and composition of the waste associated with these food flows derived. The second part of the methodology looks at the waste management capacity in African cities. Information on this is drawn from literature, various reports and case studies and interviews with waste management planners and practitioners. The methodology used to carry out this research is shown in the diagram and further described in sections 3.3-3.6.

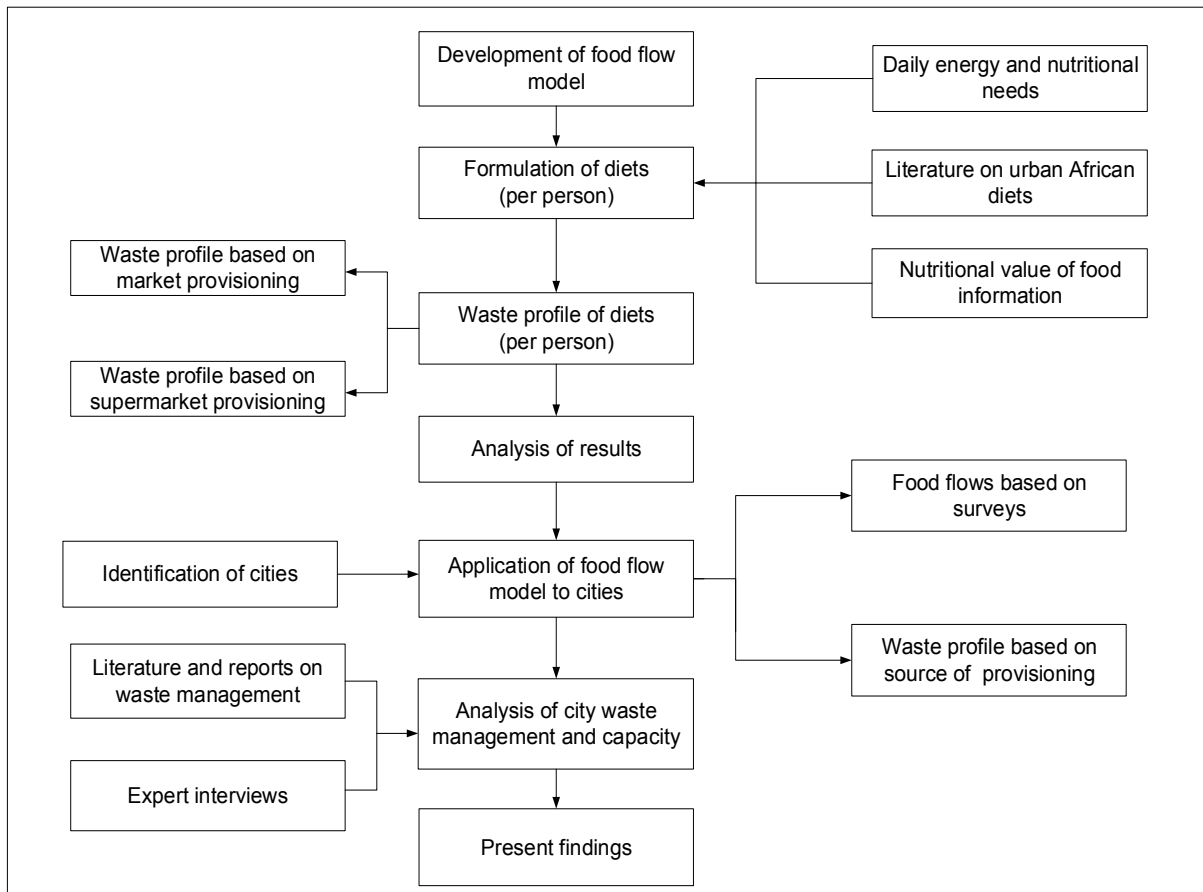


Figure 3-1: Flow diagram of methodology for research

3.4 Material Flow Analysis Model

A material flow analysis is the common method used to track flows of materials through a system. In order to analyze the effect of the changing consumption pattern in African cities on the waste management sector, it is necessary to quantify the flows of the goods consumed.

The method used in this research draws from the principles of the material flow analysis discussed in chapter 2. In this research the material flow scheme is used on a smaller level than the economy or urban level, i.e. at household scale and is draws insights from the methodology used by Codoban & Kennedy, 2008 in Toronto neighborhoods. This study uses a material flow analysis on a neighborhood, “the system” and looks at three metabolic processes i.e. operation of buildings, consumption and preparation of food and beverages and transportation. In the food system, the study looks at food flows from the grocery store through the household to final disposal. A similar approach is used in this study.

The information required for the material flow analysis is derived from a wide variety of sources. The information on food flows is obtained mainly from FAO statistics data, income and expenditure surveys, household budget surveys and food and nutrition databases. It should be noted that quality of the information used in the material balances is dependent on the underlying data and the assumptions made by the author. The procedure followed in generating the metabolic flow models for this research are described in the following section.

3.5 Urban Food Provisioning and Waste Generation Model

It is important to establish the system boundary when carrying out a material balance and in this study the urban food system forms the boundary for this research.

Figure 3-2 below shows the system boundary for the flow of food from the farm gate to disposal by the consumer and retailer in an urban setting.

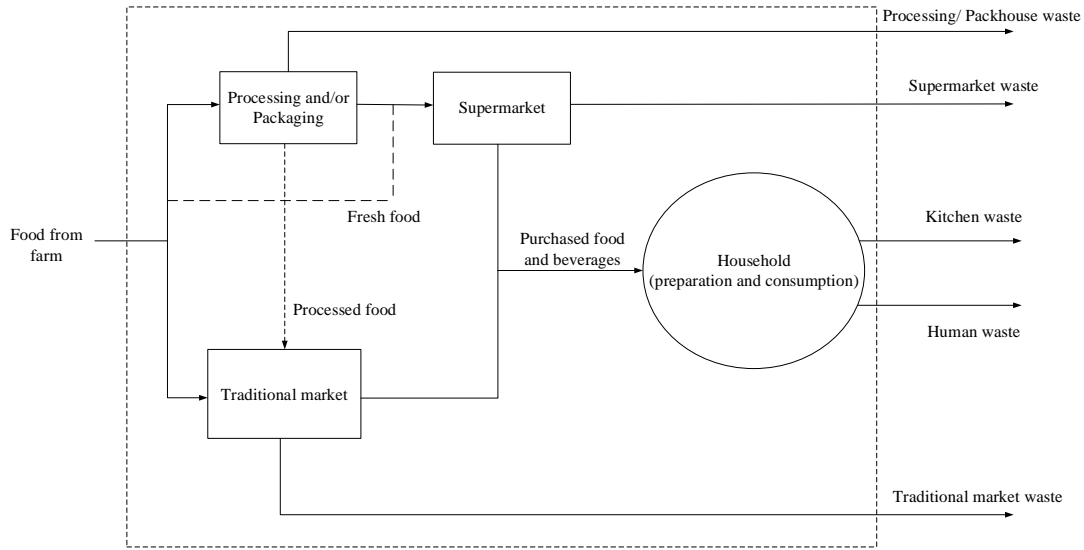


Figure 3-2: Showing system boundary

The following assumptions are made for this mass balance:

- In order to illustrate the difference in waste profile based on market or supermarket provisioning, consumption from the supermarket has been modelled to consist of only the processed food component and consumption from the market consists of only the fresh produce component. This assumption is made to simplify the modelling as well as illustrate the change in waste profile even though the reality would show a consumption of a mix of both fresh and processed produce from either source of provisioning.
- Initially, the entire edible portion of food purchased is consumed and none thrown away. This assumption is acknowledged to be unrealistic, but serves to illustrate the effect of processing and packaging.
- The total of food consumed equals food used by the human body and excreted
- Human waste is not considered in this study and thus is ignored, as the interest is on changes in solid waste profiles, with the standard definition of urban solid waste excluding human excreta. This distinction may not be useful in slum situations.
- For processed food (supermarket) provisioning, all inedible components of the produce that do not appear in household waste (e.g. peels, tops, roots) are removed during the processing or packaging step in the supermarket supply chain.

Figure 3-3 below shows the methodology used to generate the food flow model for the market and supermarket profile.

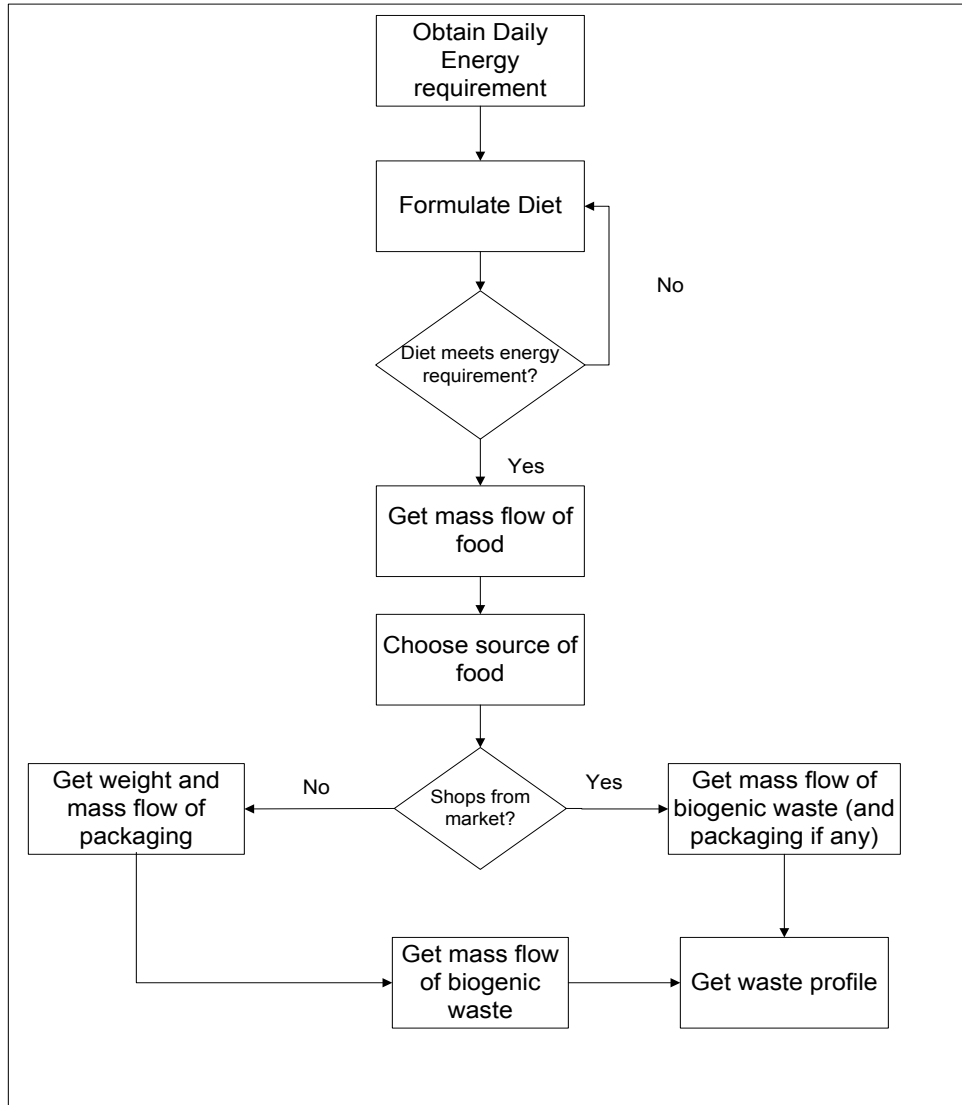


Figure 3-3: Showing methodology steps for generating food waste profile

A model is generated based on a theoretical consumer. In order to obtain the food flow and subsequent waste profile for the theoretical consumer, a theoretical diet of what the consumer eats on a daily basis is generated as described below. The diet of the theoretical consumer is subjective but serves to illustrate how what people eat in the African cities studied relates to the resulting solid waste generated.

3.5.1 Daily Energy Requirement

Food is a source of energy for living organisms. Living organisms take in food and break it down for growth and energy and in the process release waste. The human body is capable of utilizing the chemical energy that is stored in food through a process called metabolism.

The recommended daily intakes of energy and nutrients have been documented in literature and are used in this investigation to specify the required quantities of food for the specific diets. This information is also used for other purposes e.g. by policy planners when tackling food insecurity and also in the assessment of health. The energy obtained from food is often measured in kilocalories. A kilocalorie is defined as the heat required to raise the temperature of water from 15°C to 16°C. The energy content of different food values is shown below:

Table 3-1: Showing energy content of different food values (World Health Organization, 1974)

Food value	Energy (kcal/g)	Energy (kJ/g)
Carbohydrates	4	16.7
Fat	9	37.7
Protein	4	16.7
Alcohol	7	29.3

Different people require different amounts of energy based on occupation, age and size. In order to simplify the task of calculating the daily energy requirement, it is convenient to calculate the different amounts of energy in relation to a reference man and woman 25 years of age and weighing 65 kg and 55 kg respectively. In getting the recommended requirements, the following assumptions were made (World Health Organization, 1974):

- One spends 8 hours a day doing each of work, sleep and non-occupational activities and
- the reference man is a moderately active man

The energy required for various activities during the day was then obtained and is shown (World Health Organization, 1974).

Table 3-2: Showing power requirement for different daily activities (World Health Organization, 1974)

Activity	Power requirement
Work	175 kcal/h
Non-occupational activities	87.5-187.5 kcal/h
Rest	60 kcal/h

From this information the amount of energy required by the theoretical consumer will be calculated. In this research the consumer has been taken to be a moderately active male of about 25 years.

The total amount of energy required was calculated as follows.

$$\mathbf{Energy = Power\ requirement * Time\ taken} \quad \mathbf{(1)}$$

Once the recommended daily energy requirement is calculated, the next step is to obtain the energy values of the foods that are consumed by the reference man. This will be obtained from various sources which include:

- World Health Organization (WHO) nutritional information
- Food Consumption surveys
- USDA national nutrient database
- Worldwide web and other nutritional information sites

In this study, the diets formulated for the food consumption model are subjective to the author and are made up in order to illustrate the effect of food consumption choice on waste.

3.5.2 Generation of Diets

3.5.2.1 Urban Diets and Sources of Food Consumption Information

As discussed earlier, urbanization is on the rise in African cities due to the increase in rural-urban migration. The increased economic growth that has accompanied the growth in the urban population leads to a change in demand for food, in terms of both quantity and variety. In this study it is aimed to derive waste quantities from the quantity and composition of the food purchased. Different factors affect the choice of food consumed and how these factors affect food eaten has been documented extensively in literature. In order to obtain information on food

consumption profiles, surveys are usually performed. These could be done at different levels i.e. national, city or household level. However, for the purposes of this study, models illustrating food consumption profile are generated using information from literature and previously done surveys. Food balance sheets, income and expenditure surveys and household budget surveys are the sources of information used in obtaining information on the food consumed in the cities studied. A limitation to food balance sheets is that they are prone to several errors (Serra-Majem, et al., 2003). Household budget surveys thus provide a more accurate depiction than food balance sheets, but are more expensive to conduct. Household budget surveys are thus rarely done and this information is difficult to obtain especially in developing countries (Serra-Majem, et al., 2003).

Three diets were used to develop the metabolic flow models. These diets include;

- Student diet
- Working class diet
- Vegetarian diet

The student diet was constructed first, based on personal experience and this helped to generate a reasonably varied inventory which could then be quantitatively scaled to meet the nutritional energy target. This provided a basis from which to construct a likely profile of a diet of a working class family, a cornerstone of the population in an African city. Thirdly the vegetarian option was purposively investigated as a possibly strong different diet in terms of the balance of organic waste and packaging. These diets were used to develop the model used to illustrate the effect a change in choice of provisioning from the market to supermarket would have on the waste profiles of consumers falling under these diet categories. The diets were chosen in order to test the functionality of the model against three different classes of individuals consuming different kinds of foods.

The types of foods eaten in the different cities are picked out of the sources of food consumption information mentioned above. The calorie contribution of each food group is obtained based on the information from FAO food balance sheets. The amount of food eaten is generated by measuring against the daily recommended energy requirement.

3.5.2.2 Food Based Dietary Guidelines

A diet of the theoretical consumer is then formulated and checked against daily energy requirement.

The diet of the theoretical consumer is formulated based on the most commonly consumed foods in African cities. Sources of food consumption data used range from food balance sheets to detailed food consumption surveys of individuals and duplicate-diet studies. From this information, the daily diet can be formulated and checked against the daily energy requirement for a healthy person.

If this diet does not meet the daily energy requirement, it is modified and the total energy derived from the diet recalculated. This is done until the diet generated meets the daily nutritional energy requirement calculated above. In the case of African cities, the amount of food consumed is balanced against the average energy amount available in the African cities. This is less than the daily nutritional energy requirement recommended by the WHO. The energy values used in African cities are shown in Table 3-4 of section 3.7. The food included in the diet is obtained from food consumption surveys done in urban Africa. This is done so that the diet is a fair representation of the daily food consumed in African cities. The total energy available in a diet is calculated from information in the United States of America Department of Agriculture (USDA) national nutrient database.

3.5.3 Mass Flow of Food

The next step is to obtain the masses of the food that makes up the diet. This is done by generating a simple mass balance spreadsheet of the food consumed on a daily basis.

The mass of the food eaten is calculated based on different portions that are consumed. These portions are shown in Table 3-3 below.

Table 3-3: Showing portion sizes used for foods consumed (Lukmanji, et al., 2008)

Portions	Description
Slice	Mainly bread (≈ 28 g)
Cup	250 ml cup
Plate	standard size plate (≈ 200 ml)
Unit	For singular items e.g. potato
Measure	Amount commonly consumed
NLEA serving	Amount commonly consumed
Tablespoon	Standard tablespoon (= 15 ml)
Teaspoon	Standard teaspoon (= 5 ml)

The amount of food served or eaten is calculated relative to the portions above i.e. as a multiple of the portions in the table. The mass of food in each portion is obtained from food consumption databases and surveys. The mass of food eaten is then obtained from the formula;

$$M = f \times \text{mass of food in portion} \quad (2)$$

Where;

- M is the mass of food consumed
- f is any real number

The amount of energy in each serving of food is obtained from the equation below;

$$E = M \times e/100 \quad (3)$$

Where;

- E is the amount of energy derived from a certain serving of food
- e is the energy content (kCal/100g) of the food consumed.

The energy content of various foods is obtained mainly from the USDA data base and to a much lesser extent, food composition tables. The number f is adjusted to ensure that the amount of food eaten equates to the recommended daily energy requirement.

Once the mass of the food consumed is obtained, the waste profile associated with the food consumed is obtained. This is done based on whether this food is purchased from the market or the supermarket.

3.5.4 Traditional Market vs. Supermarket Consumption

From the diets formulated above, the food and ancillary material flows are then calculated based on whether the food is bought out of a supermarket or traditional market. It is expected that the flow profiles of the traditional market and supermarket consumers will differ based on the foods bought and the state in which they are purchased. The difference in level of processing is illustrated by one of the pictures from the collection of Menzel & D'Aluisio (2005) in “Hungry Planet: What the World eats” in Figure 3-4 below.



Figure 3-4: Showing food items for market and supermarket consumers (Menzel & D'Aluisio, 2008)

3.5.5 Waste Profiles

Waste varies from place to place and there are several factors that affect the quantity and type of waste generated. One of the objectives of this study is to analyze the effect of change in food provisioning on the waste generated. The waste generated that is associated with purchase from the traditional market and the supermarket is thus determined. This is attained by obtaining the weight of packaging material, mainly in the case of supermarket provisioning and the weight of the inedible portion of the food, mainly in the case of purchase from the traditional market.

The waste associated with the choice of provisioning is obtained by calculating the amount of supply-chain waste (inedibles) and post-consumer wastes (inedibles and packaging). In

estimating the amount of waste generated, it is important to note the following assumptions made:

- Only the inedible part of food purchased, plus packaging, are considered as waste
- Food purchased but thrown away is not calculated in the base case, and evaluated parametrically in other cases;
- The food packaging type and quantity is based on supermarkets in South Africa;
- The model does not account for re-use of packaging in individual households nor for waste reduction practices such as composting.

Information on the inedible part of food purchased was obtained from various sources which include the USDA national nutrient database (USDA, 2013). The weight of different food packaging as currently used in Cape Town was determined on a laboratory grade weighing scale and this information is available in Table 10-6 (Appendix 3). The waste flows of packaging are tabulated as a waste ratio calculated by the formula;

$$R = \frac{P}{M_1} \quad (4)$$

Where;

- R is the packaging weight to net food weight purchased ratio
- P is the mass of the packaging from supermarket
- M_1 is the standard net weight of food sold in supermarkets

This information is then tabulated for further analysis. The type of material from which the packaging is made is also recorded, in the categories paper & cardboard, tin, glass, plastic.

