Beatrice Obule-Abila

Knowledge management approach for sustainable waste management

Evolving a conceptual framework

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Julkaisun nimike
Tietojohtamisen lähestymistapa kestävään jätehuoltoon: käsitteellisen viitekehyksen kehittäminen

Tiivistelmä

Jätehuolto on maailmanlaajuinen kysymys, joka vaatii radikaalia muutosta. Jätehuollon radikaali muutos voidaan saavuttaa soveltamalla tietojohtamisen työkaluja ja lähestymistapoja. Tässä väitöskirjassa kehitettiin käsitteellinen viitekehys tietojohtamisen soveltamiseksi kunnallisten ja muiden jätteiden hallintaan. Väitöskirja ehdottaa myös ratkaisuja kunnallisten jätteiden ongelmiin, arvioi jätehuollon merkitystä ympäristön kestävyydelle, tarkastelee taloudellisten kannustimien merkitystä jätteiden kierrätykselle Suomessa sekä käsitystä taloudellisista kannustimista jätteiden kierrätykseen Nigeriassa. Tämä väitöskirja koostuu kuudesta artikkelista, joissa on käytetty eri tutkimusmenetelmiä tutkimuskysymyksiin vastaamiseksi. Työssä on käytetty sekä laadullisia että määrällisiä tutkimusmenetelmiä.

Tutkimuksessa esitetään käsitteellinen viitekehys jätehuollolle sekä käsitteellinen viitekehys tietojohtamiselle jätehuollossa. Tutkimus ehdottaa ratkaisuja jätehuollon ongelmiin uudenlaisesta näkökulmasta. Väitöskirja perustelee käsitteellisen jätehuollon viitekehyksen kautta holistista näkökulmaa nykyaikaisen jätehuollon määritelmäksi.

Tutkimus osoitti, että jätehuollon tietojohtamisessa on aukkoja, ja suosittelee tietojohtamisen holistista soveltamista kestävään jätehuoltoon.

Tutkimus tarjoaa perustan jatkotutkimuksille tietojohtamisen soveltamisesta jätehuoltoon.

Asiasanat
Jäte, jätehuolto, tietojohtaminen, kestävä jätehuolto, käsitteellinen viitekehys

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Knowledge management approach for sustainable waste management: evolving a conceptual framework

Abstract

Waste management is a global issue requiring radical change. Radical change for waste management can be achieved through the application of knowledge management (KM) tools and approaches. This dissertation develops a conceptual framework for applying KM in the management of municipal and other type of waste. The dissertation also proffers solutions to municipal waste problems, assesses the relevance of waste management to environmental sustainability and examines the perceived role of financial incentives for recycling waste in Finland and Nigeria.

This dissertation is a compilation of six articles achieved by employing mixed research methodologies to provide answers to the research questions. The mixed method comprises conceptual-qualitative and survey-quantitative research approaches.

The study presents a conceptual framework of waste management as well as a conceptual framework of knowledge management in waste management. The conceptual framework of waste knowledge management illustrates processes that waste companies and other stakeholders can adopt in order to attain sustainable waste management. Through its conceptual waste management framework, this dissertation establishes a contemporary definition for waste management from a holistic perspective. Furthermore, the study proffers solutions to waste management problems from an external point of view.

The research identifies the existence of knowledge gaps in waste management and recommends the holistic application of knowledge management tools, systems and approaches in waste management in order to attain sustainable waste management.

This study provides a foundation for future studies to further explore the application of knowledge management in waste management.

Keywords

Waste, waste management, knowledge management, sustainable waste management, conceptual framework

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This dissertation and doctoral degree are dedicated to the memory of my father, Fredrick C. Obule, whose diligent work, aspirations and humble achievements laid the foundation for my education.

Contents

Figures

Tables

Abbreviations

CE	Circular Economy
EU	European Union
MoE	Ministry of Environment
ICT	Information and Communication Technology
EC	European Commission
UNEP	United Nations Environment Programme
USEPA	United State Environmental Protection Agency
WB	World Bank
OECD	Organization for Economic Co-operation and Development
MWM	Municipal Waste Management
PAHO	Pan-American Health Organization
IPCC	Intergovernmental Panel on Climate Change
MSW	Municipal Solid Waste
MW	Medical Waste
WHO	World Health Organization
CDW	Construction and Demolition Waste
EEE	Electrical and Electronic Equipment
WEEE	Waste Electrical and Electronic Equipment
PDA	Portable Digital Assistant
IW	Industrial Waste
AW	Agricultural Waste
GHG	Green House Gas
SECI	Socialization Externalization Combination Internalization
WKM	Waste Knowledge Management
SPSS	Statistical Package for the Social Sciences
WM	Waste Management
KM	Knowledge Management
SWM	Sustainable Waste Management
EPR	Extended Producer Responsibility
SDGs	Sustainable Development Goals
US	United States

Publications

This dissertation is comprised of the following six articles:

[1] Abila, B., Abila, N., & Kantola, J. (2020). Knowledge management approach for sustainable waste management: evolving a conceptual framework. *International Journal of Environment and Waste Management*. Forthcoming. An earlier version of this paper was presented at the International Conference on Innovation and Management [ICIM] 2014, Vaasa, Finland.

[2] Abila, B., & Kantola, J. (2013). Municipal solid waste management problems in Nigeria: evolving knowledge management solution. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering,* 7(6), 303-308.

[3] Abila, B., & Kantola, J. (2017). Proposed solutions in municipal solid waste management*. International Journal of Environment and Waste Management, 19(4), 297-317.* An earlier version of this paper was presented at the Global Cleaner Production and Sustainable Consumption [GCPC] Conference 2015, Sitges, Barcelona, Spain.

[4] Abila, B., & Kantola, J. (2019). Waste Management: relevance to environmental sustainability. *International Journal of Environment and Waste Management, 23(4), 337-351*. An earlier version of this paper was presented at the Global Cleaner Production and Sustainable Consumption [GCPC] Conference 2015, Sitges, Barcelona, Spain.

[5] Abila, B., & Kantola, J. (2019). The perceived role of financial incentives in promoting waste recycling – empirical evidence from Finland, *Recycling, 4(1), 4.*

[6] Abila, B. (2018). Households' perception of financial incentives in endorsing sustainable waste recycling in Nigeria, *Recycling, 3(2), 28.*

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1 INTRODUCTION

1.1 Background

During the last decade, the 'circular economy' (CE) has gained increasing attention and it is the primary focus of the Helen MacArthur Foundation (Anastasiades et al., 2020). Recently there has been significant interest in the circular economy as a panacea to overcoming prevailing production and consumption models. These models are based on the increasing use of natural resources and unceasing growth (Näyhä, 2019). "CE is most frequently depicted as a combination of reduction, reuse, and recycling activities, and is potentially linked to sustainable development concepts" (Peiró et al., 2019). "CE plays a vital role in waste management (WM) by emphasizing recycling of materials and energy, and turning them into valuable resources for another actor" (Paes et al., 2019). Geng et al. (2010) emphasize that the environment, the economy, and the society can present positive effect when CE is incorporated into the management of solid waste, since these are pillars of WM (Paes et al., 2019).

WM is an important end point in all industry-demanding production and service-value chains. The entire product or some components of it end up as waste in the production cycle. Service provisions also generate waste directly or indirectly, particularly in the metropolitan settlements with high population densities. Though waste generation is at the extreme end of the production or service chain, it constitutes an important index in the assessment of the sustainability of products' or services' life cycles. WM is crucial in attaining sustainable development. WM is a cross-cutting issue impacting each of the sustainability domains (environmental, economic and social) (Silva et al., 2019).

WM is a global concern, but it is more severe in developing countries, posing varied problems and challenges to the environment, municipal authorities and inhabitants (Wilson and Velix, 2015). Managing waste sustainably may require the application of knowledge management (KM) tools, systems and approaches that will guarantee a sustainable environment and ensure the derivation of socio-economic and other benefits. Applying KM tools, systems and approaches for WM in municipalities can be essential for promoting recycling, reuse, as well as energy recovery.

"The approach of the European Union (EU) to WM is based on the waste hierarchy which sets the following priority order when shaping waste policy and managing

waste at the operational level: prevention, (preparing for) reuse, recycling, energy recovery and as the least preferred option, disposal (which includes landfilling and incineration without energy recovery)" (European Commission, 2019). The EU WM policy set out the WM objectives for recycling, recovery of materials and using waste as a source of energy (Ministry of Environment (MoE), 2011). The Finnish legislation on waste treatment is connected to EU legislation (MoE, 2013). However, the Finnish Waste Act of 2011 aims to "prevent the hazard and harm to human health and the environment posed by waste and WM, to reduce the amount and harmfulness of waste, to promote the sustainable use of natural resources, ensure functioning WM, and to prevent littering". The EU-wide legislation on waste, as well as the Finnish waste related acts, have brought about marked improvements in WM in Finland over the last decades (MoE, 2011b). Despite the progress already achieved in improving WM in Finland, there is still much to be done. There are knowledge gaps between the existing legislation and its implementation at the municipal level, at the WM companies' level, and at the level of the generators of waste in most municipalities. In a report to the United Nations Division for Sustainable Development, the MoE noted that "despite tighter requirements and technological improvements, the use of waste as substance (materials) or for energy generation has not progressed in accordance with the objectives of the revised 2005 National Waste Plan for Finland". Attainment of the Finnish National Waste plan for 2016 and the National Biowaste Strategy both require a better understanding of the existing knowledge gap.

"Finland represents a sparsely populated industrialized nation with a forest-dominated landscape" (Saikku and Mattila, 2017). Finland had a population of 5,528,008 at the end of May 2020 (Statistics Finland, 2020). Finland is situated in Northern Europe and has borders with Sweden to the west, Russia to the east, Norway to the north and Estonia to the south beyond the Gulf of Finland (Ylä-Mella et al., 2014). Finland is the eighth largest country in Europe with a total area of 338,400 km^2 of which approximately 10% is inland waters (Ylä-Mella et al., 2014). The low population density had an effect on the structure of waste management; long transportation distances led to numerous small landfills throughout the country (Sokka et al., 2007). In the 1970s it was suggested that the number of landfills should be reduced and use of existing landfills should be more effective (Piippo, 2013). Although landfilling was the main waste disposal technique until the 1990s, there were a few serious attempts at both incineration and composting (Piippo, 2013).

"African nations, of which Nigeria occupies a predominant position, are experiencing rapid urbanization and a tremendous expansion in industry and technology" (Anetor, 2016). Nevertheless, according to Abila (2017), in most

developing countries, the existing system of WM is primitive, thereby inefficient in achieving desired global goals. In Nigeria, the management of waste has been a predominant issue and challenge, posing varying degrees of problems including technical, economic, institutional, policy, social, environmental and legislative (Okot-Okumu and Nyenje, 2011; Ezeah and Roberts, 2012). Consequently, the structure of WM still adopts the conventional models and hence it is still at the preliminary phase. In Nigeria, the increasing generation of waste is facilitated by population growth, economic growth, rapid urbanization, industrialization, low level of environmental awareness, poverty, weak governance and commercialization (Adewuyi et al., 2009; Ezeah and Robert, 2014).

Nigeria has the largest population of any African country. "Significant population clusters are scattered throughout the country, with the highest density areas being in the south and south west" (World-Factbook, 2018). In July 2018, Nigeria had a population of 203,452,505 (World-Factbook, 2018). "The problem of WM is intensified with increasing population growth" (Anetor, 2016). The country has a total area of 923,768 km^2 consisting of 910,768 km^2 land mass and 13,000 km^2 water (World-Factbook, 2018). It shares borders with the Republic of Benin in the west, Chad and Cameroon in the east and Niger in the north (Adewunmi et al., 2012). Nigeria is Africa's energy giant and is richly endowed with diverse energy sources varying from crude oil, natural gas, coal and lignite, hydro power, solar radiation, wind, biomass (fuel wood, animal and plant waste) and nuclear power (Oseni, 2012). It is the continent's most prolific oil-producing nation, which along with Libya, accounts for two-thirds of Africa's crude oil reserves (Oyedepo, 2012). It ranks second to Algeria in natural gas (Oyedepo, 2012).

Rawshan et al. (2009) demonstrated that understanding behaviour is critical to minimizing municipal solid waste (MSW), but there are very significant barriers, such as lack of knowledge among the general public as well as social norms that adversely affect WM practices. A key concern is the knowledge gap or dysfunction in information provided to aid waste generators in sorting, separating, packing and delivering waste to the waste collection points.

The existence of knowledge gaps contributes to increasing inefficient use of energy, labour, machinery and processing by the WM companies. Understanding the waste generation in municipalities and knowledge-related factors underpinning WM, is usually an essential tool to meet the Finnish, EU and global targets on waste.

In fostering sustainable waste management (SWM), it is essential to assess the knowledge gap in the WM chain between the waste generation points (households, industries, businesses such as food producers and distributors within

municipalities) and the WM companies responsible for the collection and disposal of waste. Camelia and Valentina (2008) stated that the processes involved in WM are difficult to design and the knowledge in the area is not always sufficient or certain.

The derivable benefits from SWM can be environmental, economic and social. Benefits include reduced contributions to climate change, air pollution mitigation, reduced need for raw materials, resource and energy recovery, energy generation and job creation.

KM definitions vary from author to author. According to Hislop (2009), KM can be defined as a broad term that requires the systematic efforts of an organization to manage its personnel knowledge. An organization can do this through a broad range of direct and indirect methods such as specific types of Information and Communication Technology (ICT), management of social processes, structuring the organization in a particular way or via the use of particular cultural and people-management practices. Secondly, KM can be defined as the access and utilization of different resources to create an environment where individuals acquire, share and use information to build on existing knowledge (Haapalainen and Pusa, 2012). KM is one of the emerging topics in academic and professional discourse in many fields including waste management (Kebede, 2010). According to Brian (2002), KM is the collection of processes that promotes the creation, diffusion and adoption of knowledge. In essence, knowledge has to undergo a series of processes for its value to be retained and not lost. KM consists of activities and practices that are relevant to WM organizations in gaining knowledge from their own experience and the experience of others, and the judicious application of information and data.

1.2 Research problem, questions and objectives

The world population is estimated to reach to 9.7 billion by 2050, resulting in increased demand for resources and increased production of waste (Guran et al., 2019). Therefore, today's approach to WM will not be adequate for future applications (Guran et al., 2019) and a KM approach may be needed for advancing WM. Furthermore, Das et al. (2019) noted that the analysis of the research data collected in his paper revealed that an improved approach to integrate social, economic, institutional, legal, technical and environmental aspects is essential for the sustainable management of solid waste.

According to Lenkiewicz and Webster (2017) "Making progress in addressing WM issues will contribute directly to 12 out of the 17 Sustainable Development Goals

(SDGs), but has indirect links towards achieving all 17 SDGs" (UNEP, 2018). Lenkiewicz (2016) "goes so far as to state that the SDGs cannot be met unless WM is addressed as a priority" (UNEP, 2018).

SWM has direct links to many worldwide issues such as public health, climate change, ocean plastic, poverty, food security, sustainable production and consumption as well as resource depletion (UNEP, 2018). "As a cross-cutting issue, environmentally sound SWM is therefore a strong entry point to achieving a range of SDGs" (UNEP, 2018).

In comparison to other EU and non-member states, Finland generates a particularly large amount of waste. "On average, 22.4 tonnes of waste were generated per inhabitant in 2016, more than four times the 5.0 tonnes per inhabitant average across the EU-28" (Eurostat, 2019). This explains why Finland was chosen as a case country. Furthermore, in Finland, insufficient data about MSW generation and composition in different areas has been one of the challenges to increasing the recycling rate (Sahimaa, 2017). An insufficient quantity of data on waste generation and composition reveals the existence of knowledge gaps in WM. Up-to-date data on the composition of mixed MSW, i.e., residual waste left after source separation of hazardous waste and recyclables, is a precondition for developing the WM system (Sahimaa, 2017). EU countries are expected to recycle 50% of their municipal waste by 2020 (European Environmental Agency, 2013), as well as achieve the target of 65% for recycling municipal waste by 2030 (EC, 2016). In the case of Finland, the MSW recycling rate lies substantially far behind these targets, at 41% (Dahlbo et al., 2018). In order to achieve the 50% recycling target by 2020, let alone the new recycling target of the CE package, Finland has to significantly increase the recycling of MSW in the following years (Liikainen et al., 2016). Therefore, the need to investigate the role of financial incentives in executing the recycling of MSW from a consumers' perspective is critical.

The population of Nigeria is expected to increase from more than 203 million in 2018 to 392 million in 2050, becoming the world's fourth most populous country (World -Factbook, 2018). "Nigeria's sustained high population growth will continue for the foreseeable future because of population momentum and its high birth rate" (World-Factbook, 2018). It is known that the problem of WM is amplified with increasing population growth rate (Anetor, 2016). This explains why Nigeria was chosen as a case country. Generally, the status of WM in Nigeria is deplorable and therefore poses a serious threat to public health and the environment (Nnaji, 2015). Municipal waste management authorities do not have relevant data (Nnaji, 2015). The absence of a formal recycling platform is another

challenge to recycling of waste (Abila, 2018; Nnaji, 2015). Hence reliable data on recycling rate are not available.

Despite the advancement of science and technology, even with the existence of economic and social progress, municipalities, regions and countries continue to struggle with the management of waste. Meanwhile, waste is not just useless materials, but could be a source of useful materials and energy. The struggle with managing waste may be due to existing knowledge gaps in WM. The knowledge gaps include inefficient data on E-waste, lack of data for MSW, few reliable statistics for construction and demolition waste, low level of awareness of E-waste, lack of awareness on CDW, poor classification, etc. (Parthan et al., 2012; Bernado et al., 2016; Chibunna et al., 2012; Yuan 2013). To solve the research problem and achieve the research objective, I set out to ask the critical questions and attempt to provide answers through this research. The research questions are as follows:

1. What kind of framework is best suited for applying a KM approach in the management of municipal and other types of waste?

2. What kind of KM solution is best suited for MSW management problems and how useful are bi-approaches for attaining the sustainable management of MSW?

3. How environmentally sustainable are the management techniques for MSW?

4. How important are financial incentives for the recycling of MSW?

These research questions lead to the research objectives. The general objective of the study is to explore KM approach and contribution towards the sustainability of the WM sector.

The specific objectives of the study are as follows:

1. To develop a WKM conceptual framework for municipal and other types of waste.

2. To identify MSW management problems and evolve KM solution.

3. To propose two approaches for attaining sustainable MSW management.

4. To evaluate the environmental consequences of the management techniques for MSW.

5. To investigate the perceived role of financial incentives in executing the recycling of MSW in Finland.

6. To examine households' perception of financial incentives in the adoption of sustainable recycling for MSW in Nigeria.

These objectives were achieved by providing answers to the research questions in published peer reviewed scientific articles. Figure 1 shows the connections between the research questions and objectives.

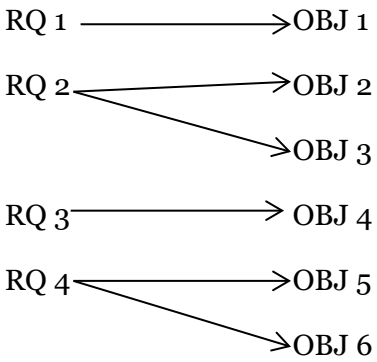

Figure 1. Connections between research questions and objectives

Other types of waste include medical waste, construction and demolition waste, electrical and electronic waste, industrial waste, and agricultural waste, but not radioactive waste. Financial incentive is relevant in this research as an instrument which facilitates KM in WM. It creates an environment where individuals acquire, share and use information to build on existing knowledge. Invariably, there is an indirect link between financial incentives and KM. The bi-approach comprises the KM solutions and product design. The bi-approach is relevant in this research as it presents one approach which focuses on KM solutions in WM and another approach which facilitates KM in WM through the explicit acquisition and use of information to build on existing knowledge.

Below, Table 1 highlights some aspects of the articles.

Table 1. Aspects of the articles

Research Objectives	Ordering of articles	Title	Research designs	Tools	Unit of Analysis
To develop a WKM conceptual framework for municipal and other types of waste.	One	Knowledge management approach for sustainable waste management: evolving a conceptual framework.	Qualitative (Formative)	Literature review and synthesis	Global
To identify MSW management problems and evolve KM solution.	Two	Municipal solid waste management problems in Nigeria: evolving knowledge management solution.	Qualitative (Formative)	Literature review and synthesis	National
To propose two approaches for attaining sustainable MSW management.	Three	Proposed solutions in municipal solid waste management.	Qualitative (Formative)	Literature review and synthesis	National
To evaluate the environmental consequences of the management techniques for MSW.	Four	Waste management: Relevance to environmental sustainability.	Qualitative (Formative)	Literature review and synthesis	Global
To investigate the perceived role of financial incentives in executing the recycling of MSW in Finland.	Five	The perceived role of financial incentives in promoting waste recycling – empirical evidence from Finland.	Quantitative (summative)	Percentages, mean, standard deviation, Spearman's rho and t-test.	Individual
To examine households' perception of financial incentives in the adoption of sustainable recycling for MSW in Nigeria.	Six	Households' perception of financial incentives in endorsing sustainable waste recycling in Nigeria.	Quantitative (Summative)	Percentages, mean, standard deviation, and Spearman's rho.	Household

1.3 Research motivation

As a development advocate and WM expert, I have been keenly observing WM and the challenges it poses in relation to attaining sustainable development in Nigeria. I lived in the mega-city of Lagos, Nigeria. With about 20 million inhabitants, managing waste in Lagos presents both opportunities and threats. Coming to Finland, I observed that WM concern is not just a problem for developing countries. Even with the advancement in science, social and technological indices, Finland, and indeed other developed countries, are struggling with WM challenges. Before starting my study, I made a number of visits to a WM company and observed the existence of a knowledge gap in the WM sector in Finland. There seems to be no KM synergy between the various stakeholders in the WM sector in Finland. For example, the KM tools and techniques being deployed by the waste companies do not fully take cognizance of the peculiarities of waste generators. More importantly, WM legislation is seriously disconnected from the WM practices at the municipal and national level. The motivation for the study evolved from the observation of a wide knowledge gap in the management of waste.

1.4 Research approach

The approach adopted in this dissertation is a mixed methods research which involves the combination of data, results and inferences from both qualitative research and quantitative research separately conducted to generate a synchronized and generalized point of view for the evolvement of KM in WM.

1.5 Research design and strategy

This research is explorative, descriptive and evaluative in nature. This study adopts a mixed research method, i.e., it employs both quantitative and qualitative methods including survey and conceptual study, respectively. Empirical data were elicited from field studies using a well-structured questionnaire which included only closed-ended questions. Respondents included waste generators from residential and educational institutions at household and individual level. Both descriptive and inferential statistics were used to analyse the data. A review of extant literature was used to gather information for the conceptual study.

This dissertation is a compilation of articles including six published articles. Articles 1 – 4 applied a qualitative, conceptual research approach through

literature analysis and synthesis. From this evolved a WKM conceptual framework for applying a KM approach in the management of municipal and other types of waste, a KM solution, bi-solutions for MSW and an analysis of the environmental consequences from management strategies for MSW. Quantitative, empirical research was implemented for articles 5 and 6 through a field survey to investigate consumers' perceived role of financial incentives in executing recycling of MSW in Finland, and to assess households' perception of financial incentives in the adoption of sustainable recycling of MSW in Nigeria. A later chapter discusses in detail the research methodology and design. Figure 2 presents an overview of the research design and steps implemented to proffer answers to the research questions and achieve the research objectives.

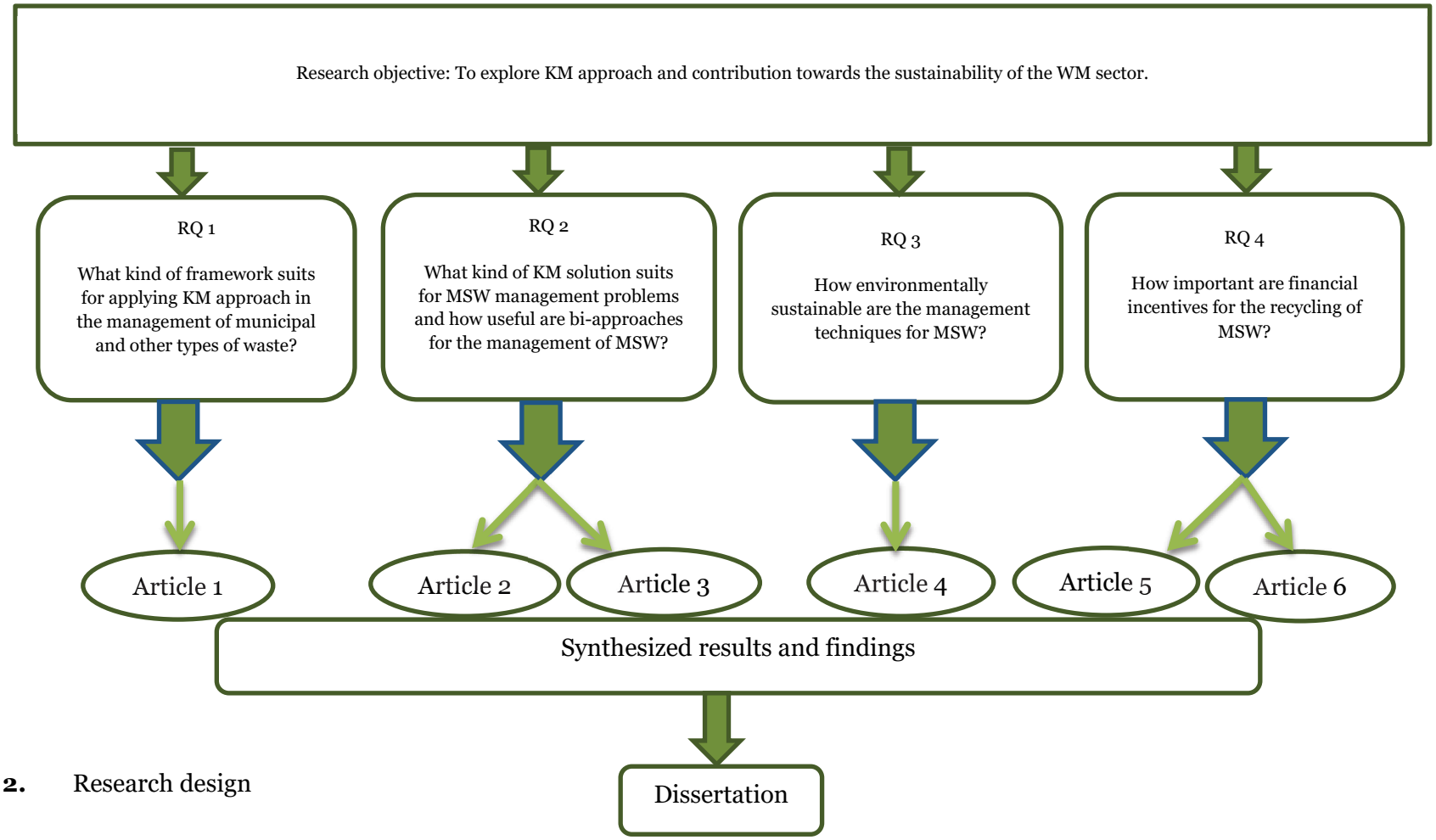

Figure 2. Research design

1.6 Structure of the dissertation

The dissertation comprises two main parts. The first is made up of six chapters and the second consists of a compilation of six articles. The first chapter presents the background to the research and research problem. This chapter highlights the research questions, research objectives as well as the research design. Chapter 2 outlines relevant literature for the research on WM and KM. Chapter 3 describes the methodological options applied for the research and the research approach. Chapter 4 summarizes the articles and outlines the findings, reliability and validity. Chapter 5 highlights the contribution of the research (including the theoretical contributions), policy implications and managerial implications. Finally, Chapter 6 presents the conclusions, research limitations and possible future research.

2 LITERATURE REVIEW

2.1 Waste

Different scholars and organizational bodies including the European Commission (EC), United States Environmental Protection Agency (USEPA), World Bank (WB), United Nations Environment programme (UNEP), Organization for Economic Co-operation and development (OECD), have outlined definitions of waste (EC 2008; OECD, 2003; UNEP, 2015; USEPA, 2018).

The term 'waste' is a very broad concept (UNEP, 2015). "The Global Waste Management Outlook focuses on one group of many usages of the word waste: unwanted or discarded materials 'rejected as useless, unneeded or excess to requirements" (UNEP, 2015). Waste can be considered as the mix of four wrongs – a wrong substance, of the wrong quality, in a wrong place, at a wrong time (UNEP, 2015). "Even this usage of waste is still broad as it includes such unwanted outputs of human activity as gases, liquids and solids as well as discharges to the three environmental receiving media of air, water and land". "The UN Statistics Division uses the term 'residuals' rather than waste in this broad context". "It is in this narrower context that internationally agreed definitions of waste exist" (UNEP, 2015).

The EC (2008) defines waste "as any substance or object which the holder discards or intends to or is required to discard". Discarding does not simply means getting rid of something, but also covers activities such as recycling and recovery. "Waste refers to materials that are not prime products (that is products produced for the market) for which the generator has no further use in terms of his or her own purposes of production, transformation or consumption, and of which he or she wants to dispose" (OECD, 2003). Waste has often been described either as residue, by-products or end products of consumption and production processes (Drackner, 2005; Singh et al., 2014). Furthermore, by-products involve the products that originate from industries and can be put to use in a similar or different production process by the same or different company. By-products are waste which, after certain processing operation such as recycling, gain market value and can be reused (Agovino et al., 2018). The Basel Convention defines waste as "substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law" (UNEP, 2015). "This includes substances or objects which are subject to disposal operations which rather lead to or do not lead to the possibility of resource recovery, recycling, reclamation, direct reuse or alternative reuses" (UNEP, 2015). An informal

overview of this definition of waste might simply be 'stuff individuals throw away' (UNEP, 2015).

It is noteworthy to state that the focus of this dissertation is on solid waste.

2.2 Waste types and definitions

The waste types reviewed in this section are based on the waste types linked to this research.

2.2.1 Municipal solid waste

There is a level of disparity in the definition of MSW across countries, regions, organizations and scholars. MSW does not include waste from production, agriculture, forestry, fishing, septic tanks, sewage networks and treatment plants (including sewage sludge), end of life vehicles or construction and demolition waste (EC, 2018). The definition is without prejudices to the allocation of responsibilities for WM between public and private sectors. OECD defines MSW to cover waste from households including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, yard and garden waste, street sweepings, contents of litter containers, and market cleansing (Hoornwerg and Bhada-Tata, 2012). Pan-American Health Organization (PAHO) defines MSW as solid or semi-solid waste generated in population centres including domestic and commercial as well as that originating from small-scale industries and institutions (including hospitals and clinics); market sweeping and from public cleansing (Hoornwerg and Bhada-Tata, 2012). The Intergovernmental Panel on Climate Change (IPCC) includes the following in MSW: food waste, garden (yard) and park waste, paper and cardboard, wood, textiles, nappies (disposable diapers), rubber and leather, plastics, metal, glass, pottery and china, ash, dirt, dust, soil, electronic waste (Hoornwerg and Bhada-Tata, 2012). MSW is composed of food waste and rubbish waste from residential areas, street sweepings, commercial and institutional waste, as well as construction and demolition debris. Industrial and faecal matter waste are not yet formally considered part of municipal waste are often found in the municipal waste stream (Eawag, 2008). According to Gupta et al. (2015), MSW is generally a combination of household and commercial refuse which is generated from the living community. MSW can be broadly classified as organic and inorganic substances. On the basis of physical classification of MSW, the waste stream has been categorized into six different components: kitchen waste or yard waste, paper or cardboard waste, plastics, metals, glass, inert and miscellaneous (Kumar and

Samadder, 2017). In Finland, MSW is classified into kitchen waste, glass and bottles, metals, landfill waste, paper and cardboard, and hazardous waste (Abila and Kantola, 2014). In Nigeria, MSW can be classified into paper, vegetable matter, plastics, metals, textile, rubber and glass (Ogwueleka, 2009).

It can be concluded that MSW is defined as waste generated from households and other sources such as business institutions, educational institutions, health institutions, agricultural institutions, construction and demolition institutions and industrial institutions that have similar waste to that generated by households.

2.2.2 Medical waste

Medical waste (MW) is synonymously referred to as health-care waste, as well as hospital waste, yet there is no global or even regional consensus on the definition of this term (Insa et al., 2010). The World Health Organization (WHO) defines MW as the waste generated from health care by health-care activities, comprised of infectious and pathological waste, sharps, chemicals, pharmaceutical and genotoxic, radioactive and heavy metal waste (Komilis, 2015). According to the WHO (2018), major sources of MW are hospitals and other health facilities, laboratories and research centres, mortuary and autopsy centres, animal research and testing laboratories, blood banks and collection services, and nursing homes for the elderly.

2.2.3 Construction and demolition waste

Previous authors have defined construction and demolition waste (CDW) in related forms. According to Menagaki and Damigos (2018), CDW is defined as a mixture of diverse materials, such as inert waste, non-inert-non-hazardous waste, and hazardous waste generated from construction, renovation and demolition activities. CDW is defined as a mixture of surplus material derived from construction, renovation and demolition activities, for instance site clearance, land excavation, roadworks and demolition (Jin et al., 2017). CDW is a combination of inert solid waste (soil, slurry, concrete and rocks) and non-inert solid waste (metals, timber, plastics and packaging waste) comprising substances abandoned due to construction, renovation or demolition of civil structures (Faleschini et al., 2017). CDW is defined as the material which needs to be transported elsewhere from the construction site or used on the site itself other than for the intended specific purpose of the project (Esa et al., 2017). It also includes material which, due to damage, excess or non-use, cannot be used due to non-compliance with the specification, or which is a by-product of the construction process (Esa et al.,

2017). CDW is composed mainly of wood products, asphalt, drywall, concrete and masonry. Other components often present in significant quantities include metals, plastics, earth, shingle, insulation, cardboard and paper (Yehehis et al., 2013). Furthermore, there is the possibility to recycle many of these materials. However, with respect to the EU decree 2008/98/EY to recycle or reuse 70% of non-hazardous CDW, Finland is yet to meet the stipulated recycling rate as 40% of the CDW is composed of wood which is incinerated (Rautkoski et al., 2016).

2.2.4 Electrical and electronic waste (E-Waste)

E-waste is a term used to cover all types of electrical and electronic equipment (EEE) that has or could enter the waste stream (Song et al., 2015). The term E-waste is synonymously used with waste electrical and electronic equipment (WEEE). EEE includes large and small household appliances, ICT equipment (including computers, computer games, peripherals), cellular phones and other telecommunication equipment, portable electronic devices (such as portable digital assistants, PDAs), video and audio equipment (including MP3 players and peripherals) and electrical tools (Babu et al., 2007).

2.2.5 Industrial waste

OECD (2001) defines industrial waste (IW) as liquid, gaseous and solid waste originating from the manufacture of specific products. IW is generated by the industrial activity of factories, mills and mines and often a significant portion of IW is solid waste (Song et al., 2015). IW includes waste generated from the production of energy and even mining waste in some countries (Singh et al., 2014).

2.2.6 Agricultural waste

Agricultural waste (AW) which is also referred to as agro-waste, comprises animal waste (manure, carcasses, etc.), crop waste (cornstalks, sugarcane bagasse, drops and culls from fruit and vegetables, prunings) food processing waste, and hazardous and toxic waste (pesticides, insecticides, herbicides, etc.) (Agamathu, 2009). OECD (2001) defines AW as the waste produced as a result of various agricultural operations and includes manure and other waste from farms, poultry houses, slaughterhouses, harvest waste, fertilizer run-off from fields, pesticides that enter into water, air or soils, and salt and silt drained from fields.

2.3 Waste management generation rates and challenges across the globe

WM is a global challenge and it has been greatly accelerated by the increasing diversity of waste characteristics, a booming economy, an increasing population, a rise in the standard of living, a lack of effective implementation of waste policies as well as changing lifestyles and increased production processes (Song et al., 2015; Mmereki et al., 2016). According to a World Bank (WB) report, waste generation rates around the world are rising (World Bank, 2019). The continuous increasing generation of waste is a challenge that needs a more focused strategy to address the root cause of the problem on how waste generation is linked to consumption (Singh et al., 2014) as well as production. The incessant generation of waste is more pronounced in developed countries than developing countries. Despite the significant progress achieved in developed countries, there are still loopholes such as the fact that WM legislation has not been fully complied with. One instance of this is the lack of conformity to the EU WM in the case of Finland and Norway who have prioritized waste-to-energy treatment for recycling. According to Statistics Finland (2019), recovery of municipal waste as energy has in recent years been the predominant recovery method. In Norway, recycling is the second waste disposal option after incineration (Malinauskatie et al., 2017). In most developing countries the improper management of waste is an issue resulting from poor funding, poor legislation and implementation of policy, limited infrastructures and professionalism, low awareness levels, poor recovery and recycling programs, and poor treatment and disposal techniques (Abila and Kantola, 2017).

Environmental, social and economic sustainability are critical global concerns arising from the increasing generation of waste and improper management of waste. These concerns vary from emissions of greenhouse gases (GHG) contributing to climate change, public health, depletion of natural resources, aesthetics and pollution. Waste issues have become regarded as global issues rather than national or local environmental problems, owing to the significant contribution of waste-related greenhouse gases to climate change (Singh et al., 2014). Waste related greenhouse gases are projected to rise from 5% to 9% in the year 2020 (Singh et al., 2014; UNEP 2011).

In the year 2016 the world's cities generated a total of 2.01 billion tonnes of solid waste, amounting to a footprint of 0.74 kilograms per capita per day (WB, 2019). With rapid population growth, industrialization and urbanization, annual waste is projected to increase by 70% from the 2016 levels to 3.40 billion tonnes in 2050 (WB, 2019). In developed countries, the waste generation rate is twice the rate of developing countries with 1.00 to 2.50 kg/capita/day and 0.50 to 1.00

kg/capita/day, respectively, due to economic and social prosperity (Kumar and Samadder, 2017). According to the Eurostat, each individual in the EU generated an estimated 475 kg of waste in 2014 (Hauser and Blumenthal, 2016) and in the United States (US) an estimated 730 kg is generated yearly (Jouhara et al., 2017). MSW definitions differ between country, region and authors, and this in the long run affects the actual global estimates for MSW generation

E-waste is mainly produced in OECD countries whose EEE markets are saturated (Ongodo et al., 2011). In 2011, it was estimated that global E-waste generation is increasing by 40 million tons per year (about 0.63 kg/year*capita, EU: 16-18 kg/year*capita) (Song et al., 2015). E-waste contains more than a thousand difference substances, many of which are toxic (Widmer et al., 2005). In US landfills, about 70% of heavy metals come from E-waste (Widmer et al., 2005). A major issue throughout the Asian region is transboundary movement of E-waste (Herat and Aghamuthu, 2012).