The mass of the inedible portion of food purchased is calculated using the inedible weight fraction of the food. This is illustrated in the formula below;

$$Y = \frac{M}{1 - U} - M \quad (5)$$

Where:

- Y is the mass of the inedible portion

- M is the mass of the food consumed (edible portion) in g calculated from the daily energy requirement
- U is the weight fraction of the inedible portion

The mass of the food consumed is obtained from the mass balance and the inedible weight fraction is obtained from food consumption and nutritional data bases.

The amount of packaging waste is calculated from the packaging ratio and the amount of food that was purchased based on how much was consumed. This is calculated from the equation below;

$$P_1 = R \times M_2 \quad (6)$$

The mass of food that was purchased based on how much was consumed, M_2 is calculated from;

$$M_2 = \frac{M}{1 - U} \quad (7)$$

In the model above, no food wastage is accounted for as it has been assumed that all the edible portion of food purchased is consumed by the human body.

In the next section, the amount of waste generated based on different percentages of food wasted is calculated. This is done in order to find the effect of food wastage on the waste profile. This is calculated according to the equation below:

$$Y_1 = (w \times \sum M) + Y(1 + w) \quad (8)$$

$$Y_2 = \sum P_1 \times (1 + w) \quad (9)$$

Where;

- Y_1 is the total mass of organic waste generated with wastage included
- Y_2 is the total mass of packaging waste generated with wastage included
- w is the fraction of extra food bought. It is assumed that this extra food bought is equal to the amount that is wasted

The above methodology is used to derive the waste profile associated with the three different diets chosen for urban consumers. The model was developed on an Excel spreadsheet.

3.5.6 Analysis of Results

The waste profiles generated based on consumption in the market vs supermarket are then analyzed and the effect of the choice of provisioning on the quantity and composition of post-consumer waste for the three different consumer diets is presented.

3.6 Identification of Cities for Study

The cities investigated in this study had to be such that the research questions posed could be answered. This section discusses the selection of cities for the study. This study relies on information on consumption, waste and waste management and this is difficult to obtain in developing countries. However, there have been numerous studies on food security, and also some studies on waste management, for several cities in Africa. The author base of such studies would serve to identify someone within the city willing to aid in the location and collection of the necessary data.

The cities investigated in this study were chosen based on those cities which are to be investigated in greater detail in a large urban food poverty study commencing in 2015, in which the supervisor of this Masters research will play a significant role. The cities are Kisumu (Kenya), Kitwe (Zambia) and Harare (Zimbabwe). This study thus develops its case studies for cities in sub Saharan Africa that are undergoing transition. Transition cities in this study are cities that are experiencing fast rates of urban and economic growth resulting in an increased demand for consumer goods and a change in consumer lifestyles.

From the above discussion, the cities investigated in this study display the following characteristics:

- Cities with high rates of urbanization
- Cities in economic transition

Multiple data collection methods are to be used when conducting the research. This also strengthens the reliability of the evidence gathered as well as the theory behind this research. The collection of data was done through literature review and interviews.

3.7 Application of Food-Waste Model to Cities

The food-waste model generated in section 3.5 above is then applied to cities chosen for this study. The classification used when applying this model to cities is based on the income groups i.e. low, middle and high. This is done for ease of calculations and analysis of data. Information of food consumed in these cities is obtained from the Food and Agricultural Organization food balance sheets and other secondary sources. The total daily energy availability of a person in these cities is calculated based on previous calorie intakes obtained in the FAOSTAT database. These values are shown in Table 3-4 and are taken from the year 2011.

Table 3-4: Showing average daily calorie availability in 3 cities in kCal/day (FAO, 2011)

City	Calorie availability
Kisumu	2189
Kitwe	1937
Harare	2210

Table 3-5: Showing daily per capita Calorie intake for different income strata (FAO, 2011)

Income Strata	Calorie intake (kCal/capita/day)
1	1800
2	1936
3	2253

Table 3-5 above shows the daily per capita consumption values for different income strata. Using the relationship of calorie intake vs. income level shown in Table 3-5 above, the daily calorie intake for low, medium and high income consumers in the three different cities was obtained. This is shown in section 5.3.

3.8 Waste Management

The next phase of the methodology is to analyze the waste management system in the African cities. This is done by:

- Gathering information from secondary sources and
- Interviews with experts in the field of waste management.

3.8.1 Secondary Information

Information on waste management in the cities was collected from various secondary sources. This included published literature as well as municipal reports on waste management done in the respective cities.

3.8.2 Expert Interviews

Semi-structured interviews were carried out with waste management practitioners in each city in both the public and private sector.

Sample questions that were asked include:

- Who is in charge of providing waste management services in the city?
- How much waste is collected and how is it disposed of?
- How often is a waste characterization survey done?
- Is there a transition in choice of consumption provisioning?
- Are they picking up on this transition in the waste profile?
- Is the waste management system able to adapt to changes in consumption and hence waste profiles?
- What do logistic centers and retail stores do with their waste?

Key experts that were interviewed include:

- Waste management practitioners
- University researchers in waste management

3.9 Limitations of Methodology

The methodology used in this study has limitations. The results generated by this methodology for the different cities should be seen as illustrative and not take as a quantitative description of what is on the ground. Firstly the data used in the food flow models of the respective cities is drawn from various sources of literature. Some of this literature is old and its validity is questionable. The food consumed is obtained from food balance sheets and these are known to have error associated with them.

The packaging used in this study is based on the packaging used in South African supermarkets. This is limiting in the sense that the type of packaging used by supermarkets differs from city to city.

No field surveys are done in this study and thus secondary data is used as the main source of information. Thus the results are limited by the assumptions and errors of prior authors. The study is mainly a desktop study and primary information is obtained via long distance through telephone interviews.

The next chapter presents the food-waste model developed and the results obtained from it. The three case studies are presented in chapter 5.

4 Characterization of Cities

The following chapter describes the characteristics of the cities studied in this research. This chapter follows from the section 3.6 of the methodology and gives a short description of the cities researched. The consumption model developed is then applied to these cities. For each city, the location, population, demographics and economic status are discussed.

4.1 Kisumu

4.1.1 Location, Political Status and Size

Kisumu is the third largest city in Kenya. It is a port city located in the western part of Kenya along the shores of Lake Victoria and is a regional capital and an administrative, commercial and industrial center for the Lake Victoria basin. The city covers an area of 417 km², of which 297 km² is dry land and approximately 120 km² under water. Kisumu was made a municipality in 1960 and was elevated to city status in 2001.

4.1.2 Population and Demographics

Kisumu currently has an urban population of 383,444 (NCPD, 2013). The city is experiencing significant urbanization with a reported annual urban population growth of 2.8% and a density of 828 people per square km (National Environment Management Authority, 2010). The urban population growth is higher than the national average of 1.7% (United Nations Department of Economic and Social Affairs, 2014). The population of Kisumu is young with 70% of the population under the age of 30 years (Desille, et al., 2013). The Municipal Council is failing to meet the increasing demand for urban infrastructure and services and 60% of the population in Kisumu live in slums located on the urban fringes of the city (UN-Habitat, 2006). These areas are densely populated and lack basic services like water, electricity and sanitation. This is a direct result of the high rate of urbanization occurring in Kenya without any of the economic and structural changes required to support it (UN-Habitat, 2008).

4.1.3 Economy

The main economic activities in Kisumu include trade, agriculture, transportation, fishing and some light industry. The region accounts for approximately 25% of Kenya's agricultural output from 4% of its area, although most the agro-processing is performed outside the region (KPMG, 2008). Kisumu is one of Kenya's fastest growing cities and the government is in the process of establishing a special economic zone in the area. Its location along the shore of lake Victoria gives it an advantage in becoming a hub for regional trade in East Africa. Recently the Kisumu airport has been upgraded to international status. Kisumu has a lot of potential given its strategic location in the East African community (Kenya Economic Report, 2013). Although the economy is primarily driven by agriculture, the retail sector has a lot of potential for growth (KPMG, 2008).

In spite of its rich resource base, Kisumu is one of the poorest cities in Kenya and food insecurity is a problem. 52% of the population works in the informal sector and nearly half the population in Kisumu live in absolute poverty, higher than the national average of 29%. The city also experiences high food poverty of 53% (UN-Habitat, 2006).

4.1.3.1 Retail Sector

Domestic trade has been claimed to be crucial for development in Kenya: Wholesale and retail trade form a significant component of domestic trade and contribute about 10 % of GDP. There are four main domestic retail chains in Kenya: Uchumi, Nakumatt, Tusker Mattresses, and the Ukwala Group and two foreign-owned chains, Metro Cash & Carry and Woolworths (Ouma, et al., 2013). These chains are mainly located in Nairobi, however increased growth of other urban areas has encouraged the spread of these stores to other cities like Kisumu. Over the past year, the area has seen unprecedented growth in the number of supermarkets in the area and these supermarkets are targeting informal settlements e.g. new supermarkets like Uchumi, Tumaini and Naivas have opened up in the area (Odhiambo, 2014). The retail sector has been identified as a key area of growth in Kisumu and development of the lake transport would further accelerate growth of this sector (KPMG, 2008), however the lack of credible and consistent data also limits analysis of this sector (Kenya Economic Report, 2013).

4.2 Kitwe

4.2.1 Location, Political Status and Size

The city of Kitwe is located in the center of the Copperbelt province of Zambia and lies 1,295 m above sea level. The city covers an area of 777 km² and is bordered by the Kalulushi, Mufulira, Luanshya, Lufwanyama and Ndola all of which are mining towns, particularly of copper (Kitwe City Council, 2012). Kitwe is also called the commercial hub of the Copperbelt province (Mwitwa & Ng'andwe, 2010).

4.2.2 Population and Demographics

Kitwe is the most populated city in the Copperbelt region and has a population of 522,092 according to the 2010 population preliminary report (Central Statistics Office, 2010).

Table 4-1: Population trends in Kitwe (Kitwe City Council, 2012)

Census year	Population	Annual Growth Rate (%)
1980	320320	4.4
1990	347024	0.8
2000	388646	1.1
2010	522092	3.3

Table 4-1 above shows the population trends for Kitwe for the last 30 years. From the table it can be seen that there was a drop in the population growth rate in the 1990s and 2000s. This drop could be explained by the fall of the copper mining sector that happened around the same time. Today the city has an annual population growth rate of approximately 3.3%.

The population of Kitwe is young with slightly over 66% of the population below the age of 25 years (UN-Habitat, 2009). The larger part of the population in Kitwe are Christian. The city of Kitwe is a main center for mining and trade activities. The area consists of low, medium and high cost residential areas with the majority of the areas being low cost and working in the informal sector (Hichaambwa, et al., 2009).

4.2.3 Economy

The main economic activity in Zambia is mining. The mining sector contributes about 40% to the country's GDP. However the country has suffered due to its high dependence on mining and fluctuations in the price of copper (UN-Habitat, 2009). Kitwe's primary economic activity is mining. The fall in the price and production of copper has led to the decline of the mining sector with a fall in its contribution to the country's GDP (Limpitlaw, 2011). This is further illustrated in Figure 4-1 below.

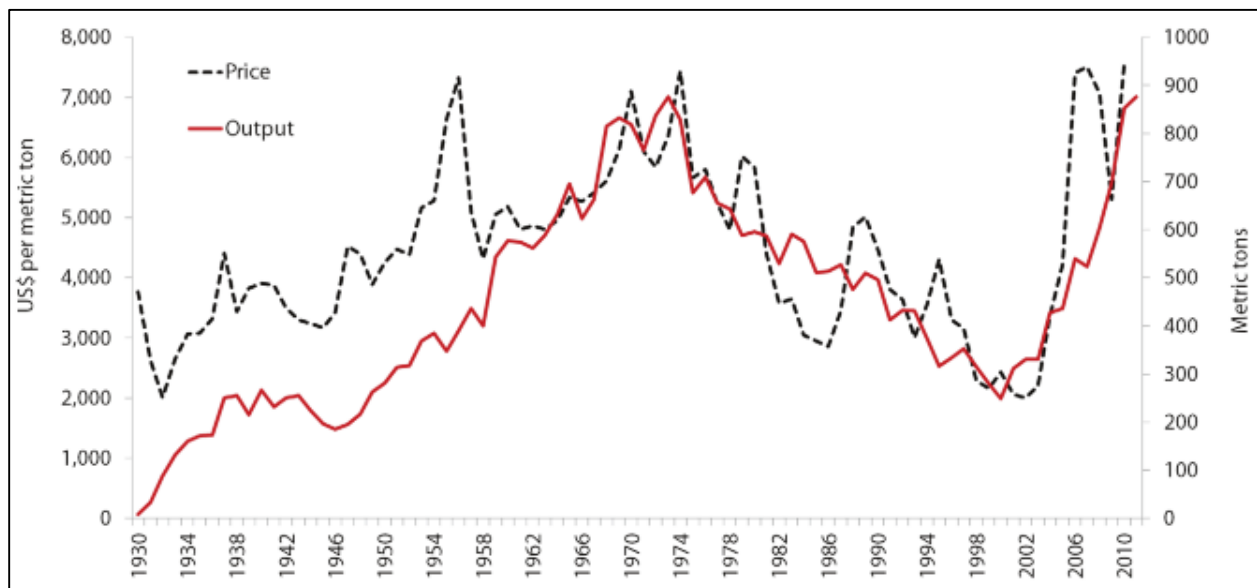


Figure 4-1: Showing trends in world copper prices and Zambian copper output (Simpasa, et al., 2013)

Figure 4-1 shows the fall in the production and prices of copper that affected Zambia from 1975 to 1999. This fall coincided with the nationalization of the copper mines and negatively affected the Zambian economy and led to a reduction in employment levels (Limpitlaw, 2011). After 1999, the copper mines were privatized and production has increased which has led to growth of employment and the economy (Limpitlaw, 2011).

Other economic activities include agriculture and manufacturing but the city mainly depends on copper mining. The trade and services sector is the second largest source of employment after mining. The daily population of Kitwe is up to 700,000 mainly because people from neighboring districts and towns conduct their business here, where the market is. The city population is expected to double in the next decade and there is thus a need to improve the city's infrastructure in order to support the increasing population (UN-Habitat, 2009).

4.2.3.1 Retail sector

There has also been a shift of consumption lifestyles with an increase in shopping in supermarkets. A survey done in 2007/2008 found that there was a change in urban diets and an increase in the significance of supermarkets to urban consumers (Hichaambwa, et al., 2009). Furthermore, it was found that:

- Wheat had overtaken maize as the most popular staple among urban consumers
- Urban diets were more diversified
- Supermarkets had up to 17% market share for staple purchases by urban households

There has been growth in the number of supermarkets in Kitwe and currently there are 3 supermarkets under construction in Kitwe (Daniel Phiri interview). Although the traditional market sector still has the majority market share in the food provisioning industry, the supermarket sector's share is increasing, particularly amongst urban consumers.

4.3 Harare

4.3.1 Location, Political Status and Size

Harare is the capital city of Zimbabwe and it houses the major administrative offices of government. Harare province is located in the high veld and experiences high rainfall. It is the most developed province in Zimbabwe (Parliament Research Department, 2011). The city lies in the tropics and has a four season climate.

4.3.2 Population and Demographics

Harare has a population of approximately 1.8 million people and the population of the city is growing at a fast rate. The population is young with 33% of the population below the age of 15 years and only 2% above 65 years (Parliament Research Department, 2011). The population of the city is growing a rate of 1% per annum (Zimsat, 2012). The growing city population has put strain on the infrastructure of the city which was originally designed for a population of only 300,000 people (Mahachi, 2012). The majority of the people live in urban areas, up to 99% of the population and only 1% living in the rural areas (Parliament Research Department, 2011). The average household size in Harare is 5.6 people and food security is a problem in the city which was worsened by the economic crisis of the late 2000s (Tawodzera, et al., 2012).

4.3.3 Economy

After nearly a decade of economic downturn, Zimbabwe has recently started to experience positive GDP growth (World Bank, 2011). Between 2009 and 2011, Zimbabwe's GDP grew at an average rate of 7.3 percent per annum making it one of the world's fastest-growing countries (Richardson, 2013). Urban agriculture has become a big contributor to the economy of Harare and this has grown in light of the Zimbabwe economic situation (Toriro, 2005). This growth can however be linked to urban poverty. Urban agriculture was mainly done by the low income earners, however with the hyperinflation in Zimbabwe as many as 60% of the households were engaged in urban agriculture by 2008 as they could no longer afford groceries from supermarkets (Tawodzera, et al., 2012). Urban poverty and unemployment has led to the existence of shanty and squatter settlements in the urban areas.

The city has a good transport network and is well connected to the rest of the country with two airports and a good road network (Parliament Research Department, 2011). Harare also houses several industries both primary and secondary which include food and beverage industries, automotive industries and tobacco processing industries. There has also been rapid and uncontrolled growth of the informal sector.

4.3.3.1 Retail Sector

The retail sector is now growing since the turn of the economy in 2009. The retail sector is a well-established sector in Zimbabwe and approximately 78% of people buy their groceries from supermarkets and consumer packaged goods account for 31% of the monthly household budget (Nielsen, 2014). The emerging affluent buyers are attracted to goods such as breakfast cereals, energy drinks and air fresheners and even the low income earners who have low to average consumption of consumer packaged goods desire to try products like packaged juices that are higher up in the value chain (Nielsen, 2014).

5 Food and Food-Waste Material Flow System Model

This chapter presents the results obtained from the food-waste metabolic flow model developed to describe the food and waste flows associated with the urban consumer. In the construction of the food flow model, three different diets were considered, viz. a student, a vegetarian and a working class diet, and the results obtained are shown in section 5.1. The model is applied to consumer diets in each of the three different cities, producing expected waste generation profiles, in section 5.2. The chapter further shows and discusses the results of the application of the food-waste metabolic model to the three cities studied in this research, in section 5.3. Finally, in section 5.4, a comparison of the transition in the three cities studied is presented.

5.1 Modeled Urban Diets

As previously discussed and reported by studies reviewed in chapter 2, it is known that the increase in urbanization and economic growth in African cities has led not only to the increase in the quantity of food demanded, but also an increase in the variety of food purchased. This section aims to illustrate the change in quantity and composition of the food purchased with the transitioning from market to supermarket provisioning. For the purposes of this study, illustrative typical consumers are profiled, using the methods and data sources discussed in chapter 3. The results from the generation of the urban diets are detailed below.

5.1.1 Daily recommended energy requirement

The diets used in this study were derived using the recommended daily energy requirement for a healthy human being i.e. factoring in the energy requirements required for different daily activities. A healthy human being in this context is one whose daily consumption meets the recommended energy requirement, 2980 kcal, as described by the WHO. The total daily energy requirements for various activities for a healthy 25 year old male weighing 65 kg were calculated and are shown in Table 5-1 below. This recommended daily energy requirement value was used for the student, vegetarian and working class diet in order to build the model.

Table 5-1: Total daily energy requirements for 25 year old male weighing 65 kg

Activity	Energy (kcal/day)
Work	1400
Non-occupational activities	1100
Rest	480
Total	2980

5.1.2 Example Diets Generated for Waste Modeling

Three different diets were formulated in order to illustrate the use of the model in describing the effect of source of provisioning on the post-consumer waste profile. These diets included the student, working class and vegetarian diet. As described in Section 3.5.2.1, the student diet is generated based on personal experience in order to generate a working inventory, the working class diet is generated to capture a sample of the population and the vegetarian diet was generated in order to include diversity. The mass flow of food consumed was generated by averaging the food consumed over the course of the week. For example for the student diet, three different daily diets were generated, with two of the diets being consumed twice a week and the third diet being consumed three times in the week. An example of a daily diet generated for the student diet is illustrated in Table 5-2 and Table 5-3 below for the market and supermarket consumer respectively. Tables showing the diets of the worker and the vegetarian are shown in Appendix 2. The diets generated are largely subjective but also draw on information from various sources of literature (Kennedy & Reardon, 1994; FAO, 2002; Hichaambwa, et al., 2009).