Another scenario for CDW where there is an absence of a reliable database to support a proper diagnosis of waste generation in urban construction as well as incomplete understanding of the link between the causes of waste generation and the increasing volume of waste generated (Magalhaes et al., 2017). Worldwide, it is estimated that about 35% of the total quantities of CDW generated is diverted to landfills (Menagaki and Damigos, 2018). In China 84% of CDW was landfilled in recent years, far exceeding the local landfill capacity (Jin et al., 2017). Mahpour (2018) summarized potential barriers to moving toward CE in CDW management. In his study he outlined numerous potential barriers including the non-green design of construction projects, inadequate policies and legal frameworks to manage CDW, a lack of supervision of CDW management, a lack of empirically based literature on the barriers, user preferences for new construction materials over reusable or recycled ones, non-standardized CDW reduction reporting as well as a lack of accessible data.

A major issue with MW is that its definition varies across countries and thus its constituents might differ (Komilis, 2015). The absence of a standard definition has led to a lack of standardization of MW streams and disposal receptacles (Windfeld and Brooks, 2015). It is recognized that certain categories of MW are among the most hazardous and potentially dangerous of all wastes arising from a community (Ali and Kuroiwa, 2009).

Generation rates for IW are largely unknown due to incomplete, heterogeneous and uncertain available data. The unreliability of the data might be due to the fact that in most countries IW is managed by the municipalities (Singh et al., 2014). IW producers are constantly faced with the options of managing their waste and

must choose from a number of disposal and treatment options. Increasingly, IW producers are opting to export their waste to other countries, mostly developing countries. The illegal dumping and transboundary movement of IW, particularly the hazardous waste, commonly attracts more attention due to the potential threat to the environment and human health (Song et al., 2015).

Millions of tonnes of agricultural waste are produced annually from both plant and animal sources (Li and Cheng, 2020). A management scenario of agricultural waste is the green biomass which is usually stocked on the farm and left to self-drying and self-decompose in more European countries, resulting to environmental problems and disposal costs (Corato, 2020). Another scenario is the burning of crop residues post harvest seasons in many developing countries, arising to increased quantity of greenhouse gases, air pollutants and particulate matter (Li and Cheng, 2020).

2.4 Waste management and sustainability

WM is a complex field, which goes beyond prevention, sorting, collection, transportation, treatment and disposal of waste. It embraces a broad ambit of socioeconomic development, government regulations, policy options and resource management (Malinauskaite et al., 2017). It involves protecting, preserving and improving the quality of the environment and human health. It also involves ensuring prudent and rational utilization of natural resources and promoting a more circular economy by improving resource use and efficiency and ensuring waste is valued as a resource (Malinauskaite et al., 2017). According to the EU (2008), WM means the collection, transport, recovery and disposal of waste, including the supervision of such operations and after-care of disposal sites and includes actions taken as a dealer or broker. The management of waste involves the generation, prevention, characterization, monitoring, treatment, handling, reuse, recycling, repair, recovery and the disposal of the final residual of various types of waste.

Brundtland (1987) defines sustainable development as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". SWM refers to the management of the system without compromising the need of future generations (Gahana et al., 2018). Furthermore, the sustainable management of waste entails applying KM approaches, systems and tools to the listed activities and the goals being pursued (Abila et al., 2014). In addition to the activities and systems in place for managing waste, ensuring joint decision-making, partnership and interaction between

stakeholders and the various agents involved in the WM chain, are also acceptable definitions of sustainability in the WM sector (Abila et al., 2014).

It can be concluded that WM is the integration of the different phases in the WM chain or system and sustainability is the management of the WM system through the application of KM tools, systems and approaches without jeopardizing the environmental, economic and social needs of future generations.

2.5 Knowledge management

KM is a discipline that is relevant to a diverse range of fields. The prominent fields are philosophy, cognitive science, management science, knowledge engineering, information science, artificial intelligence, social science and economics (Pandey and Dutta, 2013).

KM is derived from the conceptualization of two terms namely 'knowledge' and 'management'. To understand KM it is important to define knowledge and management.

"Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information" (Davenport and Prusak, 1998). "It originates and is applied in the minds of knowers". "In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms" (Davenport and Prusak, 1998). Nonaka (1994) classified knowledge into explicit and tacit. Explicit knowledge is the knowledge that is impersonal, objective, context independent, can be expressed in formal and systematic language, and is easily shared and stored (Hislop, 2009; Faucher et al., 2008). Tacit knowledge is the knowledge that resides in an individual's mind and is transparent, highly personal, subjective and inexpressible in a codified form (Hislop, 2009; Faucher et al., 2008).

The word management can be used as both a noun and an adjective (Hislop, 2009). "The word management used as a noun, refers to a group of people who have responsibility for managing people and other organizational resources. When used as an adjective, management refers to the process by which people and organizational resources are controlled and coordinated with the intention of achieving particular objectives" (Hislop, 2009).

2.5.1 Knowledge management definitions

Different schools of thoughts have defined KM in several ways and valid definitions that align with this research are considered. A number of definitions for KM are presented in Table 2.

Table 2. Definitions of knowledge management

Definition	References
KM is an umbrella term that requires systematic efforts of an organization to manage its personnel knowledge through a broad range of direct and indirect methods such as specific types of ICT, management of social processes, structuring of the organization in a particular pattern or via the use of particular culture- and people-management practices.	Hislop (2009)
KM is the accessing and utilization of different resources to create an environment where individuals acquire, share and utilize information to build on existing knowledge.	Haapalainen and Pusa (2012)
KM is the process of capturing, sharing and effectively using knowledge.	Kantola et al. (2017)
KM is the 'strategies and processes of identifying, capturing, and leveraging knowledge'.	Yahya and Goh (2002)
KM basically involves knowledge creation, knowledge dissemination and knowledge implementation.	Pillania (2009)
KM emphasis is on capturing, creating, preserving, sharing and utilizing knowledge.	Lwoga (2011)
'KM is the systematic process and strategy for finding, capturing, organizing, distilling and presenting data, information and knowledge for a specific purpose and to serve a specific organization and community'.	King (2005)
KM involves knowledge creation, knowledge interpretation, knowledge dissemination and use, and knowledge retention and refinement.	McAdam and McCreedy (1999)

In this context, it can be concluded that KM refers to a broad term that focuses on technology- and people-centred strategies through the application of KM tools and networks for creating, sharing, capturing, organizing, storing, accessing and reusing knowledge to attaining the sustainable management of waste.

2.5.2 Knowledge management strategies

A KM strategy describes the overall approach that organizations or communities intend to take to align their knowledge resources and capabilities to the intellectual requirements of the strategy, thus reducing the knowledge gap between what must be known and what is known (Merono-Cerdan et al., 2007).

There are a number of KM strategies in the KM literature. However, Hansen's et al. (1999) typology of KM strategy is the most influential and referenced (Hislop, 2018; Oluikpe, 2012). In essence, two viewpoints of KM strategy, the 'codification and personalization', have dominated KM discourse (Greiner et al., 2007; Oluikpe, 2012). The objective of the codification strategy is to collect knowledge, store it in a database and provide the available knowledge in an explicit and codified form (Greiner et al., 2007). In contrast, the focus of the personalization strategy is not to store knowledge, but to use ICT and networks to help people communicate their knowledge. The objective of the personalization strategy is to transfer, communicate and exchange knowledge via knowledge networks such as discussion forums, video conferencing, teams or communities of practice (Greiner et al., 2007).

Merono-Cerdan et al. (2007) reviewed KM strategies and identified a distinction between a system-oriented and human-oriented approach. The system-oriented approach focuses on codifying, storing and sharing knowledge formally through the evolution of information, communication and cloud technologies. In contrast, a human-oriented approach emphasizes dialogue through social networks and person-to-person contacts, focuses on acquiring knowledge via experience and skilled people, and attempts to share knowledge informally. Table 3 highlights a view of the main KM strategies.

Table 3. Types of knowledge management strategies

System-oriented	Human-oriented	Author and year
Codification	Personalization	Hansel et al. (1999), Greiner et al. (2007), Merono-Cerdan et al. (2007), Oluikpe (2012), Al-Hakim and Hassan (2013), Cheng (2017).
Exploitation	Exploration	March (1991)
Pure procedure	Pure expertise	Bohn (1994)
Exploiters	Innovators, explorers	Bierly and Chakrabarti (1996)
Explicit-oriented	Tacit-oriented	Jordan and Jones (1997)
Conservative	Aggressive	Zack (1999)
Cognitive model	Community model	Swan et al. (2000)
Technocratic	Organizational, Spatial	Earl (2001)
Codification	Tacitness	Schulz and Jobe (2001)
System-oriented	Dynamic, human-oriented	Choi and Lee (2003)

Source: Adapted from Merono-Cerdan et al., 2007.

System-oriented KM strategies are technology-based and human-oriented KM strategies are people-based. These two forms of strategies are critical in implementing KM.

2.5.3 Knowledge management model

The Nonaka socialization, externalization, combination and internalization (SECI) model is a recognized conceptual knowledge creation model reflecting the dimensions of knowledge and is perhaps the most cited theory in KM domain to date. It represents the single most influential and widely referenced theory in the KM domain (Hislop, 2009). The Nonaka model of knowledge creation spiral encompasses socialization, externalization, combination and internalization dimensions of knowledge. These four dimensions of knowledge can be classified into codification and personalization strategies (Oluikpe, 2012). The externalization and combination of views of the spiral focus more on codified knowledge while the socialization and internalization views are linked to personalization (Oluikpe, 2012). According to Nonaka and Takeuchi (1995), organizational knowledge creation is a continuous and dynamic interaction between tacit and explicit knowledge. In the Nonaka SECI model of knowledge creation spiral, there are four modes of knowledge conversion. First, socialization involves the conversion of tacit knowledge into new forms of tacit knowledge. Next is externalization which involves the conversion of tacit knowledge into explicit knowledge. Combination involves the integration of different forms of explicit knowledge to create new forms of explicit knowledge. Finally, internalization involves the conversion of explicit knowledge into tacit knowledge (Hislop et al., 2018). Figure 3 shows the Nonaka SECI model of knowledge creation.

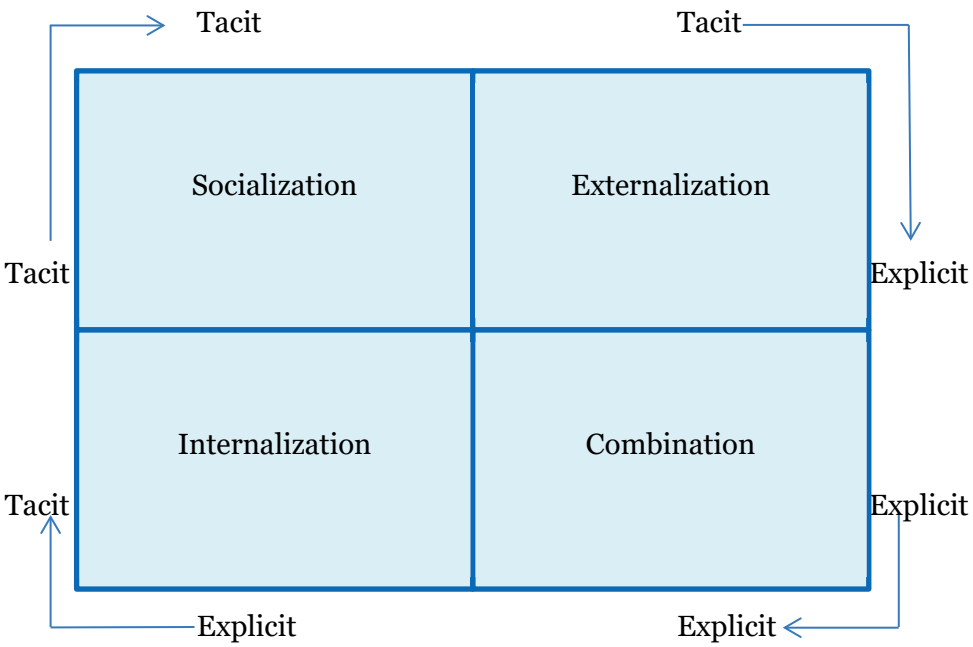

Figure 3. Nonaka SECI model of knowledge creation

Source: Nonaka (1994)

2.6 Synthesis of the conceptual framework

This research is the combination of three broad theories which connect to the literature. These theories are KM, WM and sustainability. These theories provide the fundamental principles guiding the theoretical background to achieve the research objectives in this dissertation. Despite the application of current theories in providing a strong background in WM, the concept of KM in the literature does not exist. To this end the deployment of KM in WM is new and hence the pedestal for this research. Figure 4 illustrates the synthesis of the conceptual framework.

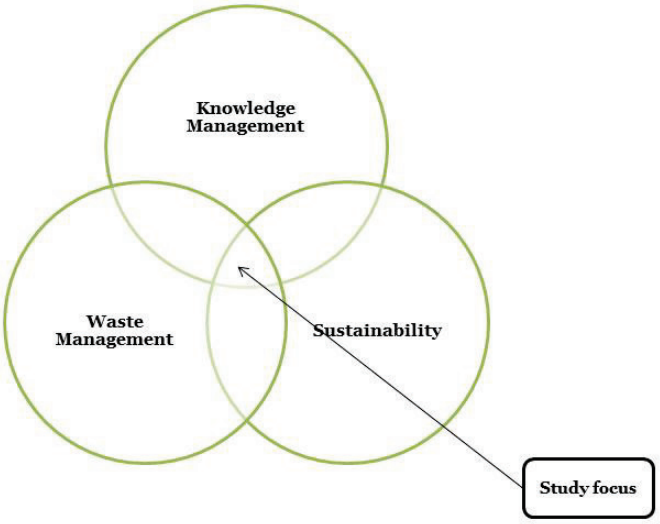

Figure 4. Synthesis of the conceptual framework

In this dissertation, the concept of KM is linked to WM through the evolution of KM tools, systems and approaches. However, this has been construed via the adoption of certain technologies and techniques in WM reflecting the KM processes. In the backdrop of prompt advancement, ICT has become an inevitable part of the plan and design of modern solid waste management (Hannan et al., 2015). These ICTs, generally known as technologies, can facilitate capturing, storing, analysing, processing and communication of information in solid waste management. These technologies can be classified into four categories: spatial technologies, identification technologies, data acquisition technologies and data communication technologies (Hannan et al., 2015). In essence, these ICTs can be designated as KM tools which are applied in the management of waste. Furthermore, Gründler et al. (2006) describes the 'WasteInfo' KM system, developed and implemented in Germany, as a clearinghouse of comprehensive information on broad categories of waste, to be made available to an array of decision-makers. KM is crucial in the pursuit of various WM goals and in creating synergy between different goals. Abila and Kantola (2013) postulated that managing MSW efficiently requires the application of KM tools throughout the WM chain. Specifically, situating KM in WM will involve deploying the KM cycle which includes acquisition, classification, organization, storage, sharing,

utilization, creation or re-creation and identification of waste (Rubenstein-Montano et al., 2001).

The three dimensions of sustainability are classified as economic, social and environmental (Cruz et al., 2019) and have been named as the pillars of sustainability (Sahimaa et al., 2017). In the wider context, environmental sustainability is superior to other dimensions, because other dimensions cannot be strengthened without the system upon which they are dependent, i.e., the environment (Sahimaa et al., 2017). Likewise, the overarching goal of WM is to attain economic, social and environmental sustainability (Paes et al., 2019). Thus, WM and sustainability are interconnected as the broad goal of WM and dimensions of sustainability are in parallel. It can be concluded that the goals of WM are embedded in sustainability. "In the context of SWM, sustainability can be defined as the assessment of environmental, economic and social impacts of available WM treatment options" (Cucchiella et al., 2017). Towards attaining sustainability solid WM approaches have been altered into a more practical and effective option on the basis of "reduce", "reuse" and "recycle" (3R) principle (Das et al., 2019).

3 RESEARCH METHODOLOGY

3.1 Research approach

The broad research approach, which is the plan or proposal to conduct research, involves the intersection of philosophical world views, research designs and specific methods (Creswell and Creswell, 2018). The approach adopted in this dissertation is the mixed methods research approach. This involves the combination of data, results and inferences from both qualitative research and quantitative research separately conducted to generate a synchronized and generalized view of the KM approach and contribution towards the sustainability of the WM sector.

3.1.1 Definition of mixed methods research

According to Creswell and Creswell (2018), "mixed methods research is an approach to inquiry involving collecting both quantitative and qualitative data, integrating the two forms of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks to yield additional insight beyond the information provided by either the quantitative or qualitative data alone". The core assumption of this form of inquiry is that the combination of qualitative and quantitative approaches provides a more complete understanding of a research problem than an individual approach (Creswell, 2014). A mixed methods study is an approach which involves the collection or analysis of both quantitative and qualitative data in a single study in which the data are collected concurrently or sequentially, are given priority, and involve the integration of the data at one or more stages in the process of research (Flick, 2011). It is an expansive and creative form of research. It is not a limiting form of research, rather it is inclusive, pluralistic and complementary (Johnson and Onwuegbuzie, 2004). Central to mixed methods research, is the idea of integrating quantitative and qualitative data sets and explicitly interrelating subsequent results to reach justifiable conclusions (Ivankova and Wingo, 2018). Viewing another definition, the mixed methods research approach is defined as consisting of a set of designs and procedures in which both quantitative and qualitative data are collected, analysed and mixed in a single study or a series of studies (Clark et al., 2008). Mixed methods research is the form of research wherein elements of qualitative and quantitative viewpoints, data collection, analysis, inference techniques are combined to achieve the broad aims of breadth and depth of understanding and corroboration (Griesvien et al., 2014). Based on the analysis of a number of definitions, Johnson et al. (2007) defined mixed methods research "as the type of

research in which a researcher or team of researchers combines element of qualitative and quantitative research approaches". Mixed methods research has a philosophical level and it concentrates on collecting, analysing and combining qualitative and quantitative data with a similar research aim at the methodological level (Zou et al., 2018). From the aforementioned definitions, a synthesis of outcomes of quantitative and qualitative research approaches implemented in sequence or concurrently, leads to a combined methods approach commonly known as mixed methods research.

3.1.2 Rationales for mixed methods research in the dissertation

It is believed that the findings of mixed methods research are more comprehensive and valid than the findings of a single method that is either quantitative research or qualitative research (Mengshoel, 2012). Furthermore, mixed methods research may be viewed as providing a more complete and deeper understanding of the subject under investigation and having greater scope (Griensven et al., 2014). In order words, through the integration of quantitative and qualitative study, researchers are able to maximize the strength and minimize the weakness of each individual approach (McLaughlin et al., 2016). The reasons for integrating quantitative and qualitative research strategies are as follows: a single data source may not be sufficient, initial results need to be explained, exploratory results need to be generalized, a second method can enhance a study, a theoretical stance is best employed with qualitative and quantitative results, and multiple research phases help to understand a research objective better (Akimowicz et al., 2018). In this dissertation mixed methods research enables the researcher to address complex research problems and questions, find answers to both exploratory and confirmatory questions within a single study and reveal a holistic picture of a phenomenon in practice (Ivankova and Wingo, 2018). Mixed methods research has been developed and is becoming increasingly important in several scientific areas (Zou et al., 2018). As a result of the above-mentioned rationales, mixed methods research is growing in its adoption globally as evidenced by a continual increase in the use of mixed methods dissertations and funded mixed methods research (Guetterman and Fetters, 2018).