Table 5-2: Student diet for market consumer

Breakfast	Mass (kg/day)	Energy (kcal/day)
Brown bread, whole wheat	110	280
Tea, black, brewed with tap water	240	2.4
Fresh milk, whole milk	240	150
Sugars, granulated white	13	49
Lunch		
Potatoes, boiled, cooked without skin, flesh, salt	840	620
Rice, white, long grain, regular, cooked	160	210
Beef, chuck for stew	170	320
Tomatoes	250	44
Onions	55	22
Carrots	120	50
Salt	6	0
Oranges, raw, all commercial varieties	260	120
Sugars, granulated white	8.4	33
Supper		
Stiff-maize meal	450	560
Beans (lima)	320	130
Tomatoes	250	44
Onions	110	44
Carrots	120	50
Oranges, raw, all commercial varieties	390	180
Sugars, granulated white	13	49
Total		3000

Table 5-3: Student diet for supermarket consumer

Breakfast	Mass (kg/day)	Energy (kCal/day)
Brown bread, whole wheat	110	280
Fresh milk, whole milk	240	150
Sugars, granulated white	13	49
Tea, black, brewed with tap water	240	2.4
Lunch		
Potatoes, boiled,cooked without skin,flesh,salt	1000	760
Beef, short loin, t-bone steak, separable lean and fat, trimmed to 1/8" fat, all grades, cooked, grilled	85	250
Orange juice drink (in carton)	260	140
Salt	1.5	0
Rice,white,long grain,regular,cooked	160	210
Supper		
Stiff-maize meal	450	560
Beans (lima)	160	67
Tomato products, canned, sauce, with onions, green peppers, and celery	410	170
Vegetables, mixed, frozen, cooked, boiled, drained, with salt	360	220
Orange juice drink (in carton)	260	140
Salt	3	0
Total		3000

The tables above show an example of a student diet generated for both a market and supermarket consumer. The amounts consumed are calculated based on the daily energy requirements as detailed in Table 5-1 and the total energy equivalent of the diets outlined above is 3000 kCal/day. The arrangement of the diet is however subjective and is used to illustrate the differences in the food purchased i.e. level of processing. The food purchased from the supermarket is processed and also packaged differently. This can be seen in Table 5-2 where the tomatoes are canned and

the vegetables are bought mixed as opposed to in the market, Table 5-1, where the vegetables are bought fresh and unprocessed. The level of processing is higher in the foods consumed from the supermarket.

5.2 Food Waste Profile

From the consumption profiles created, the waste profile associated with consumption from either a market or supermarket was generated for each of the three different diets and is detailed below, first for the idealized no-wastage situation and then showing also the effect of food wastage.

5.2.1 Idealized ‘no-wastage’ Model

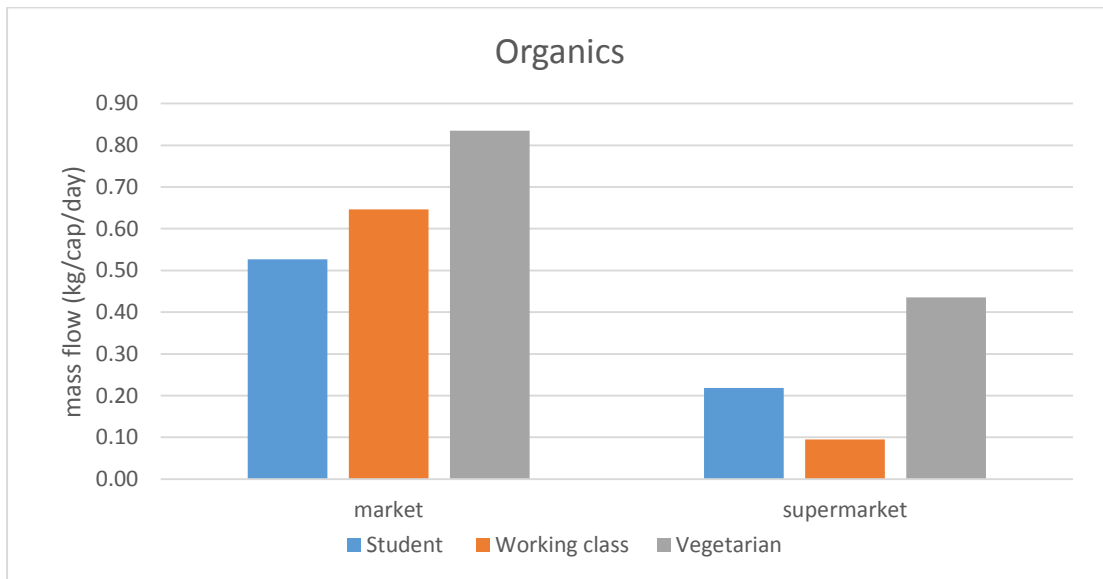


Figure 5-1: Post-consumer organic waste for student, vegetarian and working class diets for market and supermarket consumer

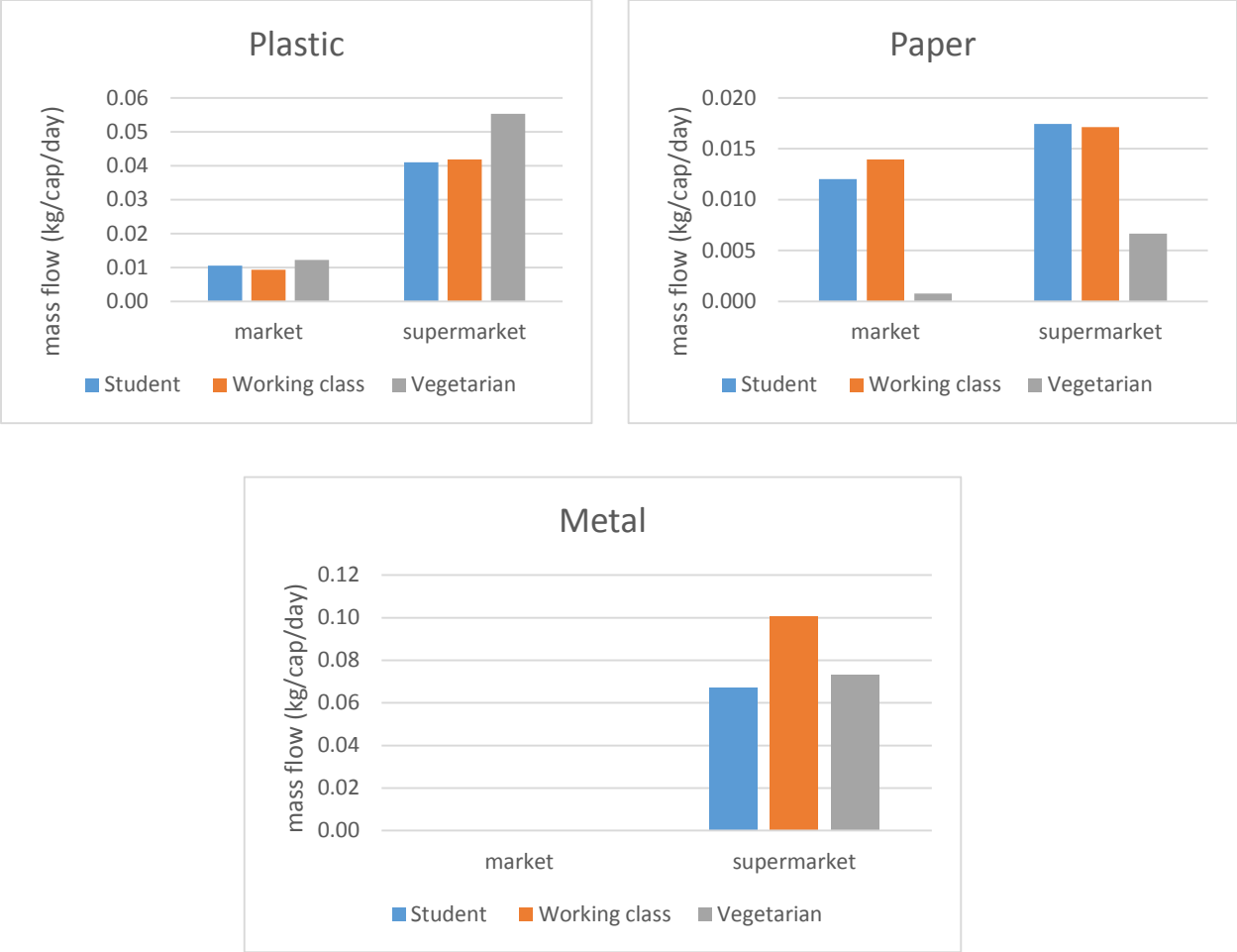


Figure 5-2: Different components of post-consumer inorganic waste generated for three different diets for market and supermarket consumer

The effect of consumption profile and provisioning choice on the waste profile is shown in Figure 5-1 and Figure 5-2 above. The graphs show the components of post-consumer waste for three different diets; student, working class and vegetarian diets. The graphs compare the difference in quantities of waste generated for each of the components of post-consumer waste. In all three diets the organic fraction forms the largest portion of the post-consumer food waste as can be seen in Figure 5-1. However, the organic waste of the supermarket consumer is less than that of the market consumer for all three diets and this is further illustrated in Table 5-4 below. It is important to note that in this study, food consumed from the market is equated to fresh produce and not processed, even though in reality both retail types (market and supermarket) usually offer both processed and unprocessed foods – though to very different

extents. Thus the only forms of packaging considered for the market produce are plastic and paper.

Table 5-4: Post-consumer organic waste generated by market and supermarket consumers for the three diets

Diet	Market (kg/day)	Supermarket (kg/day)	% decrease
Student	0.52	0.23	55
Working class	0.65	0.09	86
Vegetarian	0.83	0.44	47

Table 5-4 above shows the amounts of organic waste generated by the market and supermarket consumer for different diets. In all three diets there is a decrease in waste generated and this is attributed to a shift in the post-consumer waste to the food processing step in the supply chain. The working class diet has the largest shift in organic content to the supply chain and the smallest shift is by the vegetarian diet. With a change in consumption from the market to the supermarket there is a shift of roughly half to more than three-quarters of the organic waste from the post-consumer side to the supply side.

The organic waste generated is highest with the vegetarian diet for both the market and supermarket consumer. This can be explained by the fact that the vegetarian diet consists of a larger amount of fresh fruit and vegetables and the largest portion of inedible organic waste is associated with these items.

Table 5-5 shows the amount of inorganic waste material generated by market and supermarket consumers for the different diets. The amount of inorganic waste generated is higher for the supermarket consumer compared to the market consumer. This difference in the waste profiles is attributed to the difference in the level of processing and packaging of the food in the two different outlets. In the market, the food is not processed or packaged and the majority of it is purchased with the inedible portion while in the super market the majority of the food has been processed and most of the inedible organic portion has been removed and makes up part of the supply chain waste. The inorganic fraction of the waste is higher for the supermarket consumer due to the added packaging used for the food sold in the supermarkets.

Table 5-5: Amount of inorganic waste generated by market and supermarket consumer for the three diets

Diet	Market (kg/day)	Supermarket (kg/day)	% increase
Student	0.02	0.13	457
Working class	0.02	0.16	586
Vegetarian	0.01	0.14	941

In all three diets there is an increase in the inorganic waste generated and this attributed to an increase in packaging material used by the supermarket sector. The vegetarian diet has the largest increase in the inorganic waste while the student diet has the smallest increase. From the table it can be seen there is a four- to nine-fold increase in the inorganic waste generated by a supermarket consumer.

5.2.2 Accounting for Wastage

Initially the comparison between the market and supermarket consumer does not allow for food wastage at the consumer level and assumes that all the edible portion of food bought is consumed by the human body. The model is thus initially made under the assumption that there is zero food wastage at the consumer level. When food wastage at the consumer level is included, there is an increase in the organic and inorganic waste quantity of the supermarket consumer. This analysis is done for the supermarket consumer as it is assumed in this research that majority of food wastage occurs in the homes of supermarket consumers. There is an increase in the overall waste generated when wastage is included as shown in Figure 5-3 below.

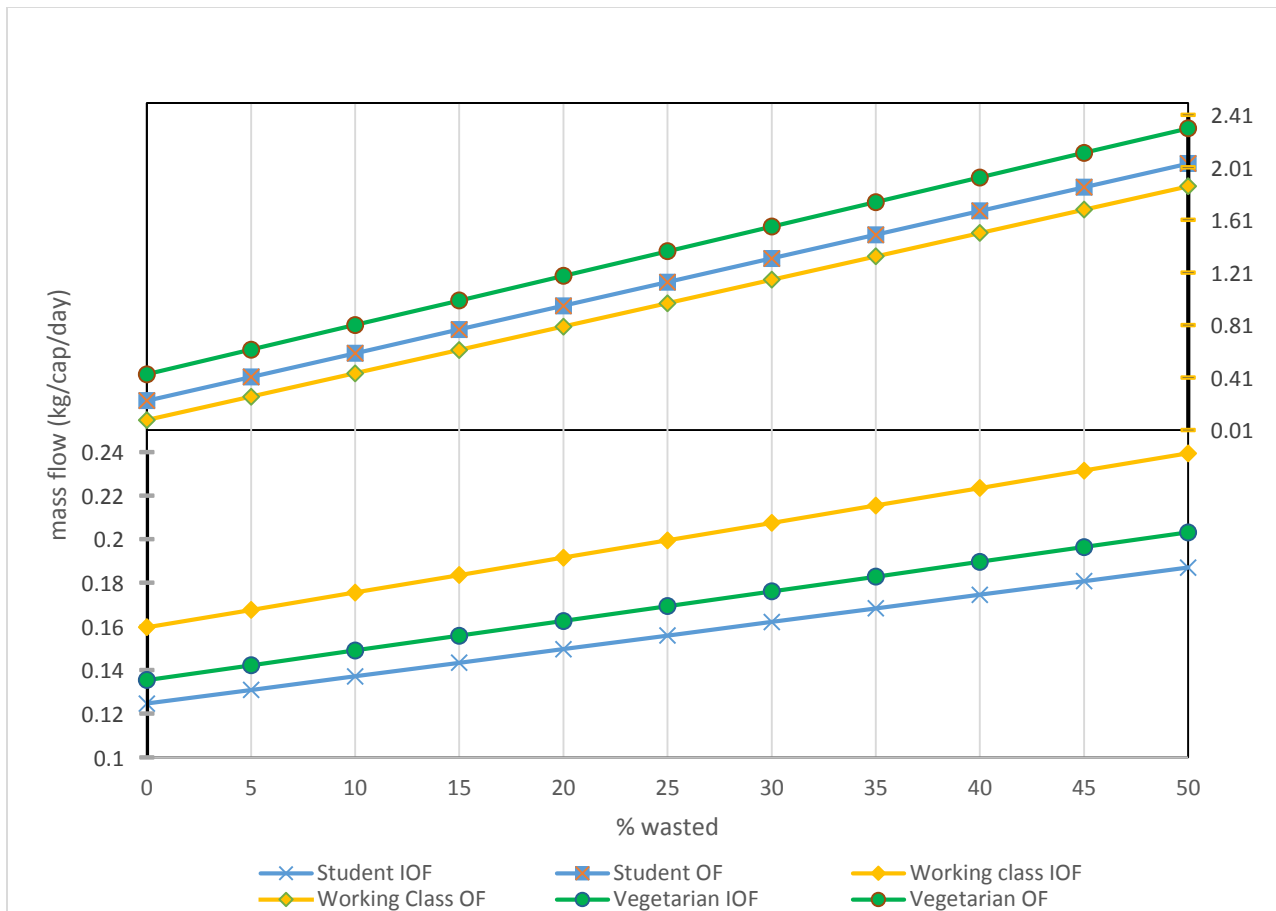


Figure 5-3: Change in per daily capita amount of waste generated with change in food wastage at consumer level for the three different consumer diets for supermarket consumer. Top chart showing organic fractions and bottom chart showing inorganic fractions. IOF- Inorganic Fraction; OF- Organic fraction

Figure 5-3 above shows the change in the post-consumer food waste generated with changes in the levels of food wastage at the consumer level. The top section of the graph shows the change in organic content while the bottom section shows change in the inorganic content of the post-consumer waste for all three diets. From the graph above it can be seen that there is an increase in the amount of waste generated for all components of household waste with increase in food wastage. At 0% wastage, the amount of organic waste generated by the supermarket consumer is less than that of the market consumer for all three diets. At wastage levels beyond 8%, 16% and 10%, the organic waste generated by the supermarket consumer is equal to that generated by the market consumer. This shows that the shift in organic waste to the supply chain is offset at these wastage points.

The sections above use the student, vegetarian and middle-class diet to illustrate how the model was generated and how it works. The next section applies this model to three African cities in order to analyze the effect of a shift in provisioning on; 1) the waste profile of consumers in these cities and 2) the waste management system in these cities. For this analysis, the study looks at the low, middle and high income groups. .

5.3 Food-Waste Model Applied to Cities

The results of the application of the food-waste metabolic model developed to the three cities are presented in the sections that follow. The model is applied to all three cities and it is assumed that there is no wastage of food in each case. As in section 5.1.1, the daily recommended energy requirement is obtained for each city and for each income group. The daily calorie consumption is obtained from FAOSTAT data and calculated as explained in section 3.7 of the methodology. The values for 2015 are obtained by extrapolation of the 2011 values in Table 3-4 in section 3.7 of the methodology. The values for the low and high income groups are obtained as explained in section 3.7, through an extrapolation based on a similar trend in Table 3-5.

Table 5-6; Showing per capita daily kilo Calorie consumption for different income groups in the three cities

Income group	Kisumu	Kitwe	Harare
Low	2100	1900	2100
Medium	2300	2100	2300
High	2500	2300	2500

In the application of the food-waste model to the cities studied in this research, the diets used are categorized as low, medium and high income consumers. Initially the model was tested using three different diets i.e. student, vegetarian and working class. Consumers of these three diets are found in these broader categories of income groups and thus it was thought easier to use income classifications. The low, medium and high income categories are used also because most literature displays information using this format and this makes access to and comparison of data simpler. The diets chosen in the three cities, though subjective, give some reflection into the types of foods consumed in these cities. The diets have all been modelled based on information obtained from published literature and the FAOSTAT database. The diets in all these three cities are similar and are characteristic of the ‘African diet’ with large consumption of starchy foods

mainly maize and low consumption of animal protein, fruit and vegetables. For example in all the diets, starch constitutes on average 60% of the diet, however, there is a slight difference in the exact type food consumed e.g. rape being a preferred vegetable in southern Africa and not in Kisumu or plantain being commonly consumed in Kisumu and not as common in Kitwe or Harare. Examples of the formulated diets are shown in Appendix 10.2.

5.3.1 Kisumu

5.3.1.1 Organic Waste

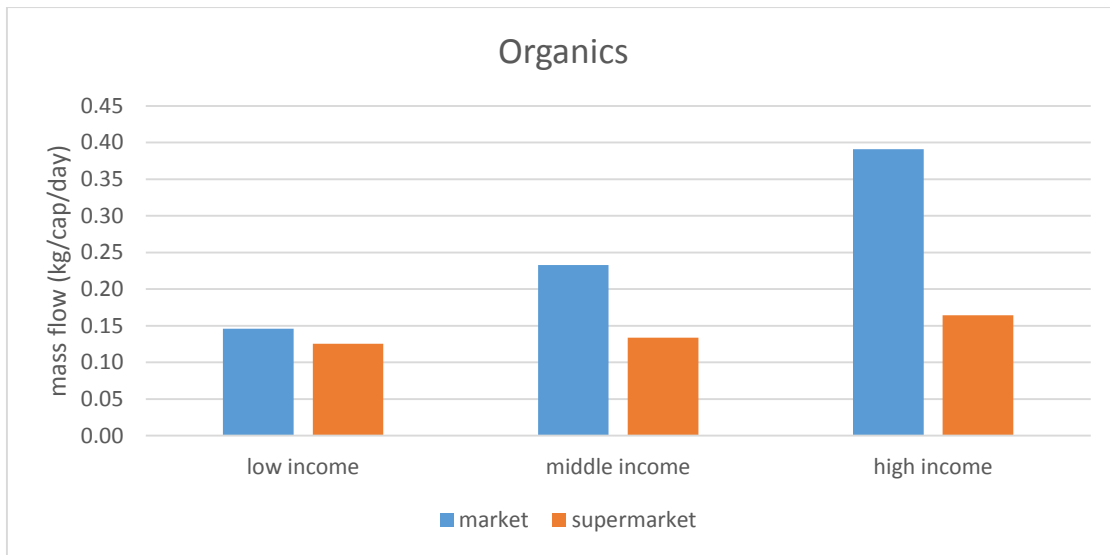


Figure 5-4: Post-consumer organic waste generated by low, middle and high income market and supermarket consumers in Kisumu

The effect of consumption choice on the organic waste profile in Kisumu is shown in Figure 5-4 above. The figure compares the different quantities of organic waste generated by different income groups based on choice of provisioning. The comparison is done between a pure traditional market and a pure supermarket consumer. According to Figure 5-4, there is a decrease in the amount of organic post-consumer waste generated with a shift from consumption in the traditional open market to the supermarket. There is a 14%, 42% and 58% shift in the organic waste from the post-consumer waste to the supply chain waste for the low, medium and high income groups respectively. The figure also shows that the amount of waste generated by the market consumer increases faster with income than that of the supermarket consumer.

5.3.1.2 Inorganic Waste

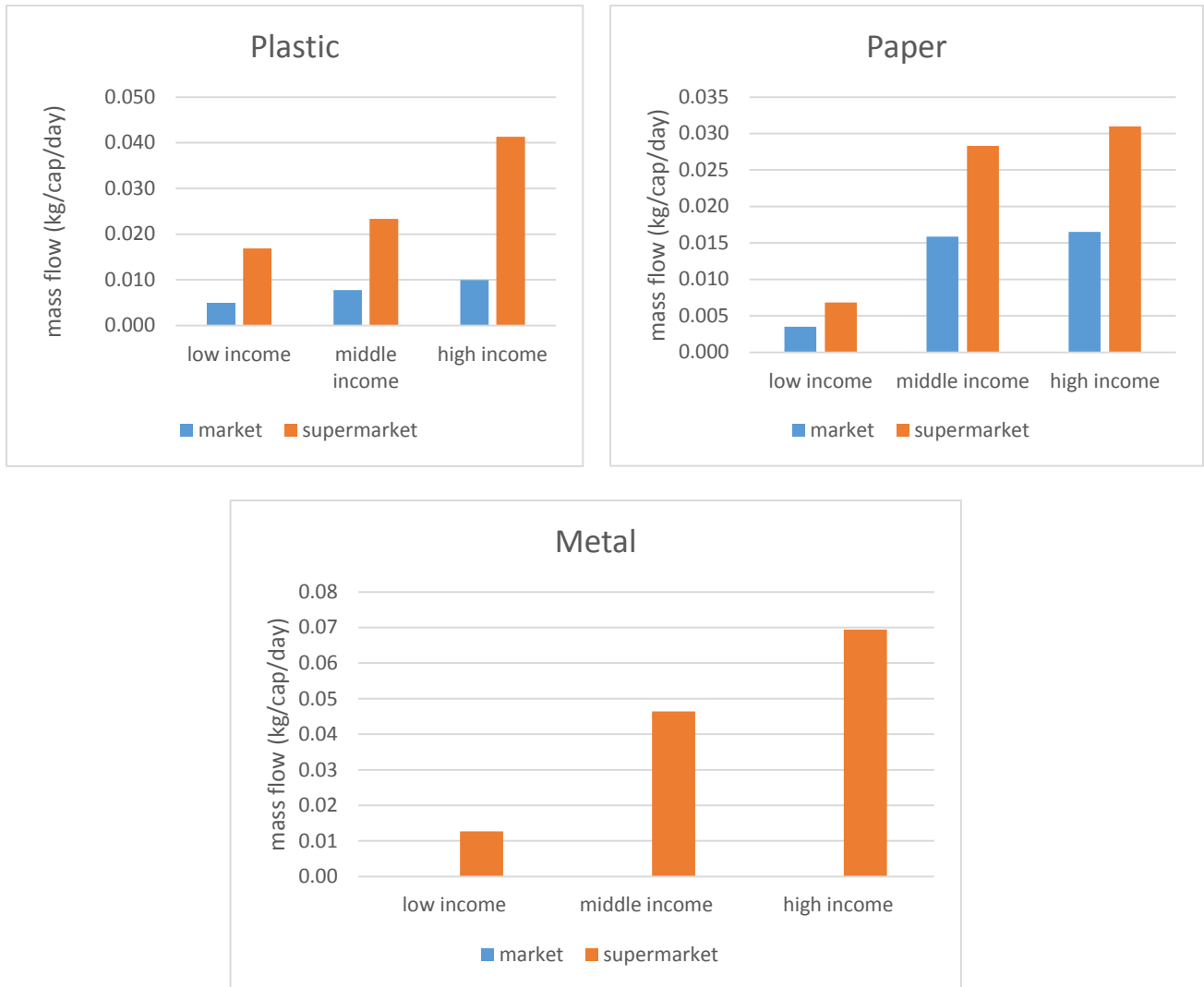


Figure 5-5: Different components of post-consumer inorganic waste generated by low, middle and high income market and supermarket consumers in Kisumu

The amount of inorganic post-consumer waste generated is higher for the supermarket consumer than for the market consumer for all income groups and for all components of inorganic waste. There is a 3-4.5 fold increase in the inorganic waste material generated with a shift in provisioning from the pure traditional market to the supermarket. The increase in Kisumu is smaller than for the other cities because of the smaller increase in the amount of paper waste generated. This is because the Kisumu urban consumer is modelled to consume more milk as represented in the FAOSTAT data and milk is assumed to be packaged in paper cartons for both the market and supermarket consumer.

5.3.1.3 Post-consumer Waste Composition Effects

The effects of a shift in provisioning from the market to the supermarket on the composition of the post-consumer waste is shown in Table 5-7 below. This effect is illustrated for the low, medium and high income groups.

Table 5-7: Showing composition of post-consumer waste for market and supermarket consumer at different income levels

Component	Low Income		Middle Income		High income	
	market	supermarket	market	supermarket	market	supermarket
Organics (%)	94.5	79	90.9	57.7	94	53.7
Plastic (%)	3.2	8.7	2.9	10.1	2.2	13.5
Paper (%)	2.3	4.3	6.2	12.2	3.8	10.1
Glass (%)	0	0	0	0	0	0
Metal (%)	0	6.8	0	20	0	22.7

As can be seen in Table 5-7 above, the post-consumer market waste is at least 90% organic and this trend is seen across all the income groups. The organic fraction of the post-consumer waste for the supermarket consumer ranges from 79% for the low income group to 54% for the high income group. This is because of an increase in the inorganic fraction of the waste from approximately 5-10% for the market consumer to 20-46% for the supermarket consumer. This is associated with the increase in the amount of packaging material that ends up in the waste of the supermarket consumer.

5.3.1.4 Accounting for Wastage

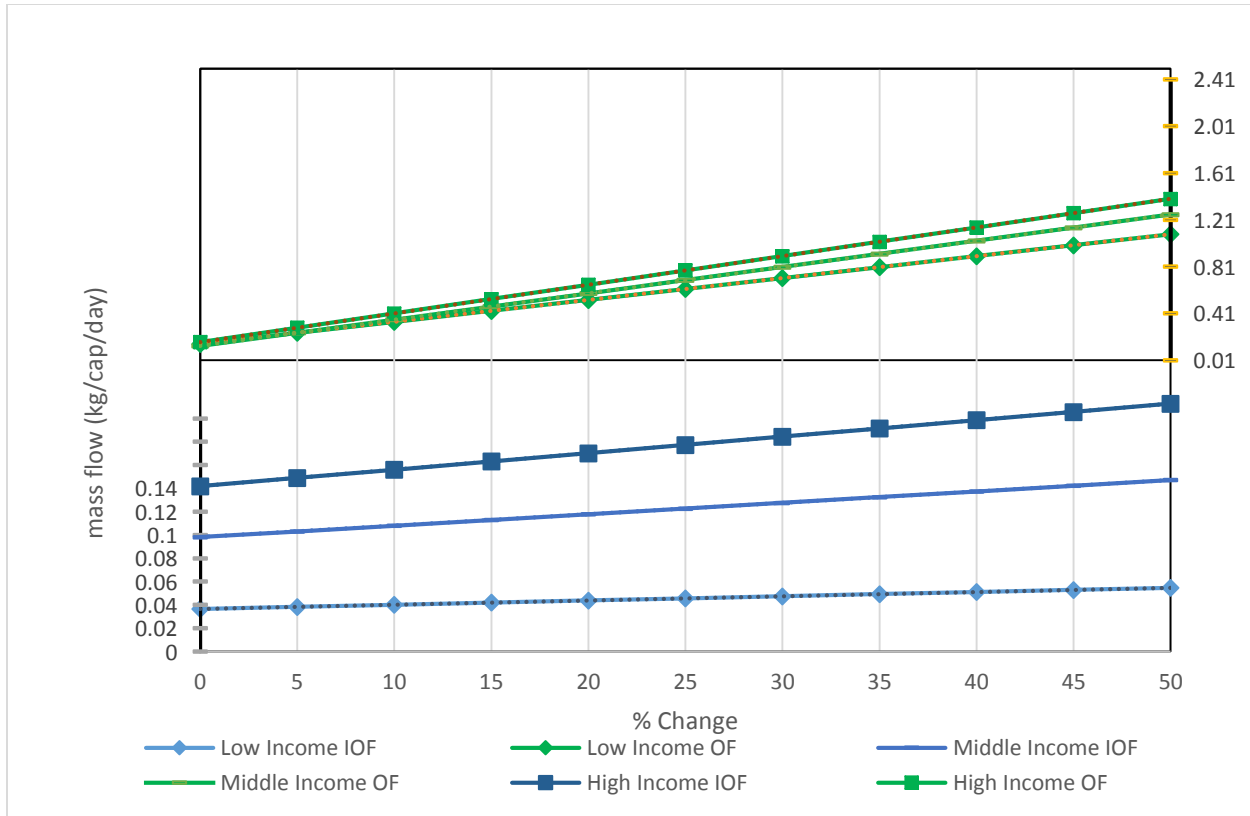


Figure 5-6: Change in daily per capita amount of waste generated with change in food wastage at consumer level for low, middle and high income supermarket consumers in Kisumu. Top chart showing organic fractions and bottom chart showing inorganic fractions. IOF- Inorganic Fraction; OF- Organic fraction

Figure 5-6 shows the change in the post-consumer food waste generated with changes in the levels of food wastage at the consumer level. The top section of the graph shows the change in organic content while the bottom section shows change in the inorganic content of the post-consumer waste for all three diets. From the graph above it can be seen that there is an increase in the amount of waste generated for all components of household waste with increase in food wastage. This is expected as increase in food wastage leads to increase in food waste.

At 0% wastage, the amount of organic waste generated by the supermarket consumer is less than that of the market consumer for all three incomer groups. At wastage levels beyond 1%, 4% and 8%, the organic waste generated by the supermarket consumer is equal to that generated by the market consumer for the low, middle and high income groups. This shows that the shift in organic waste to the supply chain is offset at these wastage points.

5.3.2 Kitwe

5.3.2.1 Organic Waste

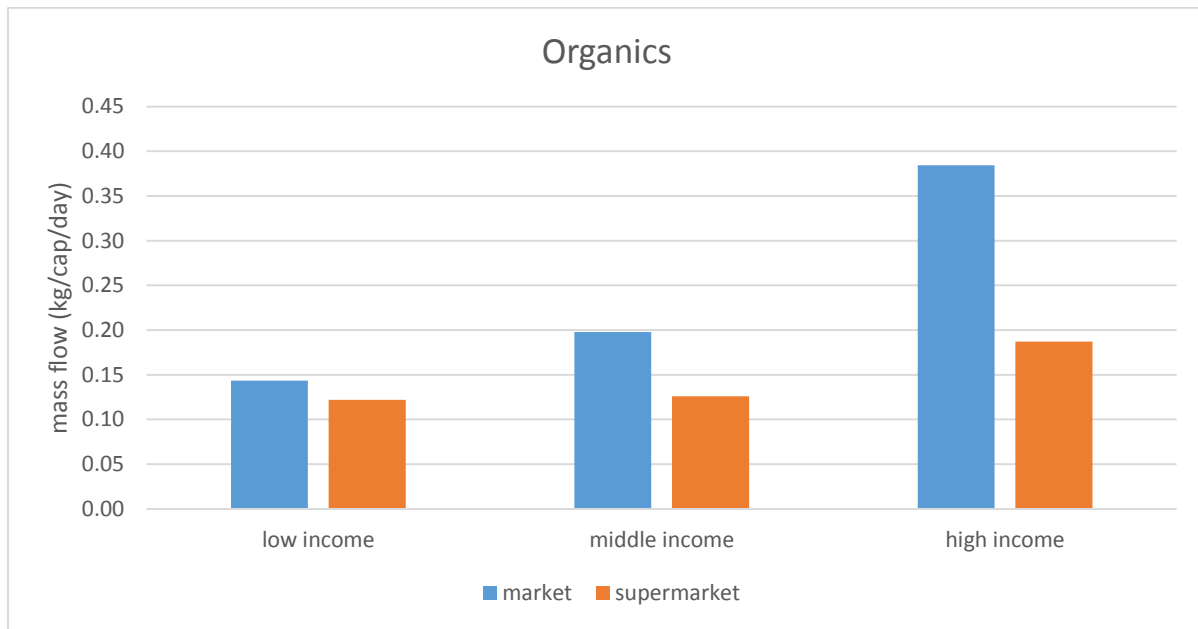


Figure 5-7: Post-consumer organic waste generated by low, middle and high income market and supermarket consumers in Kitwe

The effect of consumption choice on the waste profile in Kitwe is shown in Figure 5-7 above. The figure compares the different quantities of the components of waste associated with household food consumption. The comparison is done between a pure traditional market and a pure supermarket consumer. The figure shows that there is a decrease in the amount of organic post-consumer waste generated with a shift from consumption in the traditional open market to the supermarket. There is a 14%, 36% and 51% shift in the organic waste from the post-consumer waste to the supply chain waste for the low, medium and high income groups respectively. The figure also shows that the amount of waste generated by the market consumer increases with increasing income and that of the supermarket consumer increases slightly.

5.3.2.2 Inorganic Waste

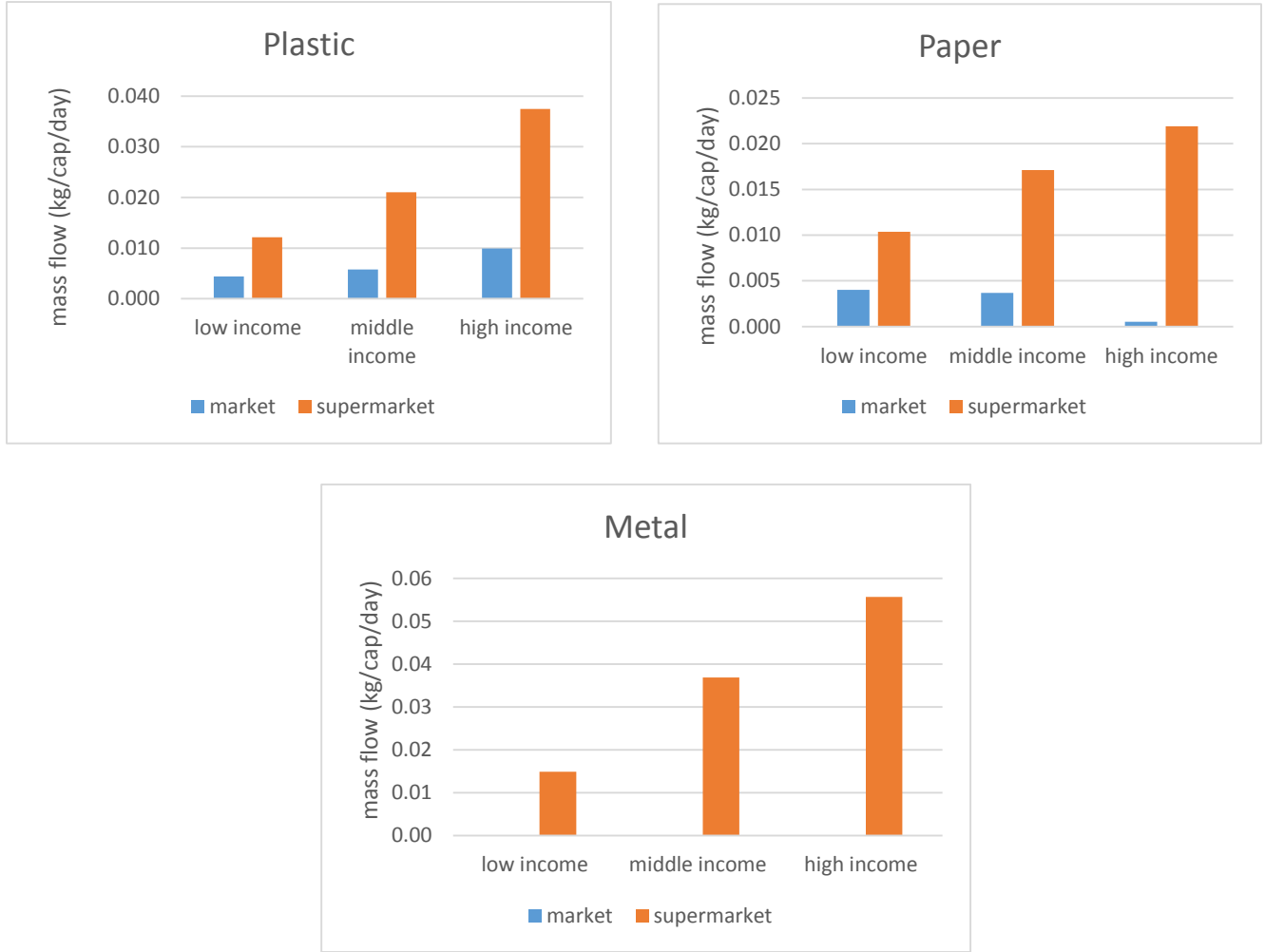


Figure 5-8: Different components of post-consumer inorganic waste generated by low, middle and high income market and supermarket consumers in Kitwe

The inorganic fraction of the post-consumer waste generated is higher for the pure supermarket consumer than for the market consumer. This is illustrated in Figure 5-8 where there is a 3-9 fold increase in the amount of post-consumer inorganic waste generated. In the case of the pure traditional market consumer, there is no metallic waste generated as it is assumed that no items are sold in metallic packaging in the traditional market. However the graph for paper waste shows a decrease in the amount of paper generated by the traditional market consumer with increase in income. This is because the high income consumers are modelled to consume less pap as was found by (Hichaambwa, et al., 2009) that wheat products were replacing maize products in the higher income urban consumers.

5.3.2.3 Post-consumer Waste Composition Effects

The effects of a shift in provisioning from the market to the supermarket on the composition of the post-consumer waste is shown in Table 5-8 below. This effect is illustrated for the low, medium and high income groups.

Table 5-8: Showing composition of post-consumer waste for market and supermarket consumer at different income levels

Component	Low Income		Middle Income		High income	
	market	supermarket	market	supermarket	market	supermarket
Organics (%)	94.4	76.6	95.4	62.7	97.3	61.9
Plastic (%)	2.9	7.6	2.8	10.5	2.5	12.4
Paper (%)	2.6	6.5	1.8	8.5	0.1	7.2
Glass (%)	0	0	0	0	0	0
Metal (%)	0	9.3	0.0	18.3	0	18.4

As can be seen in Table 5-8 above, the post-consumer market waste is at least 94% organic and is this trend is seen across all the income groups. The organic fraction of the post-consumer waste for the supermarket consumer ranges from 77% for the low income group to 62% for the high income group. This is because of an increase in the inorganic fraction of the waste from approximately 5% for the market consumer to 23- 38% for the supermarket consumer. This is associated with the increase in the amount of packaging material that ends up in the waste.