3.1.3 Philosophical worldviews/paradigms

According to Creswell and Creswell (2018), "Philosophical worldview is viewed as a general orientation about the world and the nature of research a researcher brings to a study, and it is a basic set of beliefs that guide a research action". Philosophical worldviews are paradigms that provide information on the reasons

researchers choose a specific research design or strategy (Abutabenjeh and Jaradet, 2018). The term worldview and paradigm are synonymously used in research (Griesvien et al., 2014). Hence, philosophical worldview and paradigm are used interchangeably in this dissertation. Paradigm implies a system of thought or practice that dominates thinking, feeling and doing in a field. To a large extent it becomes the norm, deviation from which can be quickly and easily detected (Dai and Chen, 2013). "It is in terms of the importance of shared beliefs within a community of researchers who share a consensus about which questions are most meaningful and which methods are most appropriate for answering those questions" (Morgan, 2014). According to Creswell (2018), four philosophical worldviews commonly discussed in the literature are postpositivism, constructivism, transformative frameworks and pragmatism.

1. Postpositivism: The postpositivist assumptions hold true more for quantitative studies than qualitative studies. It holds a deterministic philosophy in which causes (probably) determine effects or outcomes. It claims that the world exists apart from our understanding of it (Morgan, 2014).

2. Constructivism: This is habitually incorporated with interpretivism and is typically viewed as an approach to qualitative research. Inquirers generate or inductively develop a theory or pattern of meaning. Constructivists believe that individuals seek understanding of the world in which they exist and work. It emphasizes that the world is created by our conceptions (Morgan, 2014).

3. Transformative framework: A transformative worldview embraces the idea that research inquiry needs to be interwoven with politics and a political change agenda to confront social oppression at whatever levels it occurs. It focuses on the needs of groups and individuals that may be marginalized or excluded in our society.

4. Pragmatism: This is a typical paradigm that ascends out of actions, situations and consequences rather than antecedent conditions (as in postpositivism). Rather than inquirers concentrating on the research methods, they emphasize the research problem question and use all approaches available to understand the problem. It involves the application of pluralistic approaches to derive knowledge of the problem in view.

With the aforementioned delineation of the classification of paradigms, this dissertation follows the pragmatist paradigm or worldview. Also, the paradigm

classification explicitly reflects that the pragmatism paradigm followed in this dissertation is appropriate for the study.

3.1.4 Research designs and methods

Research designs are types of inquiry within qualitative, quantitative, mixed methods approaches that provide specific direction for procedures in a study (Creswell and Creswell, 2018). Research designs are the overall blueprints from which you draw inferences about the quality of the data you collect (Francisco et al., 2001). Research design is considered to be a plan that the researcher needs to determine regarding what to observe and analyse, why and how (Abutabenjeh and Jaradet, 2018). Once a research topic is identified and questions are formulated, choosing the research design is perhaps the most important decision a researcher makes (Abutabenjeh and Jaradet, 2018). Abutabenjeh and Jaradet (2018) noted that the best study designs use more than one research method, taking advantage of their different strengths. It is noteworthy to state that Creswell and Creswell (2018) classified and discussed the three groups of research designs as quantitative, qualitative and mixed research design. The desire to increase the overall generalizability of the study is an additional reason to utilize a mixed research design (Abowitz and Toole, 2010). There are different criteria used in categorizing research methods. In some studies, the criteria are based on data collection technique (e.g., interview, observation, questionnaire). In others the criteria are based on data analysis technique (e.g., quantitative, qualitative) (Chu and Ke, 2017). Consequently, there are three broad categories of research methods: quantitative methods, qualitative methods and mixed methods. This dissertation adopts the mixed research methods, more precisely survey research and conceptual research.

Table 4. Research approach adopted in the publications

Publications	Paradigms	Research methods	Research designs
1	Constructivism	Literature review and synthesis – review on waste management, global waste management concerns, global waste management goals, and situating knowledge management in waste management.	Qualitative (conceptual)
2	Constructivism	Literature review and synthesis – review on existing management of	Qualitative (conceptual)

		municipal solid waste in Nigeria, policy and regulations, problems affecting municipal solid waste management, and knowledge management challenges relating to municipal solid waste.	
3	Constructivism	Literature review and synthesis – review on waste management practices in Nigeria, challenges in policy and regulation, municipal waste management challenges, and designing a recycling solution using axiomatic design.	Qualitative (conceptual)
4	Constructivism	Literature review and synthesis – review on municipal solid waste management for different countries, waste management hierarchy for developed and developing countries, emissions emanating from municipal solid waste disposal and management, and environmental effects associated with municipal solid waste management.	Qualitative (conceptual)
5	Postpositivism	Face-to-face approach, structured questionnaire, data collection from 123 respondents (staff and students) across the five higher institutions in Vaasa, Finland. Data analytics tool – Statistical Package for the Social Sciences (SPSS), descriptive statistics (frequency, percentage, mean, standard deviation), inferential statistics (Spearman's rank order correlation, t-test,).	Quantitative (survey)
6	Postpositivism	Door-to-door approach, structured questionnaire, data collection from 135 households in Shomolu Local Government Area, Lagos State, Nigeria. Data analytics tool – Statistical Package for the Social Sciences (SPSS), descriptive statistics (frequency, percentage, mean, standard deviation), inferential statistics (Spearman rank order correlation).	Quantitative (survey)

With reference to Table 4, qualitative and quantitative research approaches are adopted for the publications. Quantitative research employs objective measures such as tests, surveys and uses statistical and numerical analysis techniques (Taguchi 2018; Griesvien et al., 2014). Conversely, qualitative research is concerned with meaning, context and personal experience with the aim to understand, represent or explain (Griesvien et al., 2014). Quantitative research relies on a postpositivism paradigm, postulating the existence of a relatively stable material reality that occurs across different cultures and contexts (Mengshoel, 2012). On the other hand, qualitative research is often based on a constructivist paradigm, postulating that there are multiple realities bound to context, time and culture that can be studied by examining people's experiences and what is happening in social situations (Mengshoel, 2012). In general, this dissertation adopts the mixed methods research approach which is derived from the fusion of two typical research approaches used for the publications.

3.2 The research onion

The research onion is used for explicitly buttressing, simplifying and expatiating the research methodology relative to each article for this study. According to Saunders et al. (2016) there are six layers to the research onion. The outermost layer of the research onion is the philosophical worldview followed by the middle layers comprising research reasoning, methodological choices, research strategy(ies), time horizon and finally the core which is research techniques and procedures. On the basis of the aforementioned, the research methodology for this study is further explained.

Philosophical worldview: As previously discussed in the above subsection, the four philosophical worldviews commonly found in the literature are postpositivism, constructivism, transformative frameworks and pragmatism. Articles 1 – 4 follow a constructivism paradigm, while articles 5 and 6 are inclined towards a postpositivism paradigm. Constructivism and postpositivism are the two paradigms reflected in these publications. Furthermore, the typical different paradigm applied to these publications leads to the pragmatism worldview resulting in the pluralistic approaches (combination of qualitative and quantitative methods) followed in this dissertation.

Research reasoning: There are three forms of research reasoning: deductive reasoning, inductive reasoning and abductive reasoning (Saunders et al., 2016). Deductive reasoning involves the development of a theory that is then subjected to a rigorous test through a series of propositions (Saunders et al., 2016). Deductive

reasoning is ascribed to the use of data to test theory. Inductive reasoning involves the development of theory as a result of analysing data already collected (Saunders and Lewis, 2012). This form of reasoning is ascribed to the use of data to build theory. Abductive reasoning moves back and forth, in effect combining deductive and inductive approaches. This combination can be either from deductive-inductive or inductive-deductive. The research logic adopted independently for the six publications are deductive and inductive in nature. For articles 1 – 4 inductive reasoning was used, for articles 5 and 6 deductive reasoning was used. It is well known that deductive reasoning is often inclined towards quantitative research and inductive reasoning is inclined towards qualitative research. Consequently, the integration of the inductive and deductive reasoning leads to the abductive reasoning linked to the research approach adopted for this study.

Methodological choice: This refers to the use of either quantitative, qualitative or mixed methods research design. Quantitative research examines the relationship between variables which are measured numerically and analysed using a range of statistical and graphical techniques (Saunders et al., 2016). It is generally associated with postpositivism, especially when used with predetermined and highly structured data collection techniques (Saunders et al., 2016). It is principally associated with experimental and survey research strategies (Saunders et al., 2016). Conversely, qualitative research looks at participants' meanings and the relationships between them. A variety of data collection techniques and analytical procedures are used to develop a conceptual framework and contributions to the theory (Saunders et al., 2016). It is often associated with an interpretive philosophy. Some principal strategies connected with qualitative research are action research, case study research, ethnography, grounded theory and narrative research (Saunders et al., 2012). Mixed methods research combines quantitative and qualitative techniques in a variety of ways that range from simple, concurrent forms to more complex and sequential forms. Saunders et al. (2016) considers realism and pragmatism as the philosophical positions that often lead to mixed methods research. It may use a deductive, inductive or abductive approach to theory development. Articles 1 – 4 adopts a qualitative research approach while articles 5 and 6 adopts a quantitative research approach. Generally, this dissertation adopts a mixed methods research approach.

Research strategy(ies): A research strategy may be defined as a plan of how a researcher will go about answering the research question within a study (Saunders et al., 2016). Articles 1 – 4 used a conceptual research strategy and articles 5 and 6 used a survey research strategy. This study adopts conceptual and survey research strategies.

Time horizon: For this phase of the research onion, the two forms of time dimension are cross-sectional studies and longitudinal studies. Cross-sectional research is the study of a particular topic at a particular time, i.e., "a snapshot". A longitudinal study is the study of a particular topic over an extended period of time (Saunders and Lewis, 2012). Articles in this dissertation follow the cross-sectional studies.

Research techniques and procedure: This phase involves the collection of data and data analysis. In this study, articles 1 – 4 involve the review of literature and synthesis. Articles 5 and 6 involve data collection and data analysis.

The literature review (articles 1 – 4) involves an extreme document review of peer-reviewed scientific papers, reports, books and information material from different schools of thought, authorities and organizations, addressing themes of interest for the research project. The databases that were used to search for peer-reviewed scientific papers include Elsevier, Springer, Emerald, Sage, Google Scholar. Reports and information were gathered from websites of organizations and institutions such as EC, WB, UNEP, Statistics Finland, MoE, USEPA, Economics Research and Consulting.

A keyword search methodology was used in the literature collection process for scientific articles. Critical articles appeared in the search with keywords such as KM, WM, Solid Waste Management, MSW management, SWM, Recycling, Sustainability.

For article 5, the study was carried out in Vaasa, a municipality on the west coast of Finland. Data for the study were collected from the five higher institutions: University of Vaasa, Vaasa University of Applied Science, Novia University of Applied Science, Abo Akaedemi University and Hanken School of Economics. A cluster sampling technique was used to obtain a representative sample for the study. This technique refers to a group of population element, which constitutes the sampling unit. The sampling unit for this study comprises the higher institutions in Vaasa.

A structured questionnaire was designed to elicit information on the perceived role of financial incentives in promoting waste recycling in Finland. The questionnaire was explicitly written in a simple format of closed-ended questions, consisting of both categorical and ordinal variables. The ordinal variables were ranked on a five-point Likert scale: strongly agree = 1, agree = 2, undecided = 3, disagree = 4, strongly disagree = 5. A number of articles were reviewed to develop questions related to the role of financial incentives for recycling and for questions focusing on drivers for recycling. Questions regarding the perceived role of financial

incentives for recycling were listed for the respondents to score on the five-point Likert scale. These statements considered the roles of financial incentive, such as stimulating knowledge for the recycling of waste, waste reduction and increased recycling. Other roles considered were behavioural change, critical motivational factors for recycling, influencing the desire to recycle waste, present positive trends for recycling waste, the tangible benefits for recycling waste, feasible goals of recycling waste, a sustainable approach for recycling waste, raising awareness of recycling waste and promotion of recycling best practices.

Subsequently, questions focusing on drivers for recycling were listed. These reflected behavioural change drivers including environmental risk, behavioural economics, resource value, economic benefit, convenience, knowledge, legislation and belief. Furthermore, questions bordering on recycling behaviour pertaining to various types of recyclable waste were also asked.

A face-to-face interview was adopted for administering the questionnaires to 123 respondents. All 123 questionnaires were administered to students and staff across the five higher institutions located in Vaasa.

The first section of the questionnaire included questions focusing on the personal characteristics of respondents, while subsequent sections of the questionnaire included questions centred on the role of financial incentives for recycling from the consumer's perspective, motivational factors for recycling and recycling behaviour. The data collected from the survey were analysed using the Statistical Package for Social Science (SPSS) software version 24. Both descriptive (frequency table, percentage, mean and standard deviation) and inferential statistics (Spearman's rank-order correlation and t-test) were used to analyse the data. The frequency table is used to display the number of times an event or characteristic occurred in this study. Percentage is adopted for displaying explicit differentiation and analysis. Standard deviation is used to indicate the extent of variability. The mean is used as a measure of central tendency. Furthermore, the choice of Spearman's rank-order correlation in this study is made on the basis that it is the appropriate statistical method for determining the strength and direction between two variables at the ordinal level. The t-test is the appropriate statistical method for determining whether there is a significant difference between the means of two groups.

For article 6, the study was conducted using primary sources of data. Primary data were collected through closed-ended questionnaires on the perception of financial incentives for households in endorsing sustainable waste recycling in Nigeria. The first section of the questionnaire included questions which centred on the personal characteristics of respondents, while subsequent sections of the questionnaire

included questions which focused on the role of financial incentives for recycling from the consumer's perspective and motivational factors for recycling. The questionnaire included nominal and ordinal variables. The ordinal variables were ranked on a five-point Likert scale: strongly agree = 1, agree= 2, undecided = 3, disagree =4, strongly disagree = 5. Questions regarding the perception of financial incentives were considered in an itemized list on the roles of financial incentives on a five-point Likert scale. These statements viewed roles such as stimulating knowledge for the recycling of waste, waste reduction and increased recycling, consideration for behavioural change, critical motivational factors for recycling, influencing the desire to recycle waste, present positive trends for recycling waste, the tangible benefits for recycling waste, feasible goals of recycling waste, a sustainable approach for recycling waste, promotion of awareness for recycling waste, and promotion of recycling best practices. Subsequently, questions covering drivers for willingness to recycle waste were considered in an itemized list that encompassed environmental risks, behavioural economics, resource value, economic benefit, convenience, knowledge, legislation and belief.

Using a door-to-door approach for the survey, 135 households were administered questionnaires in Shomolu Local Government Area, Lagos State, Nigeria. The study employed a stratified random technique. This approach guaranteed precision of the samples by avoiding sampling error. The Shomolu Local Government Area was divided into stratums of eight political wards and households were randomly approached from each political ward. To ensure a representative sample, efforts were made to ensure a geographical spread of the households. Effort was also made to capture households belonging to different socio-economic groups. The survey elicited information only from the head of the household. By means of a sample size calculator, sample size was determined by inputting a projected population of 1,361,100 (City Population, 2017) at a confidence level of 95% and confidence interval of 8%.

4 SUMMARY OF THE ARTICLES

Chapter 4 presents a summary of the dissertation based on six articles. The six articles are published in peer-reviewed international journals. These six published articles are connected to the research objectives on which this dissertation is founded. This chapter highlights the research objectives, findings and contribution.

In article 1, the main author (Beatrice Abila) was responsible for research planning and correspondence with the journal. The main author (Beatrice Abila) and second author (Nelson Abila) were in charge of the research design and writing the manuscript. The second author (Nelson Abila) and third author (Jussi Kantola) reviewed the manuscripts and provided significant comments and valuable feedback.

In article 2, the main author (Beatrice Abila) was responsible for the research planning and design, writing the manuscript and correspondence with the journal. The co-author (Jussi Kantola) reviewed the manuscript and provided significant comments and valuable feedback.

In article 3, the main author (Beatrice Abila) was responsible for the research planning and design, writing the manuscript and correspondence with the journal. The co-author (Jussi Kantola) reviewed the manuscript and provided significant comments and valuable feedback.

In article 4, the main author (Beatrice Abila) was responsible for the research planning and design, writing the manuscript and correspondence with the journal. The co-author (Jussi Kantola) reviewed the manuscript and provided significant comments and valuable feedback.

In article 5, the main author (Beatrice Abila) was responsible for the research planning, data collection, data analysis, writing the manuscript and correspondence with the journal. The main author (Beatrice Abila) and the second author (Jussi Kantola) contributed to the research design. The co-author (Jussi Kantola) reviewed the manuscript and provided significant comments and valuable feedback.

In article 6, the author was exclusively responsible for all parts.

Articles 1 – 4 are qualitative research, articles 5 and 6 are quantitative research.

4.1 Knowledge management in waste management – a conceptual framework

This first article aims to develop a conceptual framework for applying a KM approach in the management of municipal and other types of waste. This article reviewed extant literature on WM and synthesized existing knowledge to come up with conceptual frameworks for WM (Fig.7) and WKM (Fig.5). Article 1 attempts to illustrate how the application of KM tools, systems and approaches in WM can help in attaining SWM goals.

The article reveals that the problem of waste as well as its management is not associated with certain countries or continents; it is a global challenge. However, there is variation in depth and scope of WM problems between developed and developing countries. Furthermore, global WM concerns include management-related concerns and technical concerns. The broad goal of WM is to achieve economic, social and environmental sustainability. Nevertheless, specific WM goals vary across the globe. The goals relating to WM are as diverse as the multiple streams of wastes. The article also showcased instances of emerging KM innovations which are already in use globally in addressing various WM problems. Regardless of the strategies being applied at various administrative levels within the WM sector, various KM innovations are emerging.

In addressing the research question, article 1 highlights the knowledge gaps associated with each aspect of WM. It presents a conceptual framework that reflects the different aspects of WM. The review of extant literature used in writing this article aided in synthesizing various components of WM alongside its linkages in a graphical representation, the WM conceptual framework. Based on the WM conceptual framework, each of the themes implies a set of questions that borders on know-how, know-who, know-what and know-why components of the knowledge aspects.

Finally, in providing an answer to the research question, this article evolved a WKM conceptual framework, the main contribution in this article. The WKM conceptual framework entails the application of KM systems, tools and approaches to the WM chain thereby ensuring that the cycle of KM is not broken throughout the WM chain.

Figure 5. Conceptual framework of waste knowledge management (Article 1)

4.2 Municipal solid waste management problems – knowledge management solution in Nigeria

This second article seeks to identify MSW management problems and evolve a KM solution. This article reviewed the existing management of MSW, problems affecting MSW management, MSW policies and regulations and MSW generation. This article attempts a synthesis of problems associated with MSW management in Nigeria and proposes a conceptual KM approach. In tackling the management problems of MSW in Nigeria and attaining efficient MSW management, this article proposes a conceptual KM solution.

The prominently practiced MSW management techniques in Nigeria are open dumping, landfill and open burning, while incineration is seldom put to into practice. In Nigeria the processes involve in the management of MSW are storage, collection, transportation and disposal at dumpsites. The constant increase in the generation of MSW is alarming. The quantity of waste produced is directly proportional to population, socio-economic status and level of urbanization. The problems militating the efficient MSW management in Nigeria are diverse and numerous. These problems include poor funding, weak legislation and implementation of policy, limited infrastructures and professionals, low level of awareness, poor recovery and recycling programmes and poor disposal

techniques. There are a number of KM related barriers militating inefficient WM in Nigeria. These barriers include the lack of extended producers' involvement and interventions, poor communication, poor personnel morale. However, one major barrier is cultural belief. These problems are related broadly to economic, technological, political, psychological and institutional factors. It is suggested that the focus of MSW should not solely be on technology-centred strategies, but also on people-centred strategies.

In addressing the research question, article 2 presents a synthesis of problems relating to MSW management in Nigeria. In providing an answer to the research question, this article proposes a conceptual KM approach, the people- and technology-centred KM solutions for tackling MSW problems across cities in Nigeria. The KM solution involves both people-centred and technology-centred strategies. The themes of the proposed conceptual KM solution include stakeholders, stakeholders' roles, MWM problems, sources and proposed KM solutions.

4.3 Proposed solutions for sustainable management of municipal waste

This third article proposes two approaches for attaining efficient and sustainable MSW management. This article reviewed extant literature on Nigerian MSW management challenges and designing a recycling solution using axiomatic design. This article attempts a synthesis of current trends in MSW management challenges in Nigeria and proposes substantial solutions to mitigate MSW management challenges for ensuring efficient and sustainable MSW management.

The poor management of waste is the result of a combination of challenges that include poor funding, cultural belief, limited infrastructure and professionals, poor legislation and implementation of policy and poor disposal techniques. In Nigeria, population growth is one of the main contributing factors to increasing waste generation, in particular MSW which is generated in large quantities on a daily basis. Regardless of the enacted policy and regulations, truckloads of MSW collected from different generation points are transported to designated dumpsites. The sorting of waste is the primary duty of the waste holder and it is a vital process in the management of MSW. Also, it is a precondition for the other processes in the management of MSW. For conducive and timely sorting of waste materials, the generation of an explicit and comprehensive design for waste classification (labelling) on products or packages would make it possible to direct waste to the appropriate garbage or trash containers. KM is a vast topic that

focuses on technology- and people-centred strategies through the application of KM tools and approaches for the sustainable management of waste through creating, sharing, capturing, organizing, storing, accessing and reusing (Abila and Kantola, 2017).

In addressing the research question, this article attempts a synthesis of current trends in MSW management challenges in Nigeria. In providing an answer to the research question, this article proposes dual approaches to tackle WM, specifically in Nigeria. The dual approach includes a product design solution and a KM solution. Furthermore, the proposed product design solution is based on the principles of design (Suh, 1990) and the axiomatic design approach (Suh, 2001). The KM solution is based on the application of the KM approach. The dual or bi-approaches are useful in ensuring and facilitating KM application for the sustainable management of MSW.

4.4 Waste management: relevance to environmental sustainability

This fourth article aims to evaluate the environmental consequences of different management techniques for MSW. This article reviews existing literature for both developed and developing countries on MSW management, WM hierarchy, as well as emissions emanating from MSW disposal and management.

MSW management varies from country to country, or more precisely from developed to developing countries. The WM hierarchy of developing countries pursues similar objectives to that of developed countries. Notwithstanding, in developing countries the WM hierarchy operates inversely in practice. Environmental consequences are critical indices for determining the best WM options and informing decision-making. The management treatment options for energy recovery from MSW are accompanied with the release of certain gases contributing to climate change and acid rain. The generation of waste cannot be reduced significantly as population growth and industrialization are driving forces, thus it is necessary to consider, emphasize and conform to increasing recycling as an outstanding management option for MSW. Besides environmental gains, this also boosts the circular economy and green cities.

In addressing the research question, this article reviews literature on MSW management across a range of countries. In providing an answer to the research question, this article assesses the environmental consequence emanating from the influence of either the presence or absence of contaminant-based diverse management options for MSW. The outcome from the evaluation of the

environmental effect reveals that incineration (the most common waste-to-energy implementation for MSW) is accompanied by the emission of greenhouse gases, nitrogen oxide, ammonia and sulphur dioxide contributing to climate change and air acidification. Reuse and recycling may be the best environmentally friendly options for MSW.

4.5 Financial incentives and promoting waste recycling in Finland

This fifth article investigates consumers' perception of the role of financial incentives for executing sustainable recycling of MSW materials in Finland. Specifically, this article determines the relationship between consumers' perceptions of financial incentives for recycling and recycling behaviour and the relationship between drivers for recycling and recycling behaviour. This article also determines the association between income-earning consumers and non-income-earning consumers concerning their perception of financial incentives for recycling.

The empirical results obtained from data from the consumers' point of view confirm that the role of financial incentives is important in accelerating the recycling of MSW. A weak positive relationship exists between drivers for recycling MSW and recycling behaviour. There exists no statistically significant difference in the means of the perceived role of financial incentives for recycling in the two income groups (income-earning consumers and non-income-earning consumers). A weak negative relationship exists between consumers' perceived role of financial incentives for recycling MSW and consumers' recycling behaviour. Findings infer that the role of financial incentives is indispensable to the sustainable recycling of MSW. However, consumer behaviour for recycling is more driven by socio-psychological factors in the study area. This article revealed that although there already exists a mechanism for the recycling of some waste materials (newspaper, magazines, mixed papers, cardboards, PET plastics bottles, metals, glass and tetra packs), the level of participation in the recycling of these materials is barely above the average proportion of the population. Therefore, interventions are needed that will increase the participation of many more members of society in the recycling of MSW materials such as tetra packs and glass which are generated in enormous quantities on a daily basis in Finland. The interventions for promoting increasing recycling should be anchored on key drivers for recycling.

In addressing the research question, this study collected data through the use of a structured questionnaire at five higher institutions in Vaasa, Finland. The

questionnaire assessed consumers' perception about the role of financial incentives for executing recycling of MSW in Finland. In providing an answer to the research question, article 5 analysed the data through descriptive statistics. The empirical result from the study confirms that the role of a financial incentive is important in accelerating the recycling of MSW.

4.6 Financial incentives and endorsing sustainable waste recycling in Nigeria

This sixth article examines households' perception of financial incentives in the adoption of sustainable recycling for MSW in Nigeria. Specifically, this article ascertains the key motivational factors behind recycling. This article also determines the relationship between households' perception of financial incentives for recycling and drivers for households' willingness to recycle.

The empirical result from the consumer's perspective supports the hypothesis that financial incentives for recycling are vital for managing MSW sustainably. The most important drivers for willingness to recycle MSW are the detrimental environmental impacts. A moderate positive relationship exists between households' perception of financial incentives for recycling and drivers for households' willingness to recycle MSW. Drivers are indispensable for a households' willingness to recycle MSW in the study area. Adopting the extended producer responsibility (EPR) model, reverse vending options are recommended, to promote a recycling culture among citizens and residents in Nigeria.

In addressing the research question, primary data were collected for this article through closed-ended questionnaires on households' perception of financial incentives for the adoption of sustainable waste recycling. In providing an answer to the research question, article 6 analyses the data through descriptive statistics. The result from the study supports the hypothesis that financial incentives for recycling are vital for reducing and managing MSW sustainably.

4.7 Reliability and validity

Reliability and validity are two terms usually applied and discussed when conducting or reviewing research. Validity refers to the extent an instrument measures what it is intended to measure, whilst reliability refers to the consistency of measurement, the extent to which an indicator is free of random error (Barbu, 2012) as well as the dependability and replicability of the result obtained from a piece of research (Zohrabi, 2013).

According to Fitzner (2007), the main types of reliability are test-retest reliability, interterm reliability and internal consistency reliability. Nevertheless, this dissertation assesses reliability with the most frequently used approach, i.e., the internal consistency reliability (Cronbach's alpha), which measures the variance of response in one item with the overall variance (Maughan, 2009). Reliability can also be assessed on the basis of dependability and replicability of the results using methodological triangulation, investigators' position and audit trail (Zohrabi, 2013).

Besides, construct validity, Morse (2015) noted that validity includes internal validity and external validity and further identified methodological triangulation as one of the strategies for attaining validity. Methodological triangulation may enhance validity as multiple-method research and generically improve validity estimates (Morse 2015; Newman et al., 2013). Teddlie and Tashakkori (2003, 2009) proposed the term inference quality to refer to validity in the context of mixed research (Venkatesh et al., 2013).

The term inference quality is used to refer to validity and the term data quality is used to refer to reliability in mixed methods research (Venkatesh et al., 2013).

In general, this dissertation assesses reliability through the quality measures and observations (data quality) and validity via the accuracy of inductively and deductively derived conclusions (inference quality) (Venkatesh et al., 2013).

This study used Cronbach alpha to test the reliability in articles 5 and 6. Cronbach alpha is a reliability test that measures the internal consistency of a scale. In article 5, Cronbach's alpha for perceived role of financial incentives for recycling was 0.834, while that of drivers for recycling was 0.601 and recycling behaviour was 0.817. In article 6, Cronbach's alpha for household perception of financial incentives for recycling was 0.776 and willingness to recycle was 0.627. The idea that alpha should be greater than 0.7 has been disputed (McCrae et al., 2011).

5 CONTRIBUTIONS – THEORETICAL CONTRIBUTIONS AND IMPLICATIONS

5.1 Theoretical contributions

The conception of the application of KM approach in WM is new, thus research in this field is limited. Furthermore, the notion of KM approach in WM is still new. Nevertheless, there are myriad approaches which have been applied in WM. These include a biotechnological approach (Englande and Jin, 2006), an integrated approach (Shekdar, 2009), and top-down and bottom-up approaches (Joseph and Nagendra, 2007). This dissertation addresses the solution to WM problems (knowledge gaps) from an outstanding approach – the KM point of view, which is another novel instance of a theoretical contribution by evolving a WKM framework (Fig. 5).

Scholars have contributed to the theory behind WM with the evolution of different frameworks that focus on CDW, MSW, Urban waste and WM behaviour. Yuan et al. (2016) proposed a framework for assessing the eco-efficiency of CDW management in Hong Kong. Aleluia and Ferrao (2016) proposed a guiding framework in the form of a matrix. This matrix maps out approaches observed in the management of MSW in cities of developing Asian countries as a function of the city dimension share of organics on waste streams, and wealth generated by the city. Chifari et al. (2018) developed a holistic framework to organize and integrate quantitative information characterizing the performance of urban WM systems across dimensions and scales. Ding et al. 2019 developed a conceptual framework for renovation WM based on the renovation waste generation rates in China. Tekler et al. (2019) proposed a WM behavioural framework of Singapore's food manufacturing industry using factor analysis. In general, this dissertation contributes to the theory in a variety of ways. One way is through the generation of new frameworks comprising a conceptual WM framework (Fig. 7), and a conceptual WKM framework (Fig. 5). For the WM framework (Fig. 7), the synthesis of the flow and components of the waste chain are key to understanding the knowledge aspect – know-who, know-how, know-what and know-why components of KM within the subsector. These components of KM within the WM sector imply knowledge of who manages waste, knowledge of how waste is managed, knowledge of what waste is managed and knowledge of why waste is managed. The WKM framework (Fig. 7) provides the basis for understanding the connection and integration of the application of KM tools, systems and approaches in the WM chains.

Both frameworks focus on a broad scope of WM and present a comprehensive and holistic system displaying linkages within themes. This is important to foster and support the contemporary definition, conception and insight of WM as well as KM in WM.

Another contribution is the evolved technology- and people-centred KM solutions for mitigating MSW management problems. Dual-approaches through the combination of KM solutions and the application of an axiomatic design principle in designing labels for SWM, are not excluded. Besides, the environmental consequences relative to the presence or absence of contaminants from MSW management techniques are assessed. Moreover, the empirical evidence from a consumer's perspective is that financial incentives are important in accelerating the recycling of MSW as well as vital for reducing and managing waste sustainably.

Another critical contribution in this dissertation is the development of a structural definition for KM (Fig. 6). The structural definition of KM is construed from the conclusion of the definition of KM in Chapter 2 as a broad term that focuses on technology- and people-centred strategies through the application of KM tools and networks for creating, sharing, capturing, storing, accessing and reusing, for the sustainable management of waste.

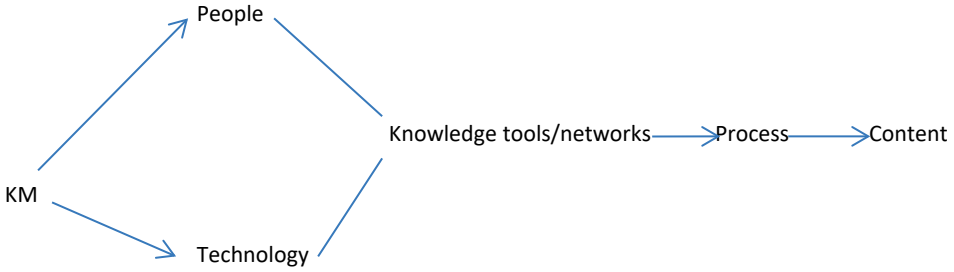

Figure 6. Structural definition of knowledge management

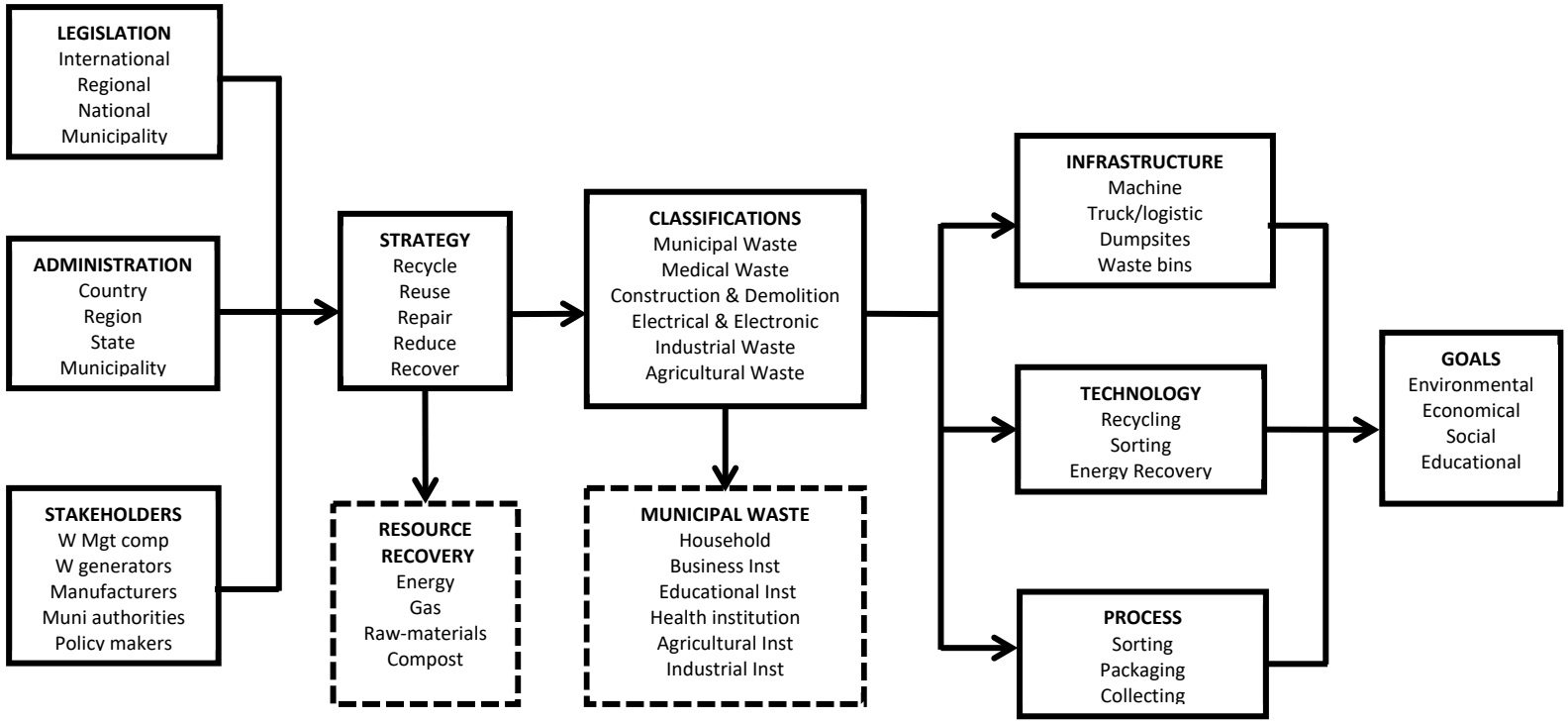

Figure 7. Conceptual framework of waste management (Article 1)

Key: W – waste, Mgt – management, Muni – municipal, Inst – institutions

5.2 Policy implications

Governments must have the WKM framework for WM at the legislative and administrative level. In the case of Finland, the introduction of financial incentives for other recyclables is required by the government to boost consumers' participation in the recycling of MSW. The government must establish a formal recycling platform for MSW management to facilitate recycling in Nigeria. Furthermore, the government must endorse the adoption of the extended producer responsibility (EPR) model and reverse vending option in an effort to promote recycling culture among citizens and residents in Nigeria. More sensitization programmes for WM in creating public awareness should be organized. An emphasis on green manufacturing possibilities at all levels of production to facilitate sustainable recycling should be encouraged.

5.3 Managerial implications

This dissertation advances the insight of managers to visualize the KM tools, systems and approaches used in the management of waste as the foundation of KM. This dissertation also reaffirms that the management of waste is not solely the duty of waste managers, but the collective duty of all stakeholders. This is in line with Guerrero et al. (2013), that in the management of waste, stakeholders with different fields of interest play a role in shaping the system of a city, but often it is seen only as the responsibility of the local authorities. Furthermore, with the refined definition of WM, managerial re-orientation for all stakeholders on waste is achievable. This dissertation will aid managers in conceiving and laying emphasis on WM from a KM perspective.

6 CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

6.1 Conclusions

This dissertation explores the KM approach and its contribution towards the sustainability of the WM sector. It considers three broad concepts relating to KM, WM and sustainability.

The kind of framework which suits the application of the KM approach in the management of municipal and other types of waste is a WKM framework.

The kind of KM solution for MSW management problems are technology- and people-centred KM solutions. The technology-centred KM solution focuses on the use of ICT and the people-centred KM solution focuses on stakeholders within the WM chain. Bi-approaches are useful substantial solutions for ensuring and facilitating KM application in the management of MSW.

The treatment options for energy recovery from waste are accompanied with the release of certain gases contributing to climate change and acid rain. Another detrimental WM technique is waste disposal in landfill with the release of contaminants such as methane, hydrogen, leachates with high content of carbon and ammonium, mercury, lead, resulting in the detrimental effects of eutrophication, air acidification, ozone layer depletion, water pollution, soil pollution, explosion hazards, global warming and nuisance odour. Backyard burning releases contaminants such as nitrogen oxides, ammonia, ethylene, carbon dioxide. It can lead to smog formation, ozone layer depletion, global warming, eutrophication and air acidification. Composting leads to the detrimental effects of air acidification, nuisance odour and eutrophication. Accordingly, recycling limits the quantity of waste diverted to landfill, reduces the depletion of natural resources, improves energy efficiency and eliminates the chance of emissions. Reduction, reuse and recycling techniques for WM present environmental gains. However, the increasing generation of waste cannot be reduced substantially since population growth and industrialization are driving forces.

In Finland the role of financial incentives is important in accelerating the recycling of MSW. In Nigeria, financial incentives for recycling are vital for reducing and managing MSW sustainably.