5.3.2.4 Accounting for Wastage

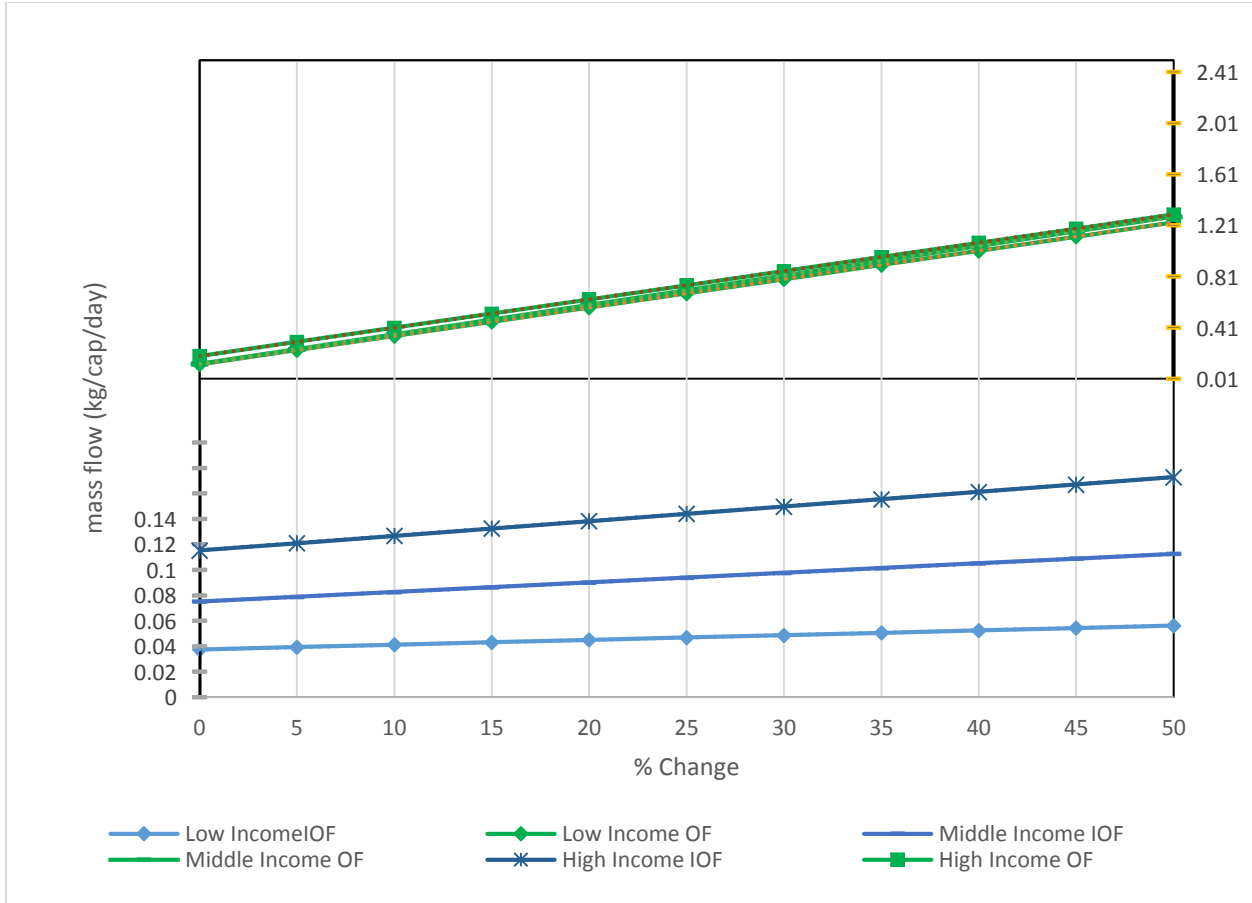


Figure 5-9: Change in daily per capita amount of waste generated with change in food wastage at consumer level for low, middle and high income supermarket consumers in Kitwe. Top chart showing organic fractions and bottom chart showing inorganic fractions. IOF- Inorganic Fraction; OF- Organic fraction

Figure 5-9 above shows the change in the post-consumer food waste generated with changes in the levels of food wastage at the consumer level. The top section of the graph shows the change in organic content while the bottom section shows change in the inorganic content of the post-consumer waste for all three diets. From the graph above it can be seen that there is an increase in the amount of waste generated for all components of household waste with increase in food wastage.

At 0% wastage, the amount of organic waste generated by the supermarket consumer is less than that of the market consumer for all three incomer groups. At wastage levels beyond 1%, 3.1% and 7.2%, the organic waste generated by the supermarket consumer is equal to that generated by

the market consumer for the low, middle and high income groups. This shows that the shift in organic waste to the supply chain is offset at these wastage points.

5.3.3 Harare

5.3.3.1 Organic Waste

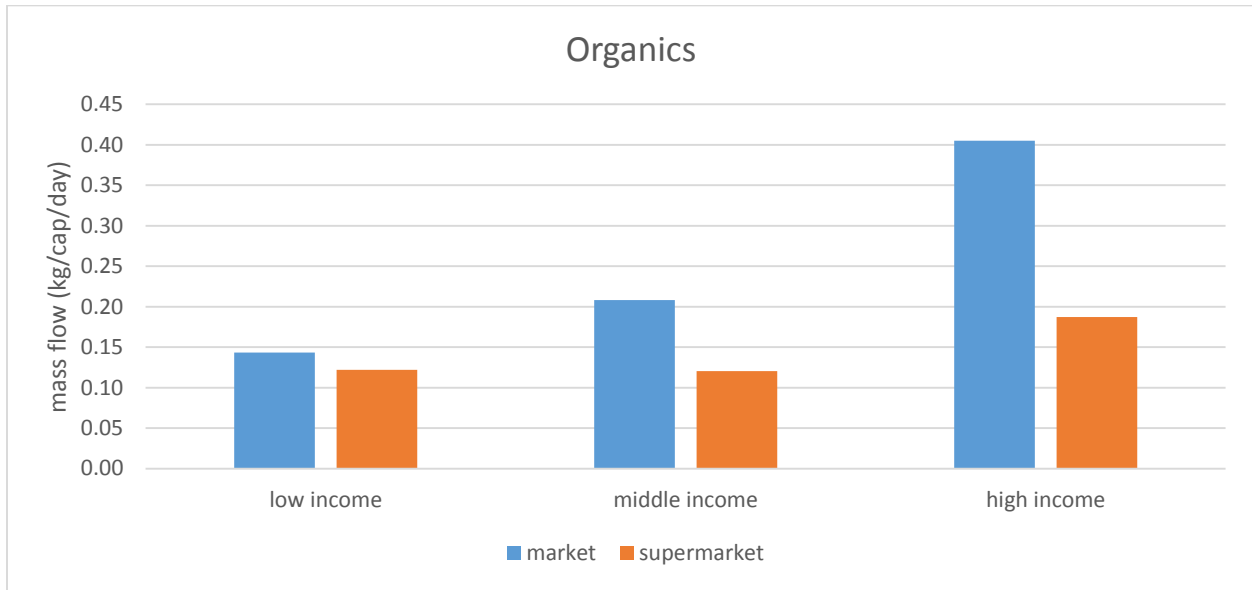


Figure 5-10: Post-consumer organic waste generated by low, middle and high income market and supermarket consumers in Harare

The effect of consumption choice on the waste profile in Harare is shown in Figure 5-10 above. The figure compares the different quantities of the components of waste associated with household food consumption. The comparison is done between a pure traditional market and a pure supermarket consumer. The figure shows that there is a decrease in the amount of organic post-consumer waste generated with a shift from consumption in the traditional open market to the supermarket. There is a 15%, 42% and 55% shift in the organic waste from the post-consumer waste to the supply chain waste for the low, medium and high income groups respectively. The figure also shows that the amount of waste generated by the market consumer increases with increasing income and that of the supermarket consumer increases slightly.

5.3.3.2 Inorganic Waste

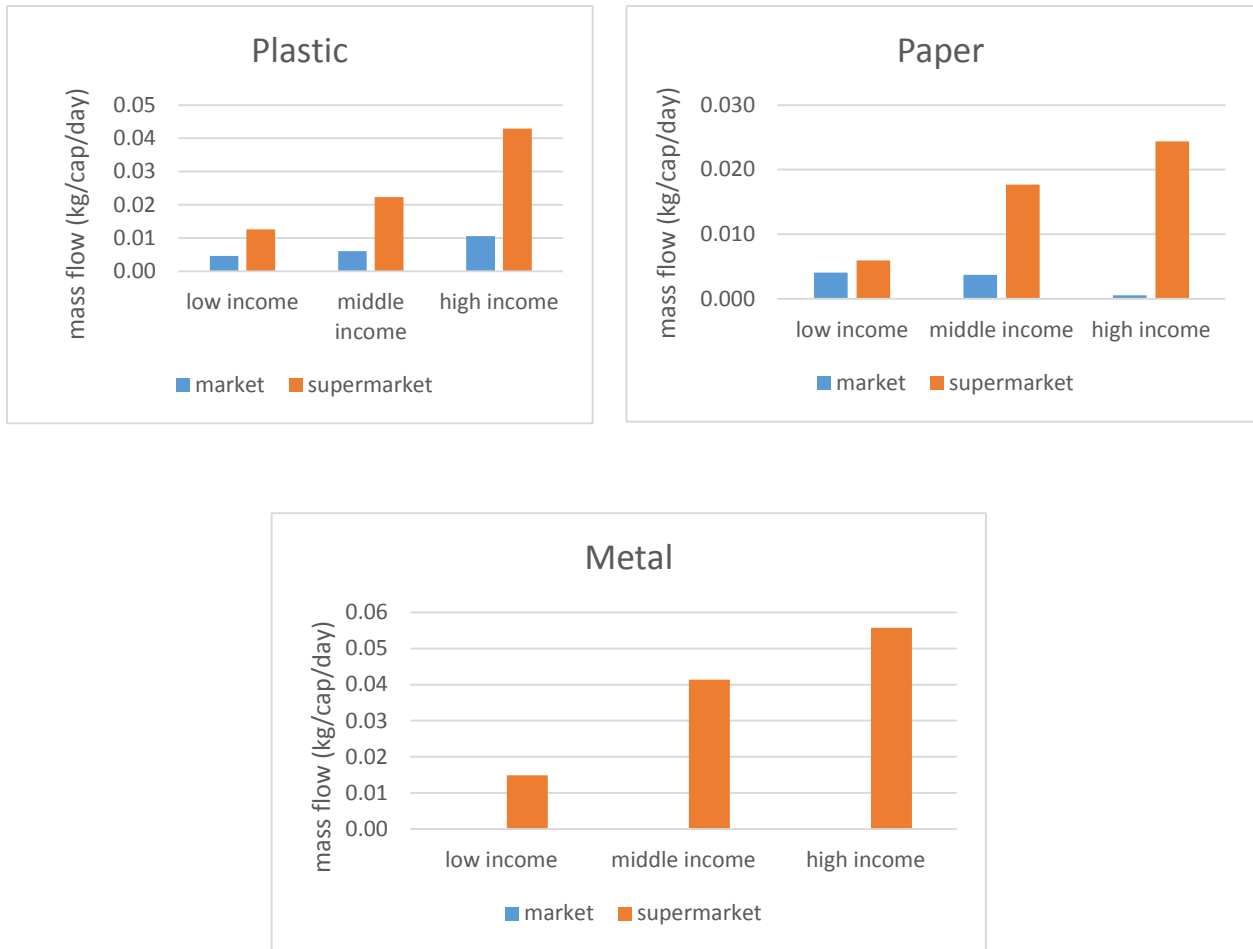


Figure 5-11: Different components of post-consumer inorganic waste generated by low, middle and high income market and supermarket consumers in Harare

The effect of consumption choice on the waste profile is shown in Figure 5-11 above. The inorganic fraction of the post-consumer waste generated is higher for the pure supermarket consumer than for the market consumer. There is a 3-10 fold increase in the post-consumer inorganic waste generated with a shift in provisioning from the pure traditional market to the supermarket. In the case of the pure traditional market consumer, there is no metallic waste generated as it is assumed that no items are sold in metallic packaging in the traditional market.

5.3.3.3 *Post-consumer Waste Composition Effects*

The effect of a shift in provisioning from the market to the supermarket on the composition of the post-consumer waste is shown in Table 5-9 below. This effect is illustrated for the low, medium and high income groups.

Table 5-9: Showing composition of post-consumer waste for market and supermarket consumer at different income levels

Component	Low Income		Middle Income		High income	
	market	supermarket	market	supermarket	market	supermarket
Organics (%)	94.4	77.8	95.4	60.0	97.3	58.5
Plastic (%)	3.0	8.0	2.8	11.1	2.6	13.5
Paper (%)	2.6	3.7	1.8	8.7	0.1	7.7
Glass (%)	0	0	0	0	0	0
Metal (%)	0	10.4	0.0	20.2	0	20.4

As can be seen in Table 5-9 above, the post-consumer market waste is at least 94% organic and is this trend is seen across all the income groups. The organic fraction of the post-consumer waste for the supermarket consumer ranges from 78% for the low income group to 58.5% for the high income group. This is because of an increase in the inorganic fraction of the waste from approximately 5% for the market consumer to 23- 38% for the supermarket consumer. This is associated with the increase in the amount of packaging material that ends up in the waste.

5.3.3.4 Accounting for Wastage

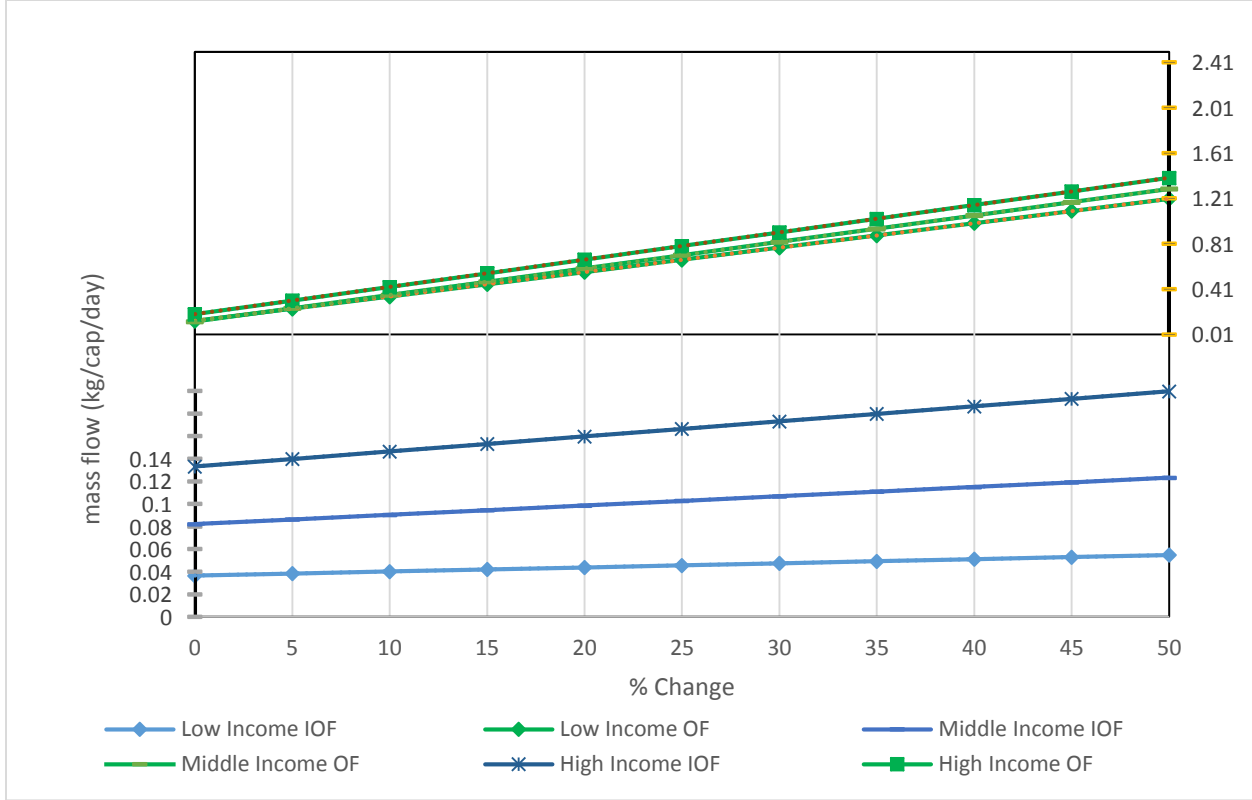


Figure 5-12: Change in daily per capita amount of waste generated with change in food wastage at consumer level for low, middle and high income supermarket consumers in Harare. Top chart showing organic fractions and bottom chart showing inorganic fractions. IOF- Inorganic Fraction; OF- Organic fraction

Figure 5-12 above shows the change in the post-consumer food waste generated with changes in the levels of food wastage at the consumer level. The top section of the graph shows the change in organic content while the bottom section shows change in the inorganic content of the post-consumer waste for all three diets. From the graph above it can be seen that there is an increase in the amount of waste generated for all components of household waste with increase in food wastage.

At 0% wastage, the amount of organic waste generated by the supermarket consumer is less than that of the market consumer for all three incomer groups. At wastage levels beyond 1%, 4% and 7.5%, the organic waste generated by the supermarket consumer is equal to that generated by the market consumer for the low, middle and high income groups. This shows that the shift in organic waste to the supply chain is offset at these wastage points.

5.4 City Food-Waste Profile Comparison

The sections above showed the waste profiles of urban consumers based on choice of provisioning in the three cities studied. The per capita daily calorie intake in all the three cities is lower than the calculated daily recommended amount, since there is under nutrition in these cities, related to poverty as mentioned in chapter 4. This results in less food being consumed and consequently less waste generated.

The amount of waste generated increases with income in all three cities. This is because, as shown in Table 5-6, the higher income groups are modeled to consume more food than the lower income groups and thus are expected to generate more waste.

As can be seen in the figures above, the effect of a shift in consumption choice on the waste profile produces a similar trend for the organic fraction of waste in all African cities i.e. a percentage of the post-consumer organic waste shifting to the supply chain due to processing. The magnitude of the percentage shifts also increase with income as more food is consumed and these magnitudes are similar for all the three cities ranging from 14-15% for low income consumers to 50-58% for high income consumers. This percentage decrease is approximately the same in all three cities.

There is also an increase in the amount of inorganic waste generated as one moves from consumption from the market to consumption from the supermarket. The increase in the inorganic waste arises from the increase in the packaging material that is used for foods bought from the supermarket. The amount of inorganic material in the post-consumer waste increases as one moves from the lower to the higher income groups. This is because in the higher income groups, people are more affluent and buy more food and hence have a larger amount of packaging. However, there are some slight deviations from the general trends shown and discussed above. The increase in the inorganic fraction in the Kitwe and Harare is higher than that in Kisumu i.e. 3-10 fold vs. 2-4.5 fold. This is due to the difference in the diets. In Kisumu, there is a larger intake of milk and milk is modelled to be packaged in paper cartons. This explains the larger amount of paper in the post-consumer waste of the market consumer in Kisumu as shown in Figure 5-5 compared to the market consumers in Kitwe and Harare.

In the case of waste paper, there is a decrease in the amount of paper produced as one moves from the low to high income group for the urban market consumer in Kitwe and Harare. This is because the high income consumer are modelled to consume less pap and majority of the paper in the waste is associated with consumption of pap as the item is packaged in paper material. This decrease is not seen in Kisumu as the high income urban consumer is modelled to drink more milk which is packaged in paper.

Table 5-7, Table 5-8 and Table 5-9 show that the changes in the composition of the post-consumer waste follows a similar trend as one shifts from market to supermarket provisioning in all three cities. The organic fraction ranges from 90-97% of post-consumer waste for the market consumer to 20-50% for the supermarket consumer. This implies increase in the inorganic fraction of post-consumer waste. The inorganic fraction increases with increase in income as they buy more food, that is processed and also has packaging material associated with it. This trend is similar across all the cities studied. The increase in the inorganic waste is mainly attributed to the increase in the metallic waste that forms 18-23% of the waste generated by the low to high income supermarket consumer across the three cities. This is because metal is the heaviest of all the inorganic materials used in packaging.

In the post-consumer waste of the market consumer, there is no metallic waste present. This is because it is assumed that no metallic packaging is associated with market fresh produce. Metallic waste is present in the post-consumer waste of the supermarket (=processed food) consumer for all income groups. In reality, metal waste would be expected for low income consumers who buy canned foods (through whatever retail outlet they have access to) given the limited storage capabilities for fresh produce.

In this research, the diets chosen and the resulting waste profiles are based on the metabolic flow model developed and thus serve as an illustration of the effect of a shift in consumption on the waste profile. More research would be required to give a more thorough quantitative and qualitative description of this effect. However, the developed model gives some indication of what this effect could look like and the results generated are in agreement with literature like, Thogersen, (1996), Warren-Rhodes & Koenig, (2001), Achankeng, (2003), Scheinberg & Mol, (2010), which speak to the effects of changing urban lifestyles on the quantity and composition of municipal solid waste.

6 Waste Management Systems in the Studied Cities

The results presented thus far have shown that shifts in food provisioning in African cities, from more fresh produce and traditional markets to more processed foods and supermarkets, is likely to induce significant shifts in where organic wastes will arise and in the composition of post-consumer waste. Clearly, this will have impacts on waste management. In order to understand the possible impacts on waste management, it is first necessary to describe the waste management status in each of the three cities studied in this research. The analyses were done as described in section 3.8 of the methodology for this research. Results were obtained from both primary and secondary sources. Primary sources include interviews with experts and secondary sources include information from published literature and reports. For each city, the sources are first introduced, thereafter the waste management systems are discussed in terms of governance, service providers, generation & collection, disposal and capacity for valorization and integrated management.