6.2 Limitations of the research/critical analysis

In any research work there is usually at least one limitation. In the case of this research, journals which are directly related to or focused on KM in WM were rarely available or at worst, non-existent. A language barrier was encountered during the data collection phase in English due to variations in multi-lingual (Finnish, Swedish and English) proficiency in Finland. The empirical validations of the proposed conceptual frameworks are yet to be established, thus require further analysis. This research is broad and thus requires further in-depth analysis and elucidation.

6.3 Future research

A possible area for future research is to firstly determine the relationship between social economic indices and waste generation rate across national, regional and global scales. Advancing waste-to-energy technologies from an environmentally friendly perspective is another area of research which will follow from this study. Further work should also be considered on stakeholders' analysis of the WM sector in line with KM objectives, problems, initiatives and strategies. Finally, conducting empirical validation of the conceptual frameworks should be considered for further analysis and to provide a robust contribution to the application of KM in WM.

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Knowledge Management Approach for Sustainable Waste Management: Evolving a Conceptual Framework

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Abstract: Attaining sustainable management of various waste streams requires applying both technical and non-technical approaches, including the deployment of knowledge management systems. Knowledge management in relation to waste management (WM) implies optimizing the application of a broad range of knowledge in WM towards attaining defined goals — the "know-why," "know-who," "know-how," and "know-what" of WM sustainability. The problem of waste and its management is not peculiar to only certain countries or continents; it is a global challenge that requires the management of vital knowledge in the WM chain for ensuring that sustainable waste management (SWM) goals are attained. Global collaboration should be established to focus on knowledge gaps across the WM chain. The application of the knowledge management approach in waste management is new. This paper reviewed existing literature on waste management and synthesized existing knowledge to come up with conceptual frameworks for waste management and waste knowledge management. The paper

also presents an array of action points and recommendations based on the conceptual frameworks towards attaining the diverse goals of sustainable management of waste.

Keywords: waste; waste management; knowledge management; sustainable waste management; conceptual framework.

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1. Introduction

Sustainable waste management (SWM) is both a theoretical and practical concern. The theoretical and practical concern refers to management (soft) and technical (hard) concerns respectively (Abila et al., 2014). These management concerns vary from information, regulation, communication, attitudes, perception, culture, and policy while the technical concerns include the lack of equipment, the use of inefficient technologies, collection and disposal problems (Abila et al., 2014). The SWM involves all aspects: generation, prevention, characterization, monitoring, treatment, handling, reuse, recycling, repair, recovery, and the disposal of the final residual (Srivastava and Nema, 2012; Waste management, 2019; Seadon,

2010) with minimal impact on the environment. The broader goals of SWM include deriving social, economic, and environmental gains from waste and reducing the hazards relating to waste (Papargyropoulou et al., 2014; Pires et al., 2011; Couth and Trois, 2010). SWM has been summarized as (1) the outright prevention of waste generation and (2) ensuring minimal ecological footprints of the various waste streams (Mohan et al., 2006). Another important element in SWM is ensuring partnership and coordination among stakeholders and agents all along the waste management chain, as well as ensuring their participation in decision making (Zhang et al., 2010; Acosta et al., 2012; Seadon, 2010).

Globally, a large share of municipal solid waste (MSW) is categorized as organic waste. In most countries in Europe where bio-waste (organic waste) represents a considerable fraction of MSW, various technologies and processes have been adopted to ensure a SWM that can generate a high-quality compost and biogas; thus avoiding the emission of greenhouse gases and loss of these high-value materials, (European Union, 2016; Zero Wastes Europe, 2014). The sustainable treatment of organic waste also helps in curbing unpleasant odours and air pollution. In European Union countries biodegradable waste usually represents between 30% and 40% but can range from 18% up to 60% of the MSW (International Energy Agency, 2013).

In the case of developing countries such as in Africa, where a large fraction of waste is organic, SWM may include the biological treatment of waste for biogas energy generation, for example through the clean development mechanism (CDM) project (Couth and Trois, 2010). For the most populous country in Africa, Nigeria, the organic component of municipal waste is estimated at above 53% (Abila, 2014). Similarly, the organic component of municipal solid waste for various cities in countries across Africa is reported to be above 50%: Mombasa, Kenya, 50%; Harare, Zimbabwe, 50%; Nairobi, Kenya, 51%; Dar es Salaam, Tanzania, 50%; Addis Ababa, Ethiopia, 60%; Kigali, Rwanda, 50%; and Kampala,

Uganda, 70% (Mbiba, 2014; Katusiimeh et al., 2013, Okot-Okumu and Nyenje, 2011). Couth and Trois (2010) reported a 56% average organic component of MSW in Africa. With the low level of manufacturing, the proportion of organic components of MSW in Africa will remain high. The above has shown that developing and less industrialized countries have high organic waste components than developed and industrialized countries. The implication of this is that developing countries will need to adopt SWM technologies and approaches that will enable them to derive more benefits from these high organic waste components of their MSW.

Managing all kinds of waste from a broad array of streams, under various classifications and levels of management, is a recurring challenge for urban managers who often do not receive sufficient attention and resources. With increasing awareness, SWM has become a major concern for an increasing number of countries (Koroneos and Nanaki, 2012). Globally, there is an increasing adoption and implementation of SWM strategies. In particular, the advanced economies are doing everything possible to reduce the negative impact of waste, through increased investments as well as allowing the participation of more stakeholders who are deploying more efficient systems, resources, tools, and technologies towards attaining SWM goals.

In developed countries regardless of the small population size and growth, the increasing generation of waste and complexity of waste streams is a challenge (UNEP, 2011; European Union, 2010). This may be due to socio-economic factors including rising incomes and economic growth leading to increased consumption of foods, beverages, and various processed products. Other challenges in some developed countries such as Poland are illegal, non-sanitary, and non-supervision of existing landfills (Mesjasz-Lech, 2014). In the case of the United Kingdom (UK), landfill accounted for 49% of MSW disposal in 2009 (Al-salem et al, 2014). This disposal of a high volume of MSW into landfills is not in accordance with the

EU waste management policies (European Union, 2015). The EU waste policies state that landfill disposal techniques of waste management should be the last option.

SWM is gaining greater attention in developed countries compared to most developing countries which still pay little or no attention to the obvious menace of waste. Many low-income countries with high population densities still suffer from low budgetary allocation and lack of investment in the waste management sector (Abila, 2014). In addition, management studies devote relatively little time and resources to the study of waste management.

The diverse problems of waste management require multipronged approaches to evolve sustainable solutions. Technological approaches at various administrative levels can create value, transforming waste into resources that are useful towards various ends. These approaches are more effective when combined with appropriate knowledge management systems and tools.

This paper presents a review of existing literature on WM to identify knowledge gaps and through synthesis proposed a conceptual framework for applying a knowledge management approach in WM. The paper is a foundation work for expanding the scope and depth of the application of knowledge management in SWM.

1.1 Knowledge Management and Sustainable Waste Management

The goals of SWM are to attain economic, social, and environmental sustainability. SWM also aims to prevent, recycle, and manage waste in such a way that most effectively protects human health and the environment (USEPA, 2002). In this regard, knowledge management is crucial for attaining specific SWM goals. To attain SWM goals, various countries, companies, and waste management (WM) entities have evolved a wide array of knowledge management systems and techniques towards ensuring efficiency in the sector. Gründler et al.

(2006) describe the 'WasteInfo' knowledge management system, developed and implemented in Germany, as a clearinghouse of comprehensive information on broad categories of waste, to be made available to an array of decision-makers. Sevigné Itoiz et al. (2013) described the CO2ZW tool, developed for monitoring and estimating the emission of greenhouse gases (GHGs) from waste, in contexts when very little data are available.

Pires et al. (2011) conducted a systems analysis of WM in European countries, analysing how technical and non-technical aspects interact in the pursuit of SWM goals. The paper argues that systems engineering models and systems assessment tools should be applied towards harmonizing the diverse goals that must be integrated for SWM. Zhang et al. (2012) investigated construction waste management that deploys the Internet of Things, namely Radio Frequency Identification (RFID) technology within the context of rule-based knowledge management technology. The Internet of Things approaches, as an intelligent WM system helps to ensure that companies comply with rules and derive optimum benefits from waste through recycling.

The waste management chain depicts the collective strategic aspects involved in the management of waste from the point of generation to the point of disposal. These processes vary from, sorting, packaging, storage, collection, transportation, processing, recycling, and recovery. Throughout the WM chain different levels of application of knowledge management tools, models, systems, and approaches helps increasingly in synchronizing a combination of strategies and technologies towards achieving SWM goals. The knowledge management cycle through which basic data and information are translated into knowledge has become a necessary process for SWM. WM companies must acquire, classify, organize, store, share, use, create, and identify appropriate waste-related data and information, in a continuous loop. Waste related data and information must be transformed into knowledge that informs WM Company's operational strategy. Knowing the – know-why, know-who,

know-how and know-what pertaining wastes in any country or county should be the pivot of SWM. Beyond this, a more advanced application of knowledge management is in developing mobile apps and deploying the same, among other knowledge management tools in SWM. It is also worth noting that a knowledge management perspective such as is illustrated by the proposed conceptual framework later in the paper, gives a good understanding of the various components of WM and how they are interlinked.

Facilitating SWM necessitates identifying and addressing knowledge gaps existing in the WM chain. The knowledge gaps include the lack of data and information on the various types of waste, improper classification, poor labelling, and assigning of waste collection bins. In some cases, a knowledge gap exists between the waste generators and collectors. This gap is seen when a waste generator is not sure of what bin to drop a particular kind of waste. Knowledge gaps also exist between WM companies and policymakers. It is crucial that all stakeholders within the WM chain are on the page in terms of their understanding of legislation, classifications, processes, goals, and among other aspects as illustrated by fig 1. Some other knowledge gaps are listed in table 1.

Knowledge management is a broad term which requires the systematic efforts of an organization to manage its institutional knowledge through a broad range of direct and indirect methods such as specific types of information and communication technologies (ICT), management of social processes, structuring of organizations in a particular pattern or via the use of particular culture and people management practices (Hislop, 2009; Abila and Kantola, 2013). Davenport (1994) defined knowledge management to encompass the entirety of processes an organization engages in to capture, develop, share, and utilize its body of knowledge effectively. The knowledge management approaches, systems, and tools being deployed must be related to the organization's core goals (Gupta and Sharma, 2004). Deploying knowledge management to WM must serve the generalized goal of SWM, or the

more specific goals of energy recovery, recycling, reuse, reducing pollution, and reducing the delivery of residuals to landfills, among others. The application of knowledge management ensures SWM cuts across the various aspects of WM namely: definition and categorization of waste (including legal definitions), specification of the required treatment within a regional or national jurisdiction, setting regulatory targets for states or local entities. In this context, knowledge management can be defined as a broad term that focuses on technology and people-centred strategy through the application of knowledge management tools and networks for creating, sharing, capturing, organizing, storing, accessing, and reusing for the sustainable management of waste.

The subsequent sections of this paper are organized as follows. Section 2 addresses global waste management concerns, section 3 discusses global waste management goals, section 4 discusses the conceptual framework for waste management, section 5 discusses situating knowledge management in waste management, while section 6 captures the conclusion of the analysis.

2. Literature review

Previous researches have explored different approaches to WM. These include biotechnological (Englande and Jin, 2006); top-down and bottom-up (Joseph and Nagendra, 2007); integrated (Shekdar, 2009); multi-criteria decision aid (Makan et al., 2013); heuristic (Yaakoubi et al., 2018) bi-level programming (Sadeghian Sharif et al, 2018); stochastic programming model (Gambella et al, 2019); and co-production (Lu and Sidortsov, 2019). However, the application of the KM approach in WM is new; hence there is limited research in this field. The ever-growing world population, estimated to reach 9.7 billion by 2050 will lead to an increase in the demand for resources and increase waste generation (Guran et al., 2019). Thus, a KM approach will be required for tackling the bound to increase WM

challenges. Besides, Das et al. (2019) noted that an improved approach to integrating social, economic, institutional, legal, technical, and environmental aspects is essential for the sustainable management of waste.

2.1 Global Waste Management Concerns

WM concerns problems are global in nature. These problems are not peculiar to a certain country, region, or continent. However, there are variations in the depth and scope of WM problems between developed and developing countries. Globally, there is a continuous increase in the generation of various types of waste. It is estimated that globally MSW production is about 1.3 billion tons per year and this quantity is projected to rise to 2.2 billion tons by 2025 (World Bank 2012; International Energy Agency, 2013). A broad grouping of 'urban waste' including MSW, commercial and industrial waste, construction, and demolition waste is estimated at around 7 to10 billion tonnes per annum (UNEP, 2015).

Stakeholders involved in managing different streams of waste at different administrative levels face a myriad of problems that can be categorized as "soft" (non-technical) and "hard" (technical). Management-related (soft) concerns include lack of data, poor information management, and low awareness or unfavourable attitudes, lack of public awareness, lack of extended producer responsibility, unfavourable perceptions of WM, and communication barriers between stakeholders. The more practical or technical concerns include the lack of equipment, inefficient equipment, mingling waste types from different sources, and lack of finance.

2.1.1. Soft (Management) Concerns

Soft concerns for WM can be categorized as communication, legislation, culture, or knowledge issues, among others. Chibunna et al. (2012) identified various concerns relating

to the management of electronic waste (e-waste) within a University campus (Universiti Kebangsaan Malaysia, UKM). Yong et al. (2019) identified various concerns relating to the management of e-waste in Malaysia. Most of the challenges identified can be classified as soft concerns, including inefficient data management, inadequate classification, low awareness of e-waste, and lack of specific regulations and policy on end-of-life for e-waste management.

2.1.2. Hard (Technical) Concerns

The technical problems of waste management, including limited access to efficient equipment, tools, and technology, are more pronounced in developing countries and in some emerging economic powers such as China. These technical problems reflect the low level of investment in WM and the low involvement of the private sector. Where public administrators and administrations are facing financial challenges, one area that suffers funding cuts is the provision of WM as a public service. As it is in many developing countries, informal operators still dominate the WM sector in China, indicating that there has been little or no investment in high-capacity and efficient technologies towards implementing the 5R's strategies (Zhang et al., 2010; Wang et al., 2008; Tong and Tao, 2016; Zhuang et al., 2008).

Table 1 highlights some common concerns of WM around the world based on the reviewed literature. Some of these concerns can be addressed through the application of knowledge management approach. Like in the case of the lack of data on various types of waste, WM companies continuously engaged in the knowledge management cycle will always have sufficient data and information which are constantly transformed into knowledge for informing decision making and ensuring improvement in SWM processes. In fact, identifying and classifying these concerns as a major knowledge management approach is a starting point

in the application of knowledge management in WM. Mattsson et al. (2003) studying recycling strategy in Sweden and the UK highlights the technical problem of littering and the wetting of recyclable papers at collection points. Other, "soft" concerns relate to the level of commitment of consumers to the recycling of materials, even with incentives such as the return of pre-charged fees: drink cans are occasionally littered or dumped with other waste rather than taken to recycling points. Ibrahim (2020) study on modelling of risk for improper sorting of waste at recycling centres in Sweden highlighted consequences from the management concerns of improper sorting. The consequences emanating from indirect costs of improper sorting of waste are increased processing costs, production errors and damages to equipment in downstream waste treatment or recycling facilities. WM companies must regularly and continuously engage in knowledge management process that will help them to properly identify and classify the WM concerns in their operational domain and develop the appropriate knowledge management solutions to address such.

Table 1: Global Waste Management Problems

Soft (management) Problems				
Problem/List	**Waste Types**	**Administrative level**	**Country**	**References**
Data/information:				
Lack of data.	MSW	Regional/Municipal	Developing countries	Parthan et al. (2012), Gallardo et al. (2015), Olay-Romero et al. (2015)
Few reliable statistics for construction and demolition waste (CDW) generation	CDW	Institution	Portugal	Bernado et al. (2016)
Inefficient data management	E-waste	Institution Municipal	Malaysia	Chibunna et al. (2012), Yong et al. (2019)
Insufficient data on waste generation and composition	MSW	Municipal	Finland	Sahimaa (2017)
Inappropriate data	MSW	Municipal	Nigeria	Nnaji (2015)
Communication:				
Poor classification and separation of waste	E-waste MSW	Institution Municipal Municipal	Malaysia China	Chibunna et al. (2012), Yong et al. (2019), Song et al.

				(2017)
Improper sorting of waste	MSW, other waste	Municipal	Sweden	Ibrahim (2020)
Low level of awareness on e-waste	E-waste	Institution Municipal	Malaysia	Chibunna et al. (2012)
Lack of communication, behaviour, and awareness between participants stakeholders, contractors, and workers)	CDW	National Regional/Municipal	China	Yuan (2013), Aslam et al. (2020)
Finance:				
Finance and investment	MSW	Municipal	Nigeria Ethiopia	Agunwamba et al. (1998), Abila and Kantola (2017), Lohri, et al. (2014)
Regulation/policy:				
Lack of specific regulations and policy on end-of-life on e-waste management and practices	E-waste	Institution Municipal	Malaysia	Chibunna et al. (2012), Yong et al. (2019)
Lack of specific regulation relating to the disposal of medical waste	Medical waste	Country/Municipal	Canada	Windfeld and Brooks, 2015
Lack of legislation/policy	CDW	Regional/Municipal	China	Yuan (2013), Aslam, et al. (2020)
Policy level legislations	E-waste	Country/Institution	India	Garlapati (2016)
Absence of legislation in stipulating the provision of separate food collections	MSW	Country	UK	Slorach, et al. (2020)
Perceptions, attitudes, and values:				
Poor attitude towards waste management	All kinds of waste	Country, Regional, Municipal	International	Bernstein (2004), Song, et al. (2017)
Hard (Technical) Problems				
Problem/List	**Waste Types**	**Administrative level**	**Country**	**References**
Collection and disposal problems	E-waste MSW MSW	Institution Municipal Municipal Municipal	Malaysia Palestine Colombia	Chibunna et al. (2012), Yong, et al. (2019), Al-Khatib (2010), Márquez and Rutkowski (2020)
The increasing volume of waste	MSW, other waste	National, Regional, Municipal	China Brazil	Zhang et al. (2010), Duan et al. (2020),Tsai (2019), Ottoni, et al. (2020), Lino et al. (2010), Pereira and Fernandino (2019),
	Medical Waste	Country/Institution	USA	Windfeld and Brooks (2015)
Lack of landfill/landfill management plans	CDW	Regional/Municipal	China	Yuan (2013), Wang et al.