6.1 Kisumu Waste Management System

The waste management system in Kisumu was analyzed and the results of the analysis are presented in this section. Information on this section is drawn from previous publications on Kisumu's waste management system and interviews conducted with selected local experts involved in waste management. Primary sources of data are interviews with two experts: Professor Stephen Agong' and Mr Alfred Omondi, coordinator of the Kisumu Local Interaction Platform (KLIP).

Secondary sources of data were obtained from published literature, in particular UN-Habitat, (2009), Munala & Moirongo, (2011), NEMA, (2010).

6.1.1 Governance

Waste management services in Kisumu are provided by collaboration between the municipal council and the private sector (Agong & Omondi, 2014). Under the municipal council, the department of environment is in charge of overseeing the provision of waste management services. However, over the years the council has failed to provide adequate services for the people of Kisumu and thus recently, private companies have come up offering waste management services. This has helped take some of the burden off the municipal council that

cannot deal with the increasing demand for these services (Munala & Moirongo, 2011). The city follows Kenya's Waste Management Regulations of 2006 and the National Environment Management Authority is responsible for ensuring compliance with these (NEMA, 2010). However a recent study reported that there is minimal compliance to the environmental regulations and the public lacks confidence in NEMA's ability to enforce compliance with these laws (NEMA, 2010). Different entities including supermarkets were surveyed and only 17.2 % of the entities were found to be compliant with these laws. The causes for non-compliance were found to be; facility unaware of the applicability of the regulation (42.9%), contracted services (21.4%), communication difficulties between the facility and NEMA (16.7%), human error and operating procedures not followed (11.9%) and equipment design or installation problems (7.1%) (NEMA, 2010).

Policies in waste management are formulated by technocrats after receiving input from the people through public forums. The draft policies are then taken to the national assembly for debate and passing of the bill before signing into law. Currently, the system is devolved and uses the same procedure as the national government. The policies to some extent consider waste structure changes due to the input from technocrats who are from such fields (Agong & Omondi, 2014). However, very little investment goes into waste management and it has been reported that these forums are often used as a public political carrot to woo voters (Agong & Omondi, 2014).

6.1.2 Waste Management Service Providers

As previously mentioned, waste management services in Kisumu are provided by the private sector in collaboration with the Municipal council of Kisumu (Agong & Omondi, 2014). The capacity of the municipal council is illustrated below;

Table 6-1: Showing structure of existing staff (UN-Habitat, 2009)

Area of Expertise	Technical (degree) (number of people)		Support staff (number of people)	
	Ideal	Current	Ideal	Current
Administration	2	1	5	6
Development Planning	3	1	5	0
Solid waste management	3	0	100	28
Conservation and protection	1	0	5	0
Monitoring and control	2	0	10	1
Community development	1	0	5	0
Urban aesthetics	1	0	30	10
Total	13	2	160	45

Table 6-1 shows that the council has fewer than the ideal amount of staff in all areas of expertise except administration where the council employs one more staff member than required. The department of environment is under staffed and does not have enough human and financial capacity to measure up sufficiently to its responsibilities (UN-Habitat, 2009).

Another reason for the inefficient provision of waste services is the lack of proper equipment to collect, transport, treat and dispose of the waste and this is illustrated in Table 6-2 below.

Table 6-2: Showing Refuse-Vehicle Types in Kisumu (UN-Habitat, 2009)

Type of vehicle	Number of vehicles		
	1980s	1990s	2000s
Isuzu canters	0	0	2
Tractor	2	2	1
Compactor	1	1	1

Table 6-2 shows the availability of refuse collection vehicles in Kisumu. From the table it is seen that the number of tractors has decreased over last 2 decades and only one compactor has been used since the 1980s. The Isuzu canters were purchased more recently in the 2000s however these are loaded manually making this method of collection is very laborious and often these vehicles are used for other activities other than waste collection (UN-Habitat, 2009). The municipal council does not have the resources to purchase new equipment. It was reported by Professor Agong that the trucks and collection tools like spades are inadequate and the few that exist are in deplorable conditions while some items like gloves and gum boots are completely lacking. This presents a challenge given the rapid urbanization and increasing economic growth taking place in Kisumu.

6.1.3 Generation and Collection

The city of Kisumu on average generates about 350 to 400 tons of waste per day. The composition and the amount of waste generated in Kisumu has been on the rise mainly due to the fast increasing urban population and the change in urban consumption lifestyle and the status of solid waste in Kisumu has seen three key trends (Munala & Moirongo, 2011);

- Increase in the volume of waste generated
- Change in the quality in waste due to changing lifestyles
- Increase in disposal of waste collected, by incineration and use of organic waste for urban agriculture

The changing nature of solid waste is further complicating the already difficult task of dealing with waste management in this lakeside city in Kenya (Munala & Moirongo, 2011). Waste composition in Kisumu is rapidly changing with an increase in packaging wastes mainly plastic/polythene bags and remains of electronic goods. The management of such wastes changes has not been in tandem with the corresponding change in waste produced and Professor Agong' there is a lack of data to show this change. However, he adds that waste management is now gaining considerable attention and studies are being conducted on waste management e.g. there is an on-going study being carried out by the Kisumu Local Interaction Platform (KLIP) researchers.

Only 20% of the waste generated in Kisumu is collected. Of this waste, half is collected by the local authority and the other half by the private sector (Munala & Moirongo, 2011). Similarly, only 17% of the households in Kisumu have access to private waste collection (Munala & Moirongo, 2011). The low income areas receive even less waste services because of poor accessibility. There is often spillage of waste as the waste collection vehicles and equipment can not contain the waste loaded. The private sector uses its own trucks and offers door to door waste collection services as well as provision of refuse collection bags to subscribed households. The municipal council offers collection services from communal dumpsites where the public dump their waste before collection (Agong & Omondi, 2014). Private collection covers mainly the major estates around the city while people in informal settlements either dump their waste at designated dumpsites or by the road side. Professor Agong reports that waste collection is still viewed by the public as a dirty job for street urchins and very few semi educated individuals do the collection, assembly and eventual dumping.

6.1.4 Waste Disposal

The majority of the waste collected in Kisumu is landfilled. The city has one dumpsite at Kachok and a variety of waste is brought to the dumpsite including residential and commercial waste, sometimes mixed with industrial residues (UN-Habitat, 2009; Munala & Moirongo, 2011). The waste disposed of at the dumpsite is often combusted, but some of the waste like glass that does not burn heaps up at the site and the dumpsite receives all types of waste as there is no separation of waste at source. The majority of the residents prefer to dispose of their wastes by burning or burying as there is limited collection service and the existing service is expensive (Munala & Moirongo, 2011). There is a lot of illegal dumping in the city and this has led to a lot of waste piling up on road sides and in the drainage system (Agong & Omondi, 2014).

The dumpsite is a source of income for some of the urban poor. However the scavengers are in danger of exposure to toxic industrial waste (Munala & Moirongo, 2011).

6.1.5 Capacity for Valorization and Integrated Waste Management

6.1.5.1 Recycling

Recycling in Kisumu is done mainly by the informal sector and a few operators. Informal collectors gather waste from road sides, dumpsites and drainage systems and sell it to waste

dealers who act as middle men between the collectors and the recycling companies (UN-Habitat, 2009). This forms a source of livelihood for a number of people in Kisumu.

The potential for recycling is huge and currently KLIP in collaboration with other stakeholders is already collecting wastes and making products like crafts and ornaments from the recycled waste for sale (Agong & Omondi, 2014).

6.1.5.2 Composting

There is no commercial composting taking place in Kisumu however there is some being done on a small scale at household level (Agong & Omondi, 2014).

6.2 Kitwe Waste Management System

The capacity of the Kitwe municipality to provide waste management was analyzed and is presented in this section. Information on this section is drawn from previous publications on Kitwe's waste management system and interviews conducted with selected local experts in waste management. Three experts were interviewed to obtain information on the waste management of Kitwe namely;

- Mr. Collin Gwanu, former managing director of the Copperbelt Waste Management Company
- Dr. Albert Malama, lecturer at the Copperbelt University and
- Mr. Daniel Phiri, a PhD student and lecturer at the Copperbelt University

Literature on waste management in Kitwe is very thin and not much work has been published. Information on the waste management in Kitwe is drawn from Senkwe, et al., (1999) Kazimbaya-Senkwe & Mwale, (2001), Kazimbaya-Senkwe & Malama, (2003), Chama, et al., (2009), Nkowane, (2013).

6.2.1 Governance

Waste management services in Kitwe are provided by the city council and private collectors. The Kitwe city council was in charge of the provision of waste management services until the 2000s when the inadequacy of its services attracted the participation of the private sector (Nkowane, 2013). There are also a number of community based organisations and NGOs that are involved in

the provision of waste services. This is because of the poor service offered by the council and the reluctance of the private sector to offer services to low income areas.

The local government Act No. 22 of 1991 is the main statutory instrument that regulates the functions of local authorities and gives them responsibility for refuse collection (Kazimbaya-Senkwe & Malama, 2003). The Environmental Council of Zambia (ECZ) is the regulatory body responsible for pollution control and environmental protection in Zambia. The ECZ is responsible for ensuring that waste management service providers adhere to the required regulations. However, the ECZ only has offices in Lusaka and this makes monitoring more difficult (Senkwe, et al., 1999).

Issues of waste management are addressed through public meetings where the council (councillors and civil servants), private operators and members of the public have plenary discussions and break up into specialisation groups where action policies/plans are formulated. These are then presented for critique and buy-in from the other participants (Mr Gwanu interview).

There is very little research being done on waste management in the area. Studies that have been done on waste management are few and limited. Notable is the one by Kizimbaya-Senkwe and Malama between 1999 and 2001, funded by the Netherlands. Another study ran from 2007 to 2009 and was funded by the German Government. This involved site visits, cross-visits, and high impact-low cost waste management activities. The city lacks the resources to fund these studies and thus they are only done when external funding is sourced (Dr. Malama interview).

6.2.2 Waste Management Service Providers

Waste management services in Kitwe are provided by the Kitwe city council and some private companies. The main waste collector is the Copperbelt Waste management company. The Copperbelt Waste management company was formed in 2007 by the local authorities to provide waste management services to the city (Dr. Malama interview, 2014). Additionally, there are private companies involved in waste management in the city as Kazimbaya-Senkwe & Malama, (2003) claims that the local authorities failed to provide adequate services that could deal with increasing population and demand for waste services. Like local government in many developing countries, the Kitwe City Council has been unable to meet the demand for solid waste

management services in the city and a number of private companies have come up to provide waste collection and disposal services (Kazimbaya-Senkwe & Malama, 2003); the current number of private waste management companies in Kitwe is estimated at six (Dr. Malama interview, 2014). In terms of involvement by other big companies, there is limited participation by the big retail companies in waste management and their participation is not structured, monitored nor managed. The practices by these retail companies may thus not be in line with the services offered by the city council and other private collectors (Mr. Gwanu interview, 2014).

6.2.3 *Generation and Collection*

Waste generation in Kitwe is reported to be on the rise due to the rapid urbanization and economic growth (Chama, et al., 2009).

Table 6-3: Showing different household waste generation per day in Kitwe (Kazimbaya-Senkwe & Mwale, 2001)

Type of waste	Waste generated (kg/cap/day)			
	Peri-urban	Low cost	Medium cost	High Cost
Plastic	0.02	0.02	0.01	0.03
Glass	0.02	0.002	0.002	0.04
Paper	0.01	0.02	0.01	0.01
Food	0.14	0.13	0.2	0.23
Metal	0.01	0.001	0.001	0.001
Garden	0.21	0.32	0.4	0.31
Other	0.01	0.08	0.01	0.01
Total	0.42	0.57	0.63	0.63

Table 6-3 above shows the daily amount of waste generated by different households in Kitwe, in 2001. The results shown represent data collected from 83 households in Kitwe. 6 day waste separation surveys were done in low, medium, high cost residential areas and peri-urban settlements. The data was recorded through questionnaires given to the individual households. The sample included 11 peri-urban households and 27, 11 and 34 low, medium and high cost households respectively. It is evident from the table that the high income areas generate more waste than the lower income areas. The relatively larger amount of metal in the peri-urban areas could be explained by the fact that many of the people living in per-urban areas were involved in

metal work and worked from home and thus wastes generated from these activities were included in the household waste. Plastic and glass wastes were highest in the high income areas where households are more likely to purchase glass wares and where the levels of shopping are generally higher thus contributing to high plastic waste which are arises from packaging. The highest percentage of ‘other’ was in low cost areas and this consisted mainly of clothes as tailoring is a major activity in this area.

The Copperbelt waste management company and private companies collect waste only in urban areas. Figure 6-1 below shows coverage by each provider.

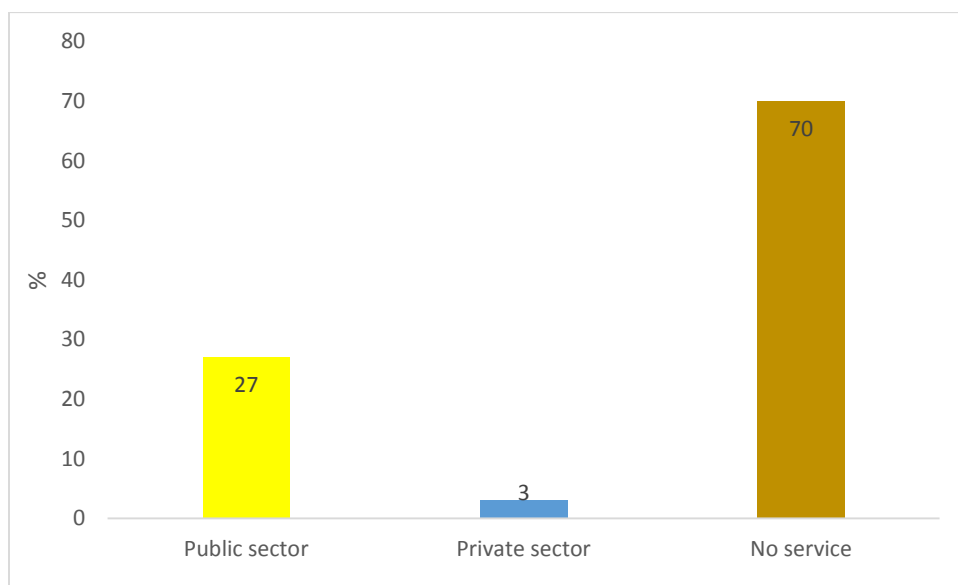


Figure 6-1: Showing % coverage of different entities providing waste services in high density areas (Nkowani, 2013)

Figure 6-1 above shows the coverage of the public and private sector in the provision of waste management services to high density areas in Kitwe. The figure shows that only 3% of the people received services from the private sector and only 27% from the city council. A large number of people, 70%, are without any form of waste management service. Private companies provide waste collection services to mainly middle and high income residential areas. Houses sign up to receive the waste management services and this is not compulsory for all houses. In some middle to high income residential areas only about 30% of the houses have signed up (Dr Malama). The other 70% bury or burn the rubbish, with the majority of the rubbish apparently burnt. There are no legal frameworks or by-laws on waste management in the area and thus the

sign up for waste management is voluntary. A wide variety of wastes are burnt or buried including plastic and paper.

Services provided by the Kitwe City Council are mainly collection from communal dumpsites in public areas while private operators provide door to door collection services (Mr. Gwanu interview, 2014). The Council and private operators use refuse compaction vehicles, skip loaders, open truck/vans, and tractor drawn trailers. Low cost housing remains largely unserved as it is not profitable to provide services here and most people are unable to pay (Mr. Gwanu interview, 2014). Waste collection services are thus provided to mainly the medium and high income areas as well to the commercial sector. The waste services bill is paid through the water bill and it is claimed that sometimes the money may not be transferred from the water company.

The people in the low income areas have to carry their waste to a single point for collection. In the medium and high income areas, door to door collection is done once a week in a plastic bag. A special color plastic bag is given to households that receive service from the Copperbelt waste management company. If the household place their waste in different colored bags, this waste is not collected (Dr. Malama interview, 2014).

6.2.4 Waste Disposal

The waste in Kitwe is taken to a dumpsite and there is no landfill for the city. The council just recently met this year to discuss plans for the development of a new landfill site (Dr. Malama interview, 2014).

The collected waste is disposed at the Uchi dumpsite. This is the only Zambia Environmental Management Authority approved dumpsite and it is reported to be inadequate. However, an engineered landfill site has been approved for construction though works are yet to commence (Mr. Gwanu interview, 2014). The Uchi dumpsite is located 2 km southeast of the town center and was initially a copper tailing dam until the early 1970's when it was converted into a landfill mainly for the purposes of reclamation (Senkwe, et al., 1999). The dumpsite since then has received all kinds of waste ranging from mining and industrial to domestic waste. The site does not meet the standards of an engineered sanitary landfill. There is no base to prevent leachate from contaminating ground water and it has no system in place to vent off methane given off. The Zambia Consolidated Copper Mines (ZCCM), Nkana division public health department

manages the site and there is a gate keeper to register the delivery trucks (Nkowane, 2013). The waste at the dumpsite is being burnt as opposed to being compressed and buried as recommended by the ECZ.

6.2.5 Capacity for Valorization and Integrated Waste Management

6.2.5.1 Recycling

There is little recycling taking place in Kitwe. No separation of waste at source is done and recycling is mainly done by informal waste pickers. Most of the recovery of recyclables is done at the disposal facility before final dumping. There has been an increase in the amount of inorganic material in the waste especially plastic arising mainly from packaging material and there is potential for recycling. Currently, however, most of the reclaimed waste is destined for export particularly to China (Mr. Gwanu interview, 2014).

6.2.5.2 Composting and Waste to Energy

It has been reported that there is no composting or waste to energy taking place in the city (Mr. Gwanu interview, 2014).

6.3 Harare Waste Management System

This section describes the waste management system in Harare city. In each subsection, the information obtained from published literature is presented first and then information obtained from the expert interviews is shown. However for some subsections, no published information could be found and only information obtained from interviews is presented. Three experts were also interviewed in order to obtain information on waste management in Harare namely;

- Mr. Emmanuel Muzah, City of Harare Waste Management
- Mr. Clifford Muzofa, city environmental regulatory planner at city of Harare
- Mr. Tawanda Matsuka, CEO of PET Recycling Company Zimbabwe (Petreco)

Secondary sources of literature used in this research included; Maseva, (2005), TARSC, (2010), Chikobvu & Makarati, (2011), Tsiko & Togarepi, (2012), Mangundu, et al., (2013).

6.3.1 Governance

Waste management services in Harare are provided by the local authority in Harare city, as well as the private sector. The private sector includes privately owned companies, voluntary organizations or non-governmental organizations and the informal sector. The city of Harare currently depends on legislation like the Harare Waste Management by-laws of 1979 and guidelines derived from Environmental Management Agency (EMA). However most of these by-laws are outdated and may not apply to today's situation (Muzah, 2014). Despite the existence of these by-laws on waste management in Harare, there is hardly anything on the ground to show that it pays to have by-laws. Residents violate these by-laws mainly because they have no option as their waste remains uncollected for long periods. Residents also do not know what these laws state or that they exist (Maseva, 2005).

6.3.2 Waste Management Service Providers

As mentioned above, the city council and private sector provide waste management services to the city. The rate of waste generated is increasing faster than the expansion of solid waste management services and the ability of the municipal authorities to improve on the financial and technical resources (Mangundu, et al., 2013). The city of Harare lacks resources to provide adequate services to the city.

Financial constraints are a big issue for the waste management department. Mr. Muzah reports that department receives no money from the government and has to borrow from both local and international banks. Other revenue is obtained from the flat fee they charge users for their service however this is able to meet only 60% of their financial needs.

There are a few private companies involved in provision of waste management services since the reinstatement of private contractors in 2012 (Tsiko & Togarepi, 2012). Delta Beverages is one of the companies involved in waste collection and Mr. Muzofa reports that there are other companies are involved in collecting recyclables and waste to energy projects (Muzofa, 2014).

6.3.3 Generation and Collection

The waste generated in Harare has been on the rise due to increasing urbanization in the city and the changing lifestyle of consumers (Munala & Moirongo, 2011).