				(2010), Zheng et al. (2017)
Use of inefficient technologies	CDW	Regional/Municipal	China	Lu and Yuan (2010), Yu et al. (2018)
Adoption of new technologies	Medical waste	Regional	European countries	Windfeld and Brooks 2015
Lack of management plans	CDW	Regional/Municipal	China	Yuan (2013) Aslam, et al. (2020)
Incomplete combustion of waste in waste to energy (WtE) systems	MSW	Municipal	China	Cheng and Hu (2010), Xin-gang, et al. (2016)
Consequences relating to existing WM Concerns				
Consequences/list	**Waste Types**	**Administrative level**	**Country**	**References**
Atmospheric pollution	MSW CDW	Countrywide	China	Tian et al. (2013), Yu et al. (2018)
Odor and environmental pollution	MSW, Agricultural waste MSW	Countrywide	USA China	Laufenberg et al. (2003), Van Dyk et al. (2013), Mukherjee et al. (2020), Song et al. (2016)
Water pollution	Wastewater, MSW, other waste agricultural waste	Countrywide, Regional	Italy International	Bertin et al. (2011), Siddiqi, et al. (2020)
The risk to human health and environment	MSW, agricultural waste	National, municipal	International	Mirabella, et al. (2014), Ansari, et al. (2019)
Littering (failure of recycling)	MSW	National	Sweden, UK	Mattsson et al. (2003)
Increased processing costs, production errors, and damages to equipment in downstream waste treatment or recycling facilities	MSW, other waste	Municipal	Sweden	Ibrahim (2020)
Inaccessibility of recycling stations	MSW	Municipal	Sweden, UK	Mattsson et al. (2003)
Inefficient recycling structure and system	MSW	Municipal	Denmark	Larsen et al. (2010), Faraca, et al. (2019)

3. Global Waste Management Goals

The overarching goal of WM is to attain economic, social, and environmental sustainability. Within this context, Brunner and Rechberger (2014) summarized the operational goals of WM as ensuring hygiene, reducing volume, protecting the environment, curbing hazardous waste, natural resource conservation, cost reduction, and attaining public buy-in of the WM approach.

WM goals vary across the globe. Various regions of the world have set WM goals for countries within their regional unions. The European Union Directive 2008/98/EC (of the European Parliament and the Council) set the WM agenda for member countries (EU, 2008). This directive, which is binding on member States, is an improvement on earlier directives. It sets the goal of reducing the 1.3 billion tons of waste generated each year within the European Union, as a framework for coordinating WM in the member states, both to limit the generation of waste and to optimize the organization of waste treatment and disposal. The African Union Agenda 2063 has set the target for recycling a minimum of 50% of the waste generated in cities across the continent (African Union Commission, 2014). UNEP (2013) illustrated the national waste management strategies across the 193 member states.

While countries have their national goals, various states, regions, and municipalities may be pursuing diverse waste management goals. Deploying appropriate knowledge management approaches can aid in making diverse waste streams useful contributors to the economy and the environment, and in reducing the negative impacts of waste. The goals relating to WM are as diverse as the multiple streams of waste. Table 2 shows a summary of various WM goals relating to the different types of waste and the management strategy.

Table 2: Global WM Goals

Waste types	Strategy	Goals	References
Municipal solid waste	Recovery – Energy generation	Electricity, biogas, environmental protection, resources/materials conservation.	Pujara et al. (2019)
Municipal solid waste - polyethylene terephthalate (PET)	Recycling	Environmental protection, resource conservation, and the development of recovery technology	Zhang and Wen (2014)
Municipal solid waste - PET	Reduction & Recycling	Conservation of fossil fuels, reduction in energy usage and curbing greenhouse emissions	Smithers Pira Organization, (2012), Coelho (2011)
	Planning	Conserving landfill space	Srivastava and Nema (2012),
	Application of GIS	Cost minimization in waste management	Zamorano et al. (2009)
	Reduction & Recycling	Reduction in harmful environmental impacts of wastes	Greene and Tonjes (2014)
Construction waste	Recycling	Material recovery	Yuan (2013)
Agricultural waste	Recovery - Energy Generation	Electricity, biogas, biochar, cost minimization, environmental protection	Ro et al. (2014), Külcü and Yaldiz (2014), González-Sánche et al. (2014), Abila (2014)
Hazardous waste	Recycling and Disposal	Reduction in harmful impact	Samanlioglu (2013)
Municipal waste and construction waste	Reduction, recycling and re-using	Green economy, environmental protection, and social benefits	European Union (2015)
E-waste	Collection and recycling	Resource recovery and pollution prevention	Prasad (2019)

4. Waste Management Framework

This section presents a conceptual framework that reflects the aspects of WM. The review of relevant literature in writing this paper has helped in synthesizing various components of WM into a graphical representation – the conceptual framework. Figure 1 illustrates these components and their linkages. This section also highlights knowledge gaps related to each aspect of WM.

4.1. The Legislation

The legislation is the starting point for reaching WM goals, setting forth clear, unambiguous definitions, principles, and practices for managing particular streams of waste. In some regions and countries, legislation has yet to cover all the various streams of waste being generated, while existing legislation has yet to be fully implemented.

Of special concern in developing countries is the emergence of new streams of waste, such as electrical and electronic waste. Waste that have been categorized as hazardous are not easily disposed of without violating local, national, or regional laws; this has given rise to cartels involved in extra-territorial shipping and dumping of waste. Some of the waste, particularly electronic, are shipped as trade in second-hand goods or as educational supplies, to avoid costs or penalties related to treating and disposing of the waste in the originating country or region. Also, appropriate legislation for the increasing generation of waste is yet to be established in developed nations as continuous production of waste is a major challenge. Legislation for the increasing generation of waste must focus on all streams of waste and more particularly on food waste and packaging waste, as they are both generated in large quantities on daily basis. In essence, regulations must be stipulated for companies to design products for re-use, recycling and reduction in materials/resource consumption. Of increasing importance is the need for international, regional and national legislation relating to trading in waste.

Legislations at various levels, including international treaties, regional, national, and municipal laws and guidelines inform the formation and application of various WM strategies. The various WM legislations are implemented at various administrative levels namely, country, region, state, and municipality. These legislations are binding on various stakeholders who are key actors within the WM chain.

Ensuring sustainable management of waste internationally, or at any administrative level, must begin with designing and enforcing the necessary legislation. Table 3 details various international conventions relating to WM. Some of these treaties have wide coverage and have been ratified and domesticated in at least some implementing countries. Stakeholders must engage continuously in creating and revising legislation, as the changing perception and understanding of environmental concerns entail continuous knowledge creation, re-creation, and application. Knowledge and research relating to legislation should not just be a check to prevent violation of rules; it must also form part of WM strategy. WM is an evolving sector, which will continue to benefit from the emergence of new knowledge, technologies, and tools. Therefore, legislation must respond to an evolving WM system.

Efficient and effective legislation must address the linkage between various waste streams, as well as the linkage between WM goals and other environmental, energy, or related goals. WM legislation must also recognize the full array of stakeholders involve in managing specific waste streams and clarify their respective roles. For most countries, a continuing problem is the lack of appropriate resources and mechanisms for enforcing existing legislation.

4.2. Administration

The SWM goals are set forth at various administrative levels. Individual countries that are members of various international organizations and bodies have different administrative structures for implementing WM legislations. The administrative levels are the pedestals for the implementation of various WM strategies. The peculiarity of a country, region, state, and municipality informs the choice of WM strategies. These administrative departments are the repository of various forms of explicit knowledge and often tacit knowledge, including archives of laws and time-series data on waste generation; as such, they must constantly

engage in knowledge management processes. Governments at the country, regional, state and municipal levels must continuously acquire, classify, organize, store, share, use, create and recreate as well as identify key data and information which must be transformed into knowledge for developing essential legislation or even adaptation of various aspects of international treaties. When various levels of administration store and share critical knowledge with key stakeholders, only then can SWM goals be achieved.

4.3. Stakeholders

The waste management chain, from generation to disposal, involves many stakeholders including waste generators, waste management companies, product manufacturers, and municipal authorities, as well as other administrative institutions and policymakers. The expert practitioners within the waste management chain also serve as a repository of tacit knowledge — such as, for example, the operators of waste management equipment or the deployment of specialized technology for WM. Irrespective of the aforementioned, literature on certain aspects of waste is insufficient or non-existence. There is also limited know-how and poor environmental and waste awareness among the general public, which is a prevailing phenomenon in developing countries and emerging economies (IEA, 2014). To overcome the challenge of limited know-how, stakeholders in developing countries must network among themselves as well as pursue the acquisition of critical knowledge by engaging the services of WM experts and international WM companies (Abila and Kantola, 2017). Sensitization programs through the use of audio-visuals must be deployed frequently by municipal authorities and governments at various other levels to help bridge the existing knowledge gap between various stakeholders along the WM value chain. Key WM stakeholders must engage in research to develop new technologies for sustainable management and disposal of waste. Waste management companies, as part of their business strategy, must engage in knowledge

management processes to ensure effective performance, competitive advantage, and quality service (Jasimuddin, 2012).

4.4. Strategy: Five R's

Various forms of knowledge such as a priori, a posteriori, explicit, tacit, propositional and non-propositional are crucial for implementing the strategies for sustainable waste management, from the basic on-the-ground knowledge of the volume of various types of waste generated to advanced technical expertise. Despite the adoption of these strategies, the lack of crucial knowledge hampers their full implementation in some jurisdictions and various administrative levels.

4.4.1. Reduce

The WM reduction strategy is tailored towards reducing waste at source as well as the volume of waste that ends up at waste-dumps or landfills. The overarching goal of the European Union Directive 2008/98/EC is to reduce the volume of waste produced each year in member states (EU, 2008). This strategy requires putting in place effective and appropriate incentives and penalties, which in turn requires knowledge, i.e., understanding the interplay of actors, processes, and goals within a WM framework.

4.4.2. Reuse

Extracting further use from products that have supposedly reached their end-of-life is a strategy gaining ground in developed economies. Reuse can take place from primary sources and also secondary sources that are from either a direct consumer or producer. In most countries, second-hand products markets are a well-established part of product lifecycles. Lane and Watson (2012) see reuse as part of the culture of stewardship, conservation, and preservation, and a growing culture globally is increasingly conscious of the environment and

of the need to conserve natural and environmental resources, including through reuse, which helps reduce the volume of waste that goes directly into landfill or other non-environment-friendly disposal options. From construction waste to household equipment and clothing, transferring ownership and extending lifecycle and derivable utilities is a strategy that needs continuous encouragement. However, not many countries have legislation or regulation to bolster this aspect of waste management. In developing countries, reuse — like other WM strategies — are left in the hands of informal practitioners. Increasing the volume of reuse will require gathering and harnessing essential knowledge. Social media and related technologies are useful tools that can help in product sharing, helping to extend product lifecycles by communicating who has what, where, and when. Locating specific products at the end of their initial life, and matching them with "new-users," is the new direction for enhancing reuse.

4.4.3. Recycling

Putting back materials recovered from waste into production or manufacturing processes can be a cost-saving strategy. Recycling includes three distinct modes: third party take-back (TPT), retailer take-back (RT), and manufacturer take-back (MT) (Zhang et al., 2014). The deployment of these strategies entails the generation and utilization of critical knowledge, such as information on the quantity and rate of recycling, and the profitability of various recycling modes (Xu and Wu, 2012). The absence of complementary activities to explain to people how and why it is important to recycle is an established knowledge gap (World Bank, 2014). To ensure an efficient recycling strategy, there is a need for waste-related data and information acquisition, classification, organization, storage, sharing, utilization, creation-recreation, and identification.

4.4.4. Repair

The repair strategy works hand in hand with the reuse strategy. Home appliances, electronics, automobiles, furniture, and clothing that might have been thrown away in 'the throwaway society' have found a place in the growing second-hand markets (Gregson, et al., 2007; Evans, 2012; McCollough, 2012). The expertise required to mend and place these products is a form of tacit knowledge. The repair strategy for WM has found a new use for technical expertise as well as new uses for expensive equipment while helping to conserve natural resources and save the environment. Information on the quantity and availability of products at the points of disposal, as well as the "know-who" to find expertise to make products useful again, are aspects of knowledge management approach that must be streamlined into an overall WM framework. Trading-in old products for an upgrade and newer version is another strategy under repairs. This allows customers to transfer the responsibility for repair and transfer-to-new-owner to be borne by the manufacturer. It is also an aspect of extended producer responsibility (EPR). Developing an efficient EPR system for various waste streams will require deploying knowledge management tools that will allow for a seamless transfer of products between manufacturers-retailers-users.

4.4.5. Recovery

The exhaustible nature of the raw materials used for manufacturing a variety of products implies that effort must be made to recover some of the components used in producing the products. To attain optimal material or energy recovery from waste, essential information must be within useful reach of stakeholders, including knowledge of the type of raw materials or quantity of energy that can be recovered from a product.

4.5. Classification

Differentiation of waste into various categories is an important step towards the implementation of the 5R's strategies. Problems of WM have persisted in many countries due to the lack of separation of waste, either at source or at collection points. Dissemination of knowledge, particularly of the classification prescribed for waste disposal strategy, is a major challenge for its implementation. Also considering the definition of municipal waste, the European policy on waste noted the inconsistencies in Member State and also the fact that the terms "household waste and municipal waste" are often used as though the two were exchangeable, albeit they do not refer to the same thing (Eunomia Research and Consulting, 2002). A general definition of municipal waste across regions must be consistent. A knowledge monitoring medium must be provided to mitigate present and future misconceptions of waste terminologies.

4.6. Infrastructure

Administrative actors and other stakeholders can contribute to efficient WM by providing the needed infrastructure. Countries, counties, and municipalities designate landfills and also (sometimes in conjunction with waste collection companies) distribute collection bins at designated kerbsides. A range of information is necessary for managing waste collection efficiently: maintaining a roster of employees and designating duties; sharing information on the location of waste collection bins and schedules; and providing for specialized waste collection. These functions call for applying best practices in knowledge management. Information and communication technologies can foster knowledge management in this area, such as the application of geographical information systems (GIS) for WM planning in Spain (Zamorano, et al., 2009). In addition, integrating information on the location of WM infrastructure on digital media (such as Google map) may be appropriate for cities and towns.

4.7. Technology

The emergence of new technologies and adaptation of the old can help solve WM problems. Administrators and stakeholders need to identify not only the appropriate technology but also the expertise for training and adapting it. They also need to maintain and share essential information on how to access these tools.

4.8. Process

Implementing the right knowledge management approach for each waste treatment process is a key part of the overall WM strategy. Some of the processes involved, such as energy generation and production of fuels from waste, require tacit knowledge that is still not available globally. An instance is a case where many developing countries' indigenous waste management authorities experience a lack of knowledge on a broad range of treatment systems regardless of the wide availability of data and information on waste treatment techniques (Filho et al., 2016). Ensuring the transfer of such advanced knowledge must be a global pursuit, particularly as part of the implementation of waste-related treaties and conventions. Considering developed and high-income countries, reporting systems are not uniform for waste. A scenario is the data reported to and collated by both EU (Eurostat) and the OECD presents gaps and questions over their inter-comparability, whereby double counting is exhibited as often when waste is processed, the output from the treatment facility is counted again as a new waste. Aside from tallying the total quantities, tracking a particular item of waste from its origin to its final destination is difficult (United Nations Environment Programme, 2015). Proper monitoring and sensitive tracking devices must be put to use from the first point of collection to processing or treatment then to final disposal.

4.9. Goals

The benefits of managing waste sustainably include economic, environmental, social, and educational impacts. The guiding legislation or convention usually sets forth waste management goals for a region, country, or municipality, within a particular timeframe (see Table 4). It is important for waste companies to stay informed about the goals of waste management set forth in various legislations. As WM evolves, there is a need for developing and applying knowledge management tools in ensuring legislation align with strategies and other aspects of the WM chains to attain set goals.

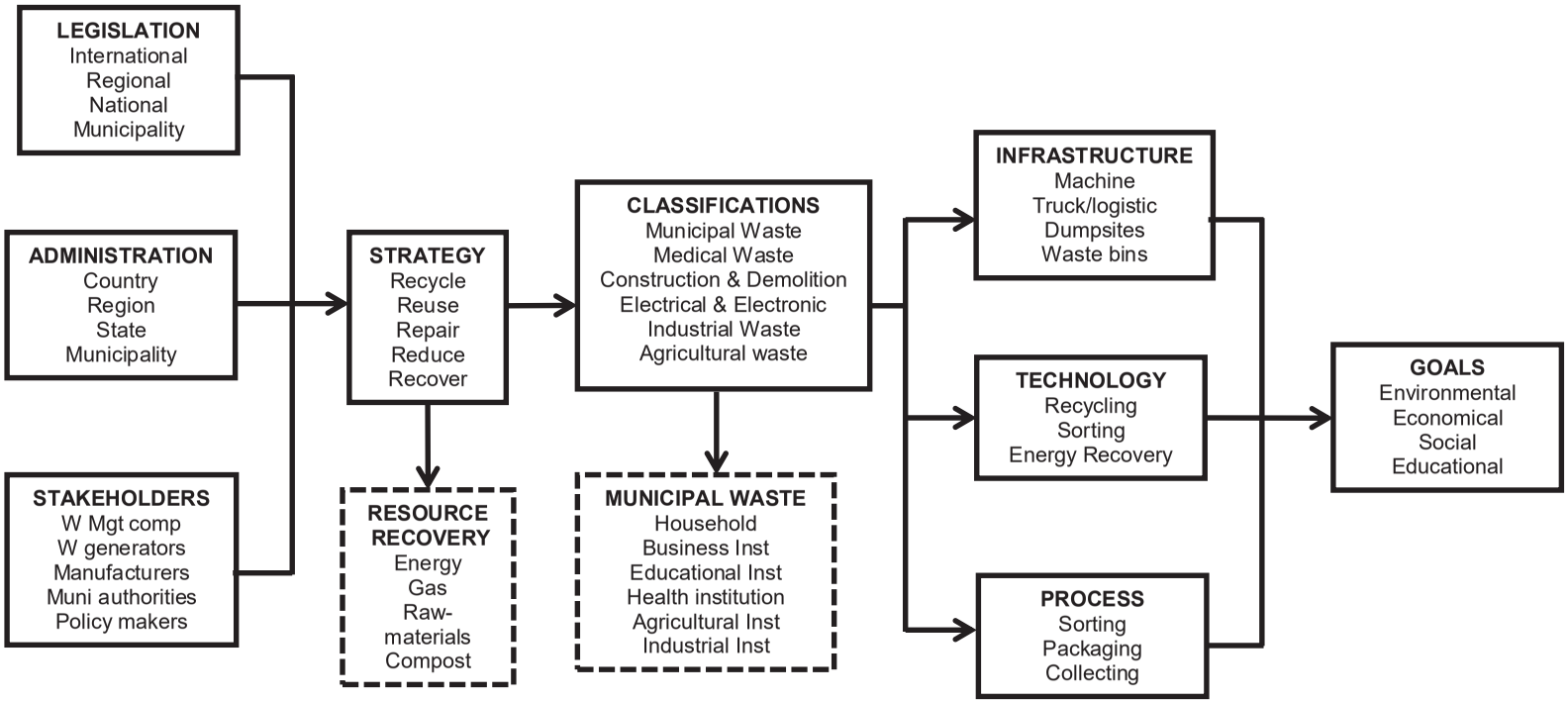

Figure 1: The Conceptual Framework of Waste Management

Key: W – waste, Mgt – management, muni – municipal, inst – institutions

Table 3: Conventions and treaties relating to wastes management

Legislation/Conventions	Issue(s) Address	No of signatories (parties) countries	Localization (Responsible Body)
The Basel Convention on the Control of Transboundary Movements of Hazardous Waste and Their Disposal	The convention aims at reducing trans-border movements of waste considered hazardous. It also aims at protecting developing countries which are increasingly becoming dumping grounds for waste from developed countries.	53(187)	International (UN Treaty)
Directive 2006/12/EC of the European Parliament and of the Council	The guideline provides a comprehensive framework for managing various streams of waste in member countries. Provides less ambiguity in classification and definition of waste.	All member states of the EU	Regional (EU/EC Directive)
The Bamako Convention	The convention aims at preventing the dumping of hazardous waste in Africa. It also serves for providing guidelines for managing waste that is considered hazardous in African countries.	30 (27)	Regional (AU Treaty)
The Rotterdam Convention	The convention aims at increasing collaboration in the management of chemicals that are hazardous. It facilitates information sharing and transparent disclosure of information about hazardous waste. This relates to chemical constituents of products and the final disposal.	72(154)	International (UN Treaty)
Stockholm Convention on Persistent Organic Pollutants	Deals with the utilization and disposal of organic pollutants.	152(179)	International (UN Treaty)
The Waigani Convention	Deals with the management of hazardous or radioactive waste in the Pacific Islands countries.	14(13)	Regional (Pacific region Treaty)
The Convention on Biological Diversity (CBD)	The convention focuses on the conservation of biological diversity (or biodiversity). It ensures the ecosystem is sustainably managed without a direct negative impact. It ensures there is a fair and equitable sharing of benefits arising from genetic resources.	168(194)	International (UN Treaty)
The United Nations Framework Convention on Climate Change (UNFCCC)	This convention relates to the prevention of the further increase in the CO2 and greenhouse gases. Creates a framework for curbing greenhouses gases from the waste dump and other waste sources. Promotes the derivation of benefits from curbing climate challenges	165(196)	International (UN Treaty)
The Ramsar Convention	The convention serves for the preservation of wetlands. It is crucial for preventing the negative utilization of wetlands, including waste disposal.	7(168)	International (UN Treaty)

5. Situating Knowledge Management in Waste Management

Knowledge management is crucial in the pursuit of various WM goals and in creating synergy between different goals. Abila and Kantola (2013) postulated that managing MSW efficiently requires the application of knowledge management tools throughout the WM chain. Specifically, situating knowledge management in waste management will involve deploying the knowledge management cycle which includes acquisition, classification, organization, storage, sharing, utilization, creation/re-creation, and identification of waste (Rubenstein-Montano, et al., 2001). Figure 2 captures some of the key processes for waste knowledge management.