Waste collection services in Harare are limited and a number of households are unwilling or cannot afford to pay for these services. The city council is unable to supply residents with bins and thus households have to rely on getting them for free from NGOs or private companies (Tsiko & Togarepi, 2012). According to the council's policy, collection should be done once a week in residential areas and every day in the CBD however collection is done very sporadically due to lack of enough resource (TARSC, 2010).

Mr. Muzah estimates that about 70% of the waste generated in Harare is organic comprising of food waste as well as garden/farm and market waste. However there has been a large increase in the amount of paper and other packaging material but there is a lack of data to quantify this increase and currently no studies on this are reported on file.

Tawanda describes the situation of waste management provision is bad but there has been an improvement. Recently the city council of Harare bought 42 refuse collection trucks for the 42 wards. This is an improvement as now each ward has a refuse collection truck. However this is still not enough as some wards require 4 or even 5 trucks. There are still issues of reliability, management and maintenance of these trucks. A large amount of waste is thus still not being collected and there are a lot of illegal dumpsites (Matsuka, 2014).

The number of trucks is not enough for waste collection in city and the department is operating at 50% capacity in terms of the number of trucks required. The majority of the waste, about 90%, is collected through door to door collection while the other portion of the waste is collected from designated dumpsites (Muzah, 2014).

Mr. Muzah reports that at the department of waste management, no studies have been done on the generation and composition of waste.

6.3.4 Waste Disposal

Solid waste collected in Harare is mainly disposed of at Pomona and Golden Quarry dumpsites. These sites are operated as open dumps instead of sanitary landfills (Tsiko & Togarepi, 2012). Most of the municipal solid waste in Zimbabwe, which is collected, is disposed in open dumps, and almost half of the wastes generated do not reach the designated disposal sites. A majority of the people still dump their waste in drainage systems and open dumps when their bins are full while others burn or bury their waste (Chikobvu & Makarati, 2011). A lot of waste in Harare is

still dumped in gutters and roadsides and this is mainly plastic and paper that arises from packaging.

There is lack of proper infrastructure at the dumpsite and it is not a sanitary landfill however, Mr. Muzofa reports that there are plans to develop a new sanitary landfill as the current landfill is not sufficient to support the current population and also expects that the new landfill will have a waste to energy plant on site.

6.3.5 Capacity for Valorization and Integrated Waste Management

6.3.5.1 Recycling

There is potential for recycling in Harare. Tawanda Matsuka, CEO of Petreco reports that many recycling companies have come up in the city since 2011. Companies doing Paper recycling existed before, however the market is not big and two of these shut down due to the economic situation in Zimbabwe. Some of the recycled paper is being exported to Zambia. Tawanda reports that there have been companies recycling paper and other forms of plastic like LDPE and HDPE. There has been an increase in PET recycling and this has been further intensified by the shift of the beverage industry from glass to plastic packaging. Another company, Delta Beverages is involved in collection of cans and bottles. Some of the recycled cans and bottles are exported to South Africa. There are also new companies that are involved in the recycling of other materials such as rubber, glass and metal cans.

Collection of recyclable waste by the recycling companies is done with the help of the informal sector. The informal collectors collect material from illegal dumpsites, street pavements and dumpsites. Recycling companies hire trucks that go around collecting waste from the informal pickers once there is adequate stock. The volumes collected are not large enough and thus it is not worth it for companies to own their own trucks.

The city council is trying to introduce the idea of getting a livelihood from waste. This will especially help the poor. The informal sector is developing much faster in this segment and a number of flea markets are coming up around the city to sell goods made from recycled materials like paper and plastic. The city council also spent 12 weeks going door to door to industries trying to get them involved and get a register of those that are involved in any form of waste management (Muzofa, 2014).

6.3.5.2 Composting

The city council is in the process of trying to promote composting in the city. Currently, there are programs to generate organic fertilizer from the organic waste collected. Pilot tests have been tried out in different areas like Chitungwiza and Epworth. These projects are however still in the research phase (Muzofa, 2014).

6.3.5.3 Waste to Energy

There is potential for harnessing of biogas from organic waste. Bio reactors have been established in Harare with funding coming from EU. Biogas is being used in Harare in hospitals, prisons, schools and in the pig industry. There are 200 m³ plants already operating within the city and a new 800 m³ bio digester has been set up.

Muzah and Muzofa both claim that there is research that is being done to convert waste to energy and the city is currently in the process of receiving proposals for waste to energy conversion from different companies.

6.4 Conclusion

Analysis of the waste management sector reveals that the waste management systems in the three cities do not have the capacity to meet the current needs of the people in the respective cities.

In all three cities, waste management services are provided by both the public and private sector. The administrative councils in these cities do not have the resources to provide adequate services and the private sector steps in to provide service to only those that can afford.

In all the three cities, the phenomenon of changing waste quantity and composition has been picked up by waste practitioners. There is evidence of increased plastic and paper associated with increased use of packaging material.

None of the cities had a sanitary landfill and dispose of their waste in dumpsites. Illegal dumping is a common feature in all cities where waste ends up in trenches and on roadsides either because there is no place to dump the waste or waste goes along time uncollected from designated dumpsites or collection points.

The majority of the recycling in these cities is done by the informal sector who sell their collectables to recycling companies. This provides a way of life for the people.

The waste management system in Harare is at a more advanced level compared to the other cities. Harare is a major city and the capital of Zimbabwe and the city is 99% urban compared to Kitwe and Kisumu that are 60% informal.

Composting and waste to energy projects only exist in Harare and again these are funded by external donors as the city council does not have adequate funds to start these projects independently. These projects are non-existent in Kisumu or Kitwe as they do not have adequate resources to start them.

Some efforts have been put in to develop the waste management sector i.e. new recycling companies coming up in all three cities and different waste management projects being started however these efforts are still lagging behind the changes in the urban waste profile that are taking place. There are few to no studies done on waste management. In Kitwe the existing studies date back to 2003 while in Kisumu the waste analyses done formed just a sub section of a larger project. The waste management sectors are underfunded and lack resources in terms of labor and infrastructure to provide adequate waste management services.

As expected at the outset of this study, urban waste management thus faces significant challenges for all three case study cities. How will already-challenged waste service provision be impacted by the changing waste composition modelled and described in chapter 5? The next chapter attempts to link these two matters together.

7 Food and Waste System Comparison

This chapter provides a link between the modelling of the food system changes (in chapter 5) and the waste analysis (in chapter 6) for each of the three cities. The chapter discusses the results obtained in the food system in relation to the results of the waste management analysis done for each city. The discussion is presented in three sections, i.e. one for each city, followed by a summary of the findings laid out at the end.

7.1 Kisumu

Kisumu is one of Kenya's fast growing cities. The city has a population of 383,444 people with about 70% of this population under 30. As discussed in section 4.1, the city's population is growing and it has been identified as an area for economic growth.

Supermarkets have started to spread the city of Kisumu and a number of supermarket branches opened up in the city in 2014. Although the city is largely informal, it has been noted that today new supermarkets in the area are targeting the informal settlements as there is high demand in these settlements for the affordable fast moving goods in these supermarkets (Odhiambo, 2014).

Application of the 'food-waste metabolic flow model' developed in this dissertation to Kisumu shows that with a switch from market to supermarket provisioning, one may expect a shift of organic waste from households to the supply chain in the range from 14% to 58% from the low to high income groups, as well as a 2-4.5 fold increase in the food-packaging inorganics in the post-consumer waste. These magnitudes were estimated for the 'no additional wastage' scenario.

Analyses of waste management documents and the conducted interviews have shown that the increase in quantity and the shift in composition of waste have been seen by waste management practitioners. However, due to limited resources, this change has not been studied or quantified. The waste management policies in Kisumu are not closely followed and there is minimal compliance of supermarkets with environmental rules and regulations. The biggest reason for the incompliance appears to be ignorance of the existence of the environmental regulations. There is also lack of capacity in terms of labor and infrastructure and this has also led to increase in incompliance with environmental regulations. This also limits opportunities for waste valorization, through projects employing as composting or waste to energy. There is limited

opportunity for recycling and yet there is a big polythene bag problem in the area. Such bags, in particular, end up on the streets, drainages and illegal dumpsites.

7.2 Kitwe

Kitwe is the commercial hub of the copperbelt region in Zambia. The city has the highest population in the region. The recent rise in the economic activity in Kitwe coincides with the restoration of the mining sector, which is the main economic activity in the area. Privatization of the copper mines as well as increase in demand and prices of copper are believed to have lifted the city's economy. The area has a population of 522,092 people and a high population growth rate of 3.3 % p.a. and a large percentage of the population, 66%, is under 25. There has been growth of supermarkets in the area; an already somewhat dated study showed supermarkets having up to 17% market share for staples (Hichaambwa, et al., 2009). This has led to diversification of the urban diets e.g. wheat taking over maize as the staple of choice among urban consumers and this is more popular amongst the younger generation.

Application of the illustrative food-waste model to Kitwe showed an expected shift of the post-consumer organic waste to the supply chain in the range from 14% to 51% for low to high income groups, when people begin to shop in supermarkets. There would also be a 3-9 fold increase in the inorganics in the post-consumer waste associated with packaging materials.

The increase in the inorganics in the post-consumer waste has been picked up by waste practitioners in Kitwe, however no studies have been done to quantify this change. There is a lack of resources to carry out studies on waste management, with the last study having been done in 2003; moreover, such studies only happen when external funding can be sourced. Due to limited information on waste in the area, there is little recycling being done and this is mostly by the informal sector. Also, no composting or waste to energy has been reported to be done. A large amount of the waste ends up in illegal dumpsites or on road sides and drainages as a large number of the people (70%) are without waste management services (Nkowani, 2013).

7.3 Harare

Harare city is the capital of Zimbabwe. It has a population of 1.8 million people with about 99% of the population living in urban areas. The supermarket sector is prominent in Harare and approximately 78% of people buy their groceries from supermarkets. Consumer packaged goods account for 31% of the monthly household budget (Nielsen, 2014).

With this growth and dominance of supermarkets, the illustrative food model-waste was applied to the city of Harare. It showed a shift of 15%, 42% and 53% of the organic waste from the post-consumer waste to the supply chain waste for the low, medium and high income groups respectively when switching from market to supermarket provisioning. There was also a 3-10 fold increase in the inorganics in the post-consumer waste. It is thus also not surprising that an increase in packaging material has been picked up by waste management practitioners in Harare. Waste services here are provided by the local authority and the private sector. Waste management services are inadequate and do not meet the demand of all the people in the city: It is estimated that about 70% of the waste generated in Harare is collected.

Due to the economic downturn in Zimbabwe between 2005 and 2009, a number of companies that engaged in waste management are reported to have closed down. In light of this, due to the shifts described above, plastic bottles and cans were becoming a significant problem on the streets of Harare. This prompted a number of new companies to startup, e.g. Petreco. It has been claimed that a number of other recycling companies are coming up today. This shows some promise for the recycling sector in Harare, however no information could be found to verify this. Of the existing companies, only one company, Delta Beverages, has begun to engage in recycling doing the collection and recycling of cans. The municipal authority still lacks resources and all the new recycling companies are owned by the private sector and operate for profit.

There is also some waste to energy and composting going on. This shows that the city is involved in some valorization of the organic waste. Waste to energy projects are mainly biogas projects and most of this waste is acquired at the location where the biogas is used e.g. piggeries, prisons and hospitals. This shows that the potential of the use of organic waste concentrated at processing houses is not explored as this waste ends up in the landfills.

The bio gas projects are being funded by the EU, showing that most of the waste management projects done in Africa are usually done when external funding has been sourced and this is due to the limited resources.

7.4 Comparison

In the cities studied, there has been an increase in the urban population. This increase in urban population has been accompanied by economic growth and increased affluence of some urban consumers – although poverty is still widespread in all three cities. This has seen a change in the consumption life styles of the urban consumers in these cities showing an increase in demand for consumer goods. This has been further reinforced by the spread of supermarkets in these areas as they seek to get a piece of this new demand. Supermarkets are offering a diverse range of products at affordable prices. In Kisumu the supermarkets have now targeted the informal settlements as they offer affordable prices the people in these areas (Odhiambo, 2014). This trend has also been observed in Kitwe and Harare and throughout Africa as reported D'Haese & Huylenbroeck, (2005) and Weatherspoon & Reardon, (2003).

The results generated have provided a quantitative estimate of the change in the quantity and composition of food-related waste generated as people move towards consumption of food from the supermarket. The results show that there would be a reduction in the weight of post-consumer waste generated, as the heavier organics become part of the supply chain waste, however the more voluminous new packaging waste will make post-consumer waste appear more plentiful than before. The reduction in weight is also likely to be offset by an increase in population, as well as consumption and possibly wastage, as people become more affluent.

These changes in waste quantity and composition have been noticed by waste practitioners in all three cities studied, but in none has it been quantified for use in waste management planning. The change in quantity is observed by the increase in waste generated as is expected with an increase in affluence and urban population. The change in waste composition has been evidenced by the increase in plastic, paper and glass packaging found in collected waste as well as along roadsides, drainage systems and illegal dumpsites.

The capacity for recycling is still low in these cities. There is no separation at source and most of this waste is either not collected or ends up in landfills where it is scavenged by informal waste

pickers. Interviews with experts showed that all the recycling in Kisumu and Kitwe is done by the informal waste pickers who then sell their items to middle men or directly to recycling companies. For Harare, there seems to be some evidence of more formal recycling schemes being set up in the recent past.

Composting and waste to energy projects were found to be done only in Harare, which is the only major city studied in this research. The secondary cities i.e. Kitwe and Kisumu had no mention of composting or waste to energy and do not appear to have the resources to engage in such valorization projects. It should be noted that Harare is a major city while the other two are secondary cities and this could account for the difference in levels of service.

8 Conclusions

The purpose of this dissertation was to illustrate what the effect of a shift in consumption from the market to supermarket would have on the waste profile of African cities and whether the waste management systems in such cities has the capacity to observe and respond to this possible metabolic shift. This chapter presents the conclusion of this research. In the first section, observations from the methodology used are presented and conclusions are drawn on the suitability of this method in contributing to this research. The second section gives an account of what has been achieved relative to the objectives set at the beginning of this dissertation. In the third section the hypotheses are reviewed and discussed. Finally recommendations are made for further research as well as urban policy makers and waste management practitioners.

8.1 Methodological Limitations and Insights

The methodology used in this research as described in chapter 3 is two-fold: Firstly it is used to describe the metabolic shift and to illustrate the effect of this shift on the waste profile; and secondly it is used to analyze the waste management systems and capacity in three case study cities.

The metabolic shift has been described as a change in provisioning from the market to the supermarket by the urban consumer. The metabolic flow model designed to illustrate the effect of the shift uses the principles of a material flow analysis in an excel spread sheet. The material flow analysis is a good method for describing the flows, however on a micro-scale, it is very dependent on the availability and the quality of the data (see section 2.3.1). In this research, there is minimal availability of data found in these African cities and thus the diets formed are subjective. However the models do illustrate the likely magnitude of the effect of the metabolic shift and the method is used is suitable.

The expert interviews done to get information on the waste management systems in these cities were all done remotely. Given that in these three cities there is limited published information, the expert interviews do provide a valuable source of data.

8.2 Achievement of Objectives

The objectives set out at the beginning of this research were to:

- 1) Develop and present models of the food flow profile for a traditional market and supermarket consumer from production to disposal and develop waste flow profiles for both the traditional market and supermarket consumer;
- 2) Analyse the effect of change in food provisioning on the waste generated ; and
- 3) Describe the impact of this effect given the current waste management capacity and structure in African cities.

The results of objective 1 and 2 are presented and discussed in chapter 5. These results are obtained from the food-waste model that is formed initially from three different diets and then applied to the three different cities. The results of objective 3 are presented and discussed in chapter 6. These results are obtained from published literature discussed at the beginning of each section in chapter 6, complemented by way of interviews with experts in each of the three cities.

8.3 Review of Hypotheses

Based on analysis of literature, the following hypotheses were drawn to shape this research. This section concludes whether these hypotheses hold.

- **Hypothesis 1:** The shift from market-based to supermarket-based provisioning doubles the waste generated per capita, as a) better organic waste utilisation resulting from supply chain optimisation is outpaced by more wastage by supermarket consumers and b) packaging waste material equals the organic waste in weight;

This hypothesis could not be shown to hold for the three cities studied in this research. In terms of weight, the food-related waste (i.e. inedibles plus packaging) produced by the pure supermarket consumer is less than the waste produced by the pure traditional market consumer, under the zero-wastage assumption. When wastage is incorporated into the model, the shift in organic waste to the supply chain is offset at a 1%, 3-4% and 7-8% level of wastage for the low, middle and high income consumer respectively.

The second part of the hypothesis does not hold for any of the three cities studied in this research. The likely increase in packaging inorganics in the waste does not equal the amount of

organic waste generated. Instead, the findings (see Table 5-7, Table 5-8, Table 5-9) show that the percentage of food-related post-consumer inorganic waste generated is a max of 46% with a shift to supermarket consumption. This value is for the high income consumer in Kisumu and all other values are lower than this for all the other groups and in all other cities. The post-consumer organic waste for the supermarket consumer thus forms more than 50 % of the waste generated across all income groups in all the three cities. This is because the inedible organics are much heavier than the light packaging material used for fast moving goods in supermarkets particularly in the food sector.

- **Hypothesis 2:** The growth in waste quantity is relatively easy to incorporate into waste management planning, but change of waste composition is usually overlooked.

Little quantitative data on waste arising over time could be found for the case study cities, and so the first part of this second hypothesis could not be verified. The model indicates that the overall amount of waste generated (i.e. that in the supply chain plus that after consumption) increases with the metabolic shift, and post-consumer waste is also very likely to increase as incomes rise, which tends to be accompanied by more wastage.

Interviews with experts confirmed that there is an increase in the variety of waste generated particularly an increase in packaging material. This is evidenced by the increase in the amount of plastics and paper that is seen at dumpsites, drainages and roadside pavements. This shows that waste management practitioners are aware of the change in the composition of the waste that is happening in these African cities. However much of this waste is disposed of in landfills or illegally and there are inadequate systems in place for valorization of the waste.

The model shows a 3-10 fold increase in the inorganic fraction of post-consumer food-related wastes where there is a shift in provisioning. This coupled with high urbanization and economic growth rates, shows that the changes are happening at a fast pace, which - given the current situation - is too high for the three cities to cope with.

The majority of the resource recovery is done by the informal sector at dumpsites and open dumps in all three cities. This shows that the recyclables in the post-consumer waste are ending up in these dumps and there is little or no separation at source. The waste management sector in these cities does not have the capacity to set up source separation of waste and thus the recycling

sector is forced to buy the waste from scavengers at these dumpsites either directly or through middle men.

There is no waste to energy or composting currently taking place in Kisumu and Kitwe and all the waste from the processing and houses ends up in the landfills. This also indicates that there is little to no involvement of the retail sector in waste management. This situation is somewhat different in Harare, where there are projects that are taking place that involve waste to energy and pilot tests for composting. There are companies like Delta beverages involved in waste recycling and there is no other company involved in waste management. However these efforts are not sufficient to deal with the waste management challenges.

There is also a lack of data to quantify the changes in consumption in all these cities. The waste management study carried out in this research is exploratory and there is also a lack of data to show how much this transition affects the waste management system in these cities. There is also no data to support the capacity for valorization of the waste and this shows that the waste management system in these African cities lacks capacity.

8.4 Recommendations

8.4.1 For Further Research

The following recommendations are made for further investigation:

This study serves only to illustrate the effect of the metabolic shift on the waste profile of urban consumers in the cities studied. The shift in provisioning has been modelled based on diets that have been formulated by the author, drawing off information from published literature that could be found. A better model could be achieved through food consumption surveys in the individual cities and thus it would be best to carry out such research in interested cities to better give a picture of the type of food eaten and where it is purchased.

Food studies done in such cities should also be done to include quantification of the flow of food through all parts of the value chain. Interviews with experts in the retail sector as well as experts in the processing and packaging industry would help shade some light on this area. Analysis of the flows through the supply chain would give a clearer picture on how the waste shift is

happening. Quantification of supply chain waste and how this has changed with the metabolic shift would be insightful information for waste management practitioners.

The waste management surveys done in these cities were done through long distance interviews and no actual survey was done on the ground in these cities. It would be recommended for waste statistics to be regularly updated in each of these cities, as available studies were either out dated or non-existent. This would give a more in depth picture on the state of the waste management sector in these cities.

8.4.2 For Material Flow Practitioners in African cities

8.4.2.1 Practitioners in Food Value Chains

The model generated shows a shift in the range of about 8-55% of the organics generated from the post-consumer waste to the supply chain waste. This presents an opportunity for new forms of waste management. The model suggests that much of the organics is now concentrated in the supply chain e.g. at pack houses. Thus it would present an opportunity for the supply chain management e.g. retailers and processors to engage in sustainable waste management practices, such as composting or waste to energy, as the majority of the organics are now concentrated here.

8.4.2.2 Waste Management Practitioners

The model shows a 3-10 fold increase in the food-related post-consumption inorganic waste generated with this metabolic shift.

The model suggests that there is potential for increased recycling opportunities at the post-consumer level especially for higher income groups. Waste management practitioners could therefore look to increase opportunities for recycling, particularly for the high income groups that have a 5-10 fold increase in the amount of inorganic waste generated. Material sorting facilities could be set up and waste separation at source encouraged as most of this valuable recyclable material ends up in landfills or is illegally dumped.

9 References

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10 Appendices

10.1 Appendix 1: Expert semi-structured Interviews

10.1.1 Kisumu Interviews

10.1.1.1 Professor Stephen Agong and Mr. Alfred Omondi

Who is responsible for the provision of Waste management services?

Private sector in collaboration with the city management

What type of waste management services do they offer? i.e. door to door collection, communal dumpsite collection?

The private waste collectors have got trucks and they do door to door collection after prior distribution of litter bags for the households to collect their litter in. They latter take them to the damp site.

The city council also have got designated points/ communal points where the public can assemble their litter after which they will be collected through city council trucks to the damp site.

Does the waste management provider have enough resources? Resources could be in terms of labour, equipment for waste collection or income.

The waste management providers do not have enough resources right from labour personnel, equipment and financial resources.

How is collection done and what is the coverage of the collection?

Collection as mentioned earlier is through door to door for private sector from the subscribed household and covers the major estates around the city. However, for informal settlement they either dump at designated points by the city management or others just throw beside the roads and dwelling places.

Are the resources for waste collection adequate?

The labour is inadequate in the sense that the public view waste collection as a dirty job left majorly for street urchins and very few semi educated individuals to do the collection, assembly and eventual dumping.

The trucks and collection tools like spades are inadequate and also the few are in deplorable conditions. Some like gloves and gum boots are completely lacking.

Very little investment goes into the waste management since its used as a public-political carrot to woo voters.

Is there any material sorting or separation of waste at source?

Recently initiatives for sorting wastes and separation at source is picking up. This has been encouraged and spearheaded majorly at the open air market places through initiatives from KLIP and other private sector players, the city management and the market traders/public in general.

How is the waste disposed of? Is it adequate?

The waste is disposed at the dump site where it is later combusted. This method seem not to be adequate in that items which do not burn like glass remain heaped at the site

Are there any studies on waste management and how are they done?

As stated earlier, waste management is now gaining considerable attention in Kisumu and major studies will soon pick up. At the moment research including KLIP researchers are carrying out studies on the same.

What has been the trend in waste composition and management over time and is this data available? (Would I be able to have access to this data?)

Waste is rapidly changing to more of packaging wastes and remains of electronic goods. The management of such wastes changes has not been in tandem with the corresponding change in waste produced. Availability of data I may not be able to confirm

How are waste management policies formulated and implemented? Do these policies consider any changes in waste structure that may occur with time?

The policies are majorly formulated by technocrats after receiving public input through public forums. The draft policies are then taken to the national assembly for debate and passing of the

bill before signing into law. At the moment the devolved system also participates through the same procedure as the national government. The policies to some extent consider waste structure changes due to the input of technocrats who are from such fields.

Are you seeing a change in the waste generated in terms of amount and composition towards more inorganics i.e. more packaging due to a changing consumer culture?

The change is pointing towards packaging but not organic. The most dominant is plastic/polythene bags.

Is there potential for recycling or other sustainable waste practices?

The potential is huge and currently KLIP in collaboration with other stakeholders is already collecting wastes and making products like crafts and ornaments for sale.

Are there any companies doing composting or waste to energy?

Currently I think at prototype level but not commercial scale.

Are the big retail companies or any other prominent companies involved in waste management?

Not any that I know of.

10.1.2 Kitwe Interviews

10.1.2.1 Dr. Albert Malama

Waste in Kitwe is provided by the Copperbelt Waste management company. The company was formed by the local authorities. There are private companies also involved in waste management in Kitwe.

The Copperbelt waste management company collects waste only in urban areas and the waste collection is not done in an economical way. Waste collection services are provided to mainly the medium and high income areas as well to the commercial sector. Low cost areas cannot afford the waste management services. The people in the low cost areas have to carry their waste to a single point for collection. In the medium and high income areas, door to door collection is done once a week in a plastic bag. A special colour plastic bag is given to households that receive service from the copperbelt waste management company. If the household place their waste in different coloured bags, this waste is not collected.

Houses sign up to receive the waste management services and this is not compulsory for all houses. On the street of Dr Malama, about 30% of the houses have signed up. The rest of the people bury or burn the rubbish. Majority of the rubbish is burnt. There are no legal frameworks or by-laws on waste management in the area and thus the sign up for waste management is voluntary. There has been no further study on waste management since the one done by Dr Malama.

The bill is paid through the water bill and sometimes the money may not be transferred from the water company.

The waste in Kitwe is taken to a dumpsite and there is no landfill for the city. The council just recently met this year to discuss plans for the development of a new landfill site.

No separation of waste at source is done and recycling is mainly done by informal waste pickers. There are 6 private waste management companies. Recently a recycling company has come up.

10.1.2.2 Mr. Collin Gwanu

Who is responsible for the provision of Waste management services?

There is no formal waste management sector in Kitwe. Therefore the Council and private operators provide services.

What type of waste management services do they offer? i.e. door to door collection, communal dumpsite collection?

Services provided by the Council are communal dump collection in public areas. Private operators provide door to door collection services.

Does the waste management provider have enough resources? Resources could be in terms of labour, equipment for waste collection or income.

The resource capacities are inadequate particularly for low cost and peri-urban housing. Higher end customers are well covered.

How is collection done and what is the coverage of the collection?

The Council and private operators use refuse compaction vehicles, skip loaders, open truck/vans, and tractor drawn trailers. The service coverage is approximately 45%. Low cost housing remains largely unserved.

Is there any material sorting or separation of waste at source?

There is little recycling at source. Most of the recycling is done at the disposal facility before final dumping.

How is the waste disposed of in Kitwe? Is it adequate?

Open dumping is practiced at the only Zambia Environmental Management Authority approved disposal site. It is certainly inadequate. However, an engineered landfill site has been approved for construction though works are yet to commence.

Are there any studies on waste management and how are they done?

Studies have been done on waste management. Of note is one that ran from 2007 to 2009 that was funded by the German Government. This involved site visits, cross-visits, and high impact-low cost waste management activities.

What has been the trend in waste composition and management over time and is this data available?

Most of the waste dumped is plastic and bio-degradable waste. No volume monitoring of the waste is currently undertaken.

How are waste management policies formulated and implemented in Kitwe? Do these policies consider any changes in waste structure that may occur with time?

Public meetings are held where the council (councilors and civil servants), private operators and members of the public have plenary discussions and break up into

specialization groups where action policies/plans are formulated. These are then presented for critique and buy-in from the other participants.

Are you seeing a change in the waste generated in terms of amount and composition towards more inorganics i.e. more packaging due to a changing consumer culture?

Yes – more plastic.

Is there potential for recycling or other sustainable waste practices in Kitwe?

There is potential for recycling and a number of companies has commenced. However, most of the waste is reclaimed for export particularly China.

Are there any companies doing composting or waste to energy?

None.

Are the big retail companies or any other prominent companies involved in waste management?

Their participation is not structured, monitored, nor managed.

10.1.3 Mr. Daniel Phiri

Possible questions that will be asked to retail experts include:

- Is there a shift in consumption provisioning towards supermarkets?

Yes,

- What are the most commonly consumed foods?

Food stuffs

- Is there a fast growth rate of supermarkets?

Yes, 3-4 supermarkets are under construction

- Is there a growth in demand for consumer goods?
Yes, but have no data
- What is the waste profile for retail waste and how is this waste handled?
Plastics, glass bottles, vegetables mainly

Possible questions that will be asked to waste management experts include:

- Who is in charge of providing waste management services in the city?
Cop Waste and Private Collectors
- Collection, transportation and disposal services, adequate? Any separation?
- What proportion of city receives this service?

High and medium cost areas

- How has this changed over the years?
Not changed much
- How much waste is collected and how is it disposed of? (safe disposal, adequate facilities)
Do not have data
- How often is a waste characterization survey done?
Rarely
- Is there a transition in choice of consumption provisioning?
No
- Are they picking up on any effects of this transition in the waste profile?
No

- Is the waste management system able to adapt to changes in consumption and hence waste profiles?

No

- What do logistic centers and retail stores do with their waste?

Wait for local authorities to collect

- What are the major challenges to waste management in the city?

Yes, lack of equipment; no sanitary landfill

- Are there any sustainable waste management programs e.g. recycling, composting?

None, only dumping at a designated dump site

10.1.4 Harare Interviews

10.1.4.1 Mr. Tawanda Matsuka Interview Notes

Epworth has a local board that is supposed to be responsible for provision of waste management services. However Literature shows services are provided by CBOs and NGOs. Epworth is also considered under Harare. Epworth does not have proper infrastructure and is an informal settlement. It is overcrowded and poorly planned. However some areas are starting to become formalised.

The situation of waste management provision is bad but there has been an improvement. Recently the city council of Harare bought 42 refuse collection trucks for the 42 wards. This is an improvement as now each ward has a refuse collection truck. However this is still not enough as some wards require 4 or even 5 trucks. This is an improvement from 2008 (check literature for 2008). There are still issues of reliability, management and maintenance of these truck. A large amount of waste is thus still not being collected and there are a lot of illegal dumpsites.

Recycling companies do exist and have also started to come up. Tawanda, CEO of Petreco says there have been companies recycling paper and other forms of plastic like LDPE and HDPE.

However PET was not considered. However PET became a very serious problem. This was further intensified by the shift of the beverage industry from glass to plastic packaging.

Collection of recyclable waste by the recycling companies is done with the help of the informal sector. The informal collectors go around collecting the material from illegal dumpsites, street pavements and collection sites. The recycling companies hire trucks to go around collecting this waste once there is adequate stock. The volumes collected are not large enough and thus it is not worth it for them to have their own trucks.

Many recycling companies have come up in the last 12 months. There are other companies doing Paper recycling that have been around, however the market is not big. In 2009 two major paper industries shut down due to the economic situation in Zimbabwe. Some of the recycled paper is however being exported to Zambia.

At the start of PETRICO, there were no numbers on plastic flows available. This information is still not there and studies on waste management are lacking. Two studies have been recently done at the University of Zimbabwe but however the reliability of the waste figures is questionable. However these studies offer a good starting point. There is a National waste management strategy coming up.

10.1.4.2 Mr. Muzofa Interview

Harare waste management is provided by the local authority in Harare city. The statistics for waste management are recorded every three months (quarterly). The waste is divided into organics, plastic, paper, glass, cans and hazardous waste. Majority of the waste is sent to the landfill. There are plans to develop a new sanitary land fill as well as have a waste to energy plant on site. They spent 12 weeks going door to door to industries trying to get them involved and getting those that are involved in waste management.

In terms of the Environmental management act, they plan to set up environmental action plans and environmental groups for the city of Harare.

A lot of recycling is done by the informal sector. Mainly by scavengers who wait for compactors. The recycling industry is starting to take off. There are new guys on the block who are involved

in the recycling of rubber. A lot of paper and plastic recycling is happening now. They are trying to introduce the idea of getting a livelihood from waste. This will especially help the poor. A large volume of plastic and paper from packaging being collected for recycling. The informal sector is developing much faster in this segment and a lot of flea markets are coming up around the city to sell goods made from recycled paper and plastic.

Delta Beverages is involved in collection of cans and bottles. Some of the recycled cans and bottles is being exported to South Africa. Baling of aluminum cans is also happening.

There is an organization that is coming in to recycle glass, cans and plastic

There are programs to generate organic fertilizer from the organic waste collected. This has been tried out in Chitungwiza and Epworth and is to be introduced in Harare. This is however still in the research phase. Organic fertilizer program is being set up ward by ward.

Separation of waste is happening in Mbare.

Bio reactors have been established in Harare with funding coming from EU. 800m³ bio digester has been set up. Bio gas has been used in Harare in hospitals, prisons, schools and in the pig industry. There are 200m³ plants already operating in the city.

There is research that is being done to convert waste to energy.

10.1.5 Mr. Emmanuel Muzah Responses

Who is responsible for the provision of Waste management services?

City of Harare (Council) is responsible

What type of waste management services do they offer? i.e. door to door collection, communal dumpsite collection?

Are the resources for waste collection adequate?

Door to door collection. Can also bring waste to the dumpsite and pay dumping fees

Does the waste management provider have enough resources? Resources could be in terms of labour, equipment for waste collection or income?

Not enough resources in terms of refuse trucks and landfill equipment. Financing Challenges

Coverage comprises residential, commercial, industrial- just about all waste. There is no material separation at source. The waste is comingled.

How is the waste disposed of? Is it adequate?

The waste is disposed by landfilling with severely inadequate equipment to the extent that the site is more of a dump

Are there any studies on waste management and how are they done?

Have no documents on file for any studies done

What has been the trend in waste composition and management over time and is this data available? (Would I be able to have access to this data?)

There has been a remarkable increase in paper and other packaging. I can only provide estimated streamlining/profile. No record of trends is available

How are waste management policies formulated and implemented? Do these policies consider any changes in waste structure that may occur with time?

For Harare we depend on legislation like the Harare Waste Management by- Laws of 1979 and guidelines derived from EMA. Agree these may be outdated.

About 70% of the waste is organic comprising food and other household waste as well garden and farm/markets waste

There is a high potential for recycling and waste to energy ventures. There are some recycling companies for paper and plastic and now PET. Still require big investors with funds and technology. We are receiving proposals for waste conversion and recycling. There is no large scale composting

Are the big retail companies or any other prominent companies involved in waste management?

Are there any companies doing composting or waste to energy?

There are few companies engaged in waste collection from industry and commerce.

10.2 Appendix 2: Diets

Table 10-1: Showing example of working class diet

Breakfast	Measure	Amount	Mass (g)	kCal
Brown bread, whole wheat	1 slice	4	112	277
Fresh milk, whole milk	1 cup	2	488	298
Tea, black, brewed with tap water	1 cup	1	237	2
Sugars, granulated white	1 tsp	3	12.6	49
Lunch				
Stiff-maize meal	1 plate	1	450	557
Peanuts, all types, dry-roasted, without salt	1 cup	0.5	73	427
Tomatoes	1 medium Tomato	2	246	44
Onions	1 medium	1	110	44
Carrots	1 medium carrot	2	122	50
Spinach, cooked, boiled, drained, with salt	1 cup	1	180	41
Passion-fruit, (granadilla), purple, raw	1 cup	1	236	229
Sugars, granulated white	1 tsp	3	12.6	49
Salt	1 tsp	0.25	1.5	0
Supper				
Rice, white, long grain, regular, cooked	1 cup	1.5	237	308
Fish, fresh, stew	1 small fish	1	135	115
Tomatoes	1 medium Tomato	2	246	44
Onions	1 medium	1	110	44
Carrots	1 medium carrot	2	122	50
Passion-fruit, (granadilla), purple, raw	1 cup	1	236	229
Sugars, granulated white	1 tsp	2	8.4	33
Salt	1 tsp	0.25	1.5	0
			Total	2890

Table 10-2: Showing example of vegetarian class diet

Breakfast	Measure	Amount	Mass (g)	kCal
Tea, black, brewed with tap water	1 cup	2	474	4.74
Brown bread, whole wheat	1 slice	4	112	276.64
Bananas	1 NLEA serving	2	252	224.28
Sugars, granulated white	1 tsp	4	16.8	65.016
Lunch				
Brown bread, whole wheat	1 slice	4	112	276.64
Margarine, regular, 80% fat, composite, stick, with salt	pat (1" sq, 1/3" high)	2	10	71.7
Lettuce, green leaf raw	1 leaf outer	2	48	7.2
Tomatoes	1 medium Tomato	1	123	22.14
Peppers, sweet, red, raw	medium	0.5	54.5	16.895
Cucumber, peeled, raw	1 small	0.5	79	9.48
Bananas	1 NLEA serving	2	252	224.28
Oranges, raw, all commercial varieties	1 fruit	3	393	184.71
Sugars, granulated white	1 tsp	3	12.6	48.762
Supper				
Potatoes, boiled, cooked without skin, flesh, salt	1 medium potato	4	668	574.48
Peas, green, cooked, boiled, drained, with salt	1 cup	1.5	240	201.6
Rice, white, long grain, regular, cooked	1 cup	1	158	205.4
Tomatoes	1 medium Tomato	2	246	44.28
Onions	1 medium	1	110	44
Spinach, cooked, boiled, drained, with salt	1 cup	1	180	41.4
Peppers, sweet, red, raw	medium	2	218	67.58
Avocados, raw, all commercial varieties	1 avocado	0.5	100.5	160.8
Oranges, raw, all commercial varieties	1 fruit	3	393	184.71
Salt	1 tsp	0.25	1.5	0
Avocados, raw, all commercial varieties	1 tsp	2	8.4	32.508
			Total	2989.241

10.3 Appendix 3: Packaging Weight

Table 10-6: Showing packaging weight and ratios for different materials

Packaging material	Quantity	Unit	Mass of pack (g)	mass of net quantity of item (g)	Weight Ratio:pack/net
Food can	330	g	37	330	0.112
Food can	410	g	52	410	0.127
Long Life Carton (milk)	1	l	49.23	1032	0.048
long life carton milk cap	1	l	1.62	1032	0.002
Orange juice bottle	1	l	46.51	1038	0.045
Orange juice bottle cap	1	l	2.37	1038	0.002
Plastic bag	1	bag	6	6000	0.001
Water bottle	500	ml	22.75	500	0.046
Water bottle cap	500	ml	2.00	500	0.004
Mixed vegetable bag	1000	g	9.65	1000	0.010
Mince wrapping Styrofoam tray	244	g	3.9	244	0.016
Mince wrapping Cling wrap	244	g	3.1	244	0.013
Meat wrapping styrofoam tray	366	g	8.9	366	0.024
Meat wrapping Cling wrap	366	g	3.9	366	0.011
Chicken pack (styrofoam tray)	520	g	8.9	520	0.017
Chicken pack (cling wrap)	520	g	5.8	520	0.011
Fish pack	400	g	38.5	400	0.096
Rice pack	2000	g	17.3	2000	0.009
Oats box	1100	g	55.9	1100	0.051
Cereal box	500	g	95.4	500	0.191
Plastic in cereal box	500	g	8.4	500	0.017
Bread pack	500	g	6.6	700	0.009
Pnp plastic bag	1	bag	12.3	8000	0.002
18 large egg tray	1	tray	86.6	918	0.094
Spaghetti pack	500	g	4.3	500	0.009
Coke can	440	ml	38.7	488.4	0.079
Yoghurt bowl	1000	g	34.9	1000	0.035
Yoghurt cap	1000	g	8.0	1000	0.008
Peanut butter pack	400	g	52.5	400	0.131
Peanut butter cap	400	g	8.3	400	0.021
Beans (black)	1000	g	8.7	1000	0.009
Plastic bag(fruit & veg in supmkt)		g	2.2	2000	0.001
Plastic bag(for fruit & veg in mkts)			1.0	1000	0.001
Plastic Curry package	100	g	3.3	100	0.033
Tea paper box	25000	g	39.9	25000	0.002
Tea foil wrap	8333	g	1.3	8333	0.000
Salt	500	g	2.8	500	0.006
Sugars, granulated white	1000	g	9.0	1000	0.009
2 l PET bottle	2	l	49.0	2220	0.022
2 l PET bottle cap	2	l	2.2	2220	0.001
Sunflower oil bottle	2	l	55.4	1838	0.030
Sunflower oil bottle cap	2	l	3.3	1838	0.002
lettuce	200	g	5.6	200	0.028
sweet corn/maize	206	g	8.9	206	0.043
sweet corn/maize	206	g	2.3	206	0.011
maize meal (pap)	2500	g	16.3	2500	0.007
muesli	750	g	14.2	750	0.019