The increasing concern about waste problems has led to the development of various knowledge management innovations. Table 4 shows various knowledge management innovations identified while reviewing relevant literature for this study. The outcome of the literature review shows that indeed, irrespective of the strategies being applied by various administrative levels, various knowledge management innovations are emerging. WM companies who themselves are the repository of knowledge must remain innovative, applying various knowledge management tools and approaches for responding to changing scenarios within their operational domain. The WM companies must constantly be updating their repository of tacit and explicit knowledge to attain SWM Goals.

Table 4: Knowledge Innovations for sustainable waste management

Sustainable Waste Management Strategy	Knowledge Management Innovation	Types of waste	The administrative level of application	References
General	Geographical Information System (GIS) Technology for Vehicle Routing and Scheduling in MSW Collection Systems	MSW	Municipal	Chang et al. (1997)
Reduce	Waste Info knowledge management system for a clearing-house of comprehensive information on broad categories of waste.	Municipal, Commercial, Institutional, Agricultural	National	Gründler et al. (2006)
Recycle	Helsinki Region Environmental Services Authority (HSY) GPS/internet recycling point locator	Municipal Solid Waste	Municipal	HSY (2014)
	Internet of Things (IoT) which uses RFID technology ensures that companies comply with rules and derive optimum benefits from waste management through recycling.	Construction Waste	National	Zhang et al. (2012)
Recovery	Computational Fluid Dynamics (CFD)	Municipal Waste	Municipal	Shin et al. (1998)
	RFID			Zhang et al. (2012)
	CO2ZW tool for monitoring and estimating the emission of greenhouse gases (GHG) from waste.	Municipal	Municipal/landfill	Sevigne Itoiz et al. (2013)

Situating knowledge management in WM requires linking theory and practice. Each of the themes within the WM framework (Fig. 1) entails a set of questions — i.e., the know-how, know-who know-what, and know-why component of knowledge management within that subsector. The know-how, know-who, know-what and know-why components of knowledge management within the waste management subsectors imply knowledge of how waste is managed, knowledge of who manages waste, knowledge of what waste is managed, and knowledge of why waste is managed. These components in turn entail various types of knowledge: explicit knowledge and tacit knowledge. Explicit knowledge is the knowledge that is documented and shared in a formal and systematic language (Massingham, 2014). This

includes data, documents, manuals, promotional materials, guidelines, laws, regulations, and even contacts information for relevant stakeholders. Tacit knowledge is the knowledge that exists in human minds (Massingham, 2014). For instance, the tacit kinds of knowledge that exist within WM institutions include personal, procedural, and propositional knowledge that individual WM practitioners have acquired over the years. In order to retrieve such tacit knowledge, stakeholders within the WM chain must collect, classify, organize, store, share, and properly tag knowledge relating to their activities. These knowledge management approaches are designed to ensure that the cycle of knowledge management is not broken throughout the WM chain. Situating knowledge management in WM entails applying these approaches to legislation, administration (including "know-who"), technologies, processes, infrastructure, and even the goals of WM. The WKM framework (Fig. 2) provides the basis for understanding the connection and integration of the application of KM tools, systems, and approaches in the WM chains.

Figure 2: The Conceptual Framework of Waste Knowledge Management (WKM)

6. Conclusion

This paper reviewed existing literature on waste management to identify knowledge gaps and synthesized existing knowledge to come up with a conceptual framework for applying a knowledge management approach in WM. The conception of the application of KM approach in WM is new; hence study in this field is limited. Its background provided a description of the complexities, concerns, and goals of WM. It outlined the various components which are considered crucial in the application of knowledge management in WM. This paper has attempted to illustrate how the application of knowledge management systems, tools, and approaches can help in attaining SWM goals. It provided examples of emerging knowledge management innovations and tools which are already in use globally for addressing various WM problems. Though some WM concerns are global in nature, others are specific to the conditions and peculiarities of various countries and municipalities. This paper contributes to existing theory in waste management from an entirely different approach. The conceptual framework of waste management presented in this paper provides a pivot for understanding the link between legislation, administration, stakeholders, classifications, infrastructure, technology, the processes and goals of waste management. The conceptual framework of waste knowledge management illustrates processes that waste companies and other stakeholders can adopt towards attaining sustainable waste management. Both frameworks focus on a broad scope of WM and present a comprehensive and holistic system displaying linkages within themes. This is important to foster and support the contemporary definition, conception and insight of WM, as well as KM in WM.

It is hoped that the conceptual frameworks presented in this paper, will provide the foundation for further studies exploring the application of knowledge management in WM. The empirical validations of the proposed conceptual frameworks are yet to be established, thus require further analysis. Governments must have the WKM framework for waste at the

legislative and administrative levels. This paper advances the insight of managers to visualize the KM tools, systems, and approaches used in the management of waste as the foundation of KM. This paper will aid managers in conceiving and laying emphasis on WM from a KM perspective.

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Municipal Solid Waste Management Problems in Nigeria: Evolving Knowledge Management Solution

Beatrice Abila and Jussi Kantola

***Abstract*—**The paper attempts a synthesis of problems relating to municipal waste management in Nigeria and proposes a conceptual knowledge management approach for tackling municipal waste problems in cities across Nigeria. The application of knowledge management approach and strategy is crucial for inculcating a change of attitude towards improving the management of waste. The paper is a review of existing literatures, information, policies and data on municipal waste management in Nigeria. The inefficient management of waste by individuals, households, consumers and waste management companies can be attributed to inadequate information on waste management benefits, lack of producers' involvement in waste management as well as poor implementation of government policies. The paper presents an alternative approach providing solutions promoting efficient municipal waste management.

Keywords—Environment, Knowledge management, Municipal waste management, Nigeria.

I. Introduction

THE sustainable management of waste approach aims at global environmental quality, and environmental quality is a pre-requisite for a rise in per capita welfare over a period of time [8]. "Efficient management of waste is a global concern requiring extensive research and development works towards exploring newer application for a sustainable and environmentally sound management" [11]. The problem of waste management is a primordial and present issue in developing countries in Africa, particularly Nigeria. Municipal waste management problems in Nigeria cut across concerns for human health, air, water, and land pollution among others. The analysis of the key problem affecting the efficient management of municipal waste is critical for evolving a workable solution in an emerging economy like Nigeria. The transformation of the existing trends in municipal waste management is necessary for ensuring sustainable environments and other objectives.

The continuous indiscriminate disposal of municipal solid waste is accelerating and is linked to poverty, poor governance, urbanization, population growth, poor standards of living, and low level of environmental awareness [4], [22] and inadequate management of environmental knowledge. Most of these wastes are generated from domestic sources and are mostly characteristics of household waste [9]. The persisting problems of municipal waste management in Nigeria prompt the need for communicating innovations and knowledge to achieve desire transformation in overcoming socio-economic and environmental challenges. The need to mitigate environmental pollution is crucial due to its direct impacts on human, plants and animals and the increasing contribution to climate change. Furthermore, energy conservation, energy generation, resource and material recovery from waste through improved municipal waste management is possible by deploying best solutions.

Different approaches and interventions have been developed in the past for tackling municipal waste concerns with little or no progress. Managing municipal waste efficiently requires intensification and application of knowledge management tools that guarantee sustainable environment and socio economic growth. "Municipal solid waste management is an important part of urban infrastructure that ensures the protection of environment and human health" [6].

Knowledge management definition varies from author to author, but for the purpose of this paper two different definitions which are applicable are adopted. Knowledge management is a broad term that requires systematic efforts of an organization to manage its personnel knowledge through a broad range of direct and indirect methods such as specific types of ICT, management of social processes, structuring of organizations in a particular pattern or via the use of particular culture and people management practices [17]. In addition, knowledge management is a vast topic which focuses on both technology and people centre strategy. According to [16], Knowledge management is the access and utilization of different resources to create an environment where individuals acquire, share and use information to build on existing knowledge.

The paper attempts a synthesis of problems associated to municipal solid waste management and propose a conceptual knowledge management approach for tackling municipal solid waste problems in Nigeria. For an in depth understanding of these issues and solutions, the article covers the existing management of municipal solid waste, municipal waste policies and regulations, problems affecting municipal waste management, knowledge management challenges relating to municipal solid waste, proposed knowledge management solutions and conclusion.

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World Academy of Science, Engineering and Technology
International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering Vol:7, No:6, 2013

II. Existing Waste Management Processes and Practices in Nigeria

Municipal waste management is the collective process of sorting, storage, collection, transportation, processing, resource recovering, recycling and disposal of waste. In Nigeria, wastes are usually dumped on roadsides, available open pits, flowing gully water and drainage channels [10], [26]. The indiscriminate disposal of municipal waste is increasingly a prominent habit in most urban cities of Nigeria. Unlike urban cities, in rural communities municipal solid waste quantity are less and managed in household backyards by burning, composting, as feeds to animals and occasionally disposed at dump sites. In Nigeria the processes involved in the management of waste are, storage, collection, transportation and disposal at dumpsites.

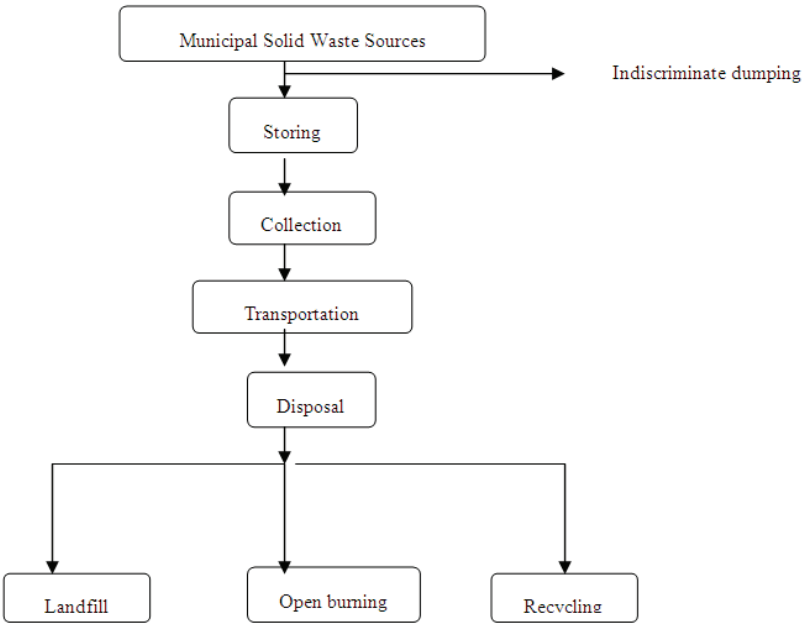

Fig. 1 Existing municipal solid waste management flowchart for Nigeria

There are different techniques of municipal solid waste disposal but the common techniques are landfill, incineration, composting and anaerobic digestion and recycling [18]. Although presently in Nigeria the prominently practiced municipal waste management technique is open dumping, land fill, followed by open burning while incineration method is seldom put to practice. Incineration is a cost effective municipal waste disposal option which is seldom applied in Nigeria hospitals where medical waste are incinerated at a minimal scale [24]. The cheapest and simplest method of waste disposal is landfill. The resulting environmental impact of landfills is enormous but could be mitigated provided sanitary precautions are undertaken and waste reduction is advocated. Landfills were responsible for 49% of England's methane emissions in 2007 [12]. Moreover, recycling which is an environmentally friendly option is not fully adopted. There are no formal recycling sectors in Nigeria. Waste are recycled informally by scavengers who buy un-use valuables from people and also go to legal and illegal dumpsites in search of materials that than can be re-use and recycled.

III. Municipal Solid Waste Generation

25 million tonnes of municipal solid waste are generated annually in Nigeria and the waste generation rates ranged from 0.66kg/cap/d in urban areas to 0.44kg/cap/d in rural areas as opposed to 0.7-1.8kg/cap/day in developed countries [24]. There is a continuous increase of municipal solid waste production by households, educational institutions, commercial institutions, and among others. In Nigeria, municipal waste generators include household, commercial, industrial, agricultural and institutional establishments and among others. The quantity and composition of waste generated vary from urban areas to rural areas and likewise from state to state. Waste generated is directly proportional to population, socio-economic status and level of urbanization [2], [3], [25], hence the quantity of waste generated varies from state to state and also increases per year. Also the composition of waste generated per state is a function of the socio economic status, industrialization and commercialization. This is linked to urbanization and socio-economic growth.

World Academy of Science, Engineering and Technology
International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering Vol:7, No:6, 2013

TABLE I
MUNICIPAL SOLID WASTE GENERATION FOR SOME CITIES IN GEOPOLITICAL ZONES IN NIGERIA

Geopolitical Zones	Population	Waste Generation Kg/pers/day	Waste Generation (ton per month)	Waste Generation density (kg/m^3)
		South West		
Lagos	8,029,200	0.63	255,556	294
Ibadan	307,840	0.51	135,391	330
Ado-Ekiti	241,200	0.71	9,518	-
Akure	369,700	0.54	-	-
Abeokuta	529,700	0.66	-	-
		South East		
Nsukka	100,700	0.44	12,000	370
Onitsha	509,500	0.53	84,137	310
Aba	784,500	0.46	236,703	-
		South South		
Port Harcourt	1,053,900	0.60	117,825	300
Warri	500,900	-	66,721	-
Uyo	102,400	-	20,923	-
		North Central		
Abuja	159,900	0.66	14,785	280
Markurdi	249,000	0.48	24,242	340
Ilorin	756,400	-	-	0.43
		North West		
Kano	3,248,700	0,56	156,676	290
Kaduna	1,458,900	0.58	114,433	320
		North East		
Maiduguri	971,700	-	850,000	-

Source: [7], [24]

IV. WASTE MANAGEMENT POLICIES AND REGULATIONS

The waste management policies and regulations were propagated to guide and mitigate the continuous disposal and dumping of waste to rivers, pathways, water channels and illegal dumpsites. The Federal Government of Nigeria enacted Decree number 58 for the establishment of a Federal Environmental Protection Agency (FEPA) on 30th December 1988 to achieve a set of goals. In Nigeria waste management is among the very core management of the local government, state government and federal government. For instance, in Lagos the main government institutions responsible for environmental protection are the Lagos State Waste Management Agencies (LAWMA), Lagos State Environmental Protection Agencies (LASEPA), Local Government Councils (LCGs) and the ministry of environment and Physical Planning (MEPP) [20]. Moreover, at the state levels – the state environmental protection agencies and state waste management agencies are in charge of municipal waste management. Presently wastes are managed by each state environmental protection agency and state waste management agencies in urban cities and big towns in Nigeria. Municipal solid waste collected from the generation point are loaded into waste trucks and transported to designated dumpsites. Consequently, the collection of municipal waste by the state environmental agency requires the payment of certain amount of charges by each household. The size of an apartment determines the allocation of waste collection charges. As a result of income status of people some households cannot afford the monthly payment. This financial limitation promotes indiscriminate dumping of refuse by such individuals. However, most rural dwellers are not provided with such opportunity.

Federal Government of Nigeria Policy Objectives includes:

- Secure quality environment for all Nigerians for their health and well-being;
- Raise public awareness and promote understanding of the importance of relation between environment and development; and
- To encourage individual and community participation in environmental protection and improvement efforts [28].

The local, state and federal environmental protection agencies enacted laws are similar and include the following:

- The National Protection Management of Solid and Hazardous Wastes Regulation of 1991.
- The Pollution Abatement in Industries and Facilities Generating Waste Regulation of 1991.
- The General Guidelines for Pollution Abatement in Industries 1991. (U.S. Environmental Protection Agencies [1], [19], [28].

V. FACTORS AFFECTING MUNICIPAL WASTE MANAGEMENT AND KNOWLEDGE MANAGEMENT LINKAGES

The problem militating municipal waste management in Nigeria are diverse and numerous; and according to [5] these problems are related to economical, technological, psychological and political aspects in Nigeria. These problems vary from poor funding, poor legislation and implementation of policy, Limited infrastructures and professionals, level of awareness, poor recovery and recycling programme, and disposal technique [13], [15].

A. Poor Funding

This is one of the major problems constraining the waste management sector [22]. Incapability of purchasing new waste collection trucks, limited staffs, poor vehicle maintenance, unsubsidized waste storage containers, inability to purchase equipments among others are all attributed to shortage of capital. Actualizing waste management projects require consistent funding to achieve answers to strategies yet to be implemented.

B. Poor Legislation and Implementation of Policy

The constitutional strength of municipal waste management policy is weak and ineffective. Also implementation of this policy is not monitored. The policy is not well structured and definitely tends to be weak. There are instances in which due process is obstructed and sanctioned penalty are not expended on certain municipalities and individuals. Policies are yet to be aimed at the 3R's of waste management – reduce, reuse and recycle. Government policy on waste are not revisited, reaffirmed, restructured and upgraded in a comprehensive tune and form.

C. Limited Infrastructures and Professionals

Limited solid waste infrastructures are one of the major contributing indexes of poor waste management system in Nigeria. Nonetheless, experts to man these machineries are

World Academy of Science, Engineering and Technology
International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering Vol:7, No:6, 2013

also not on ground. The environmental protection agencies and waste management personals are not experts and exposed to workshops and trainings that meet international standards on technology use, information management and knowledge management. Most of the state environmental protection agencies lack adequately trained personals [5].

D. Level of Awareness

In Nigeria, populace awareness on sustainable waste management is still very poor and effort by the agencies to increase awareness is still very low. Municipal members are not well informed on the adverse effects of indiscriminate and improper disposal of waste and also the benefits of such act.

E. Recovering and Recycling

Access to possible recyclable material possesses great difficulty due to poorly limited recycling programs. The informal recycling programs involve scavengers' effort search of recyclable items. Presently, the informal sector renders the service of retrieving and recycling of materials in Nigeria [23]. The introduction of an advance formal recycling program presents positive and accelerating outcomes for municipal waste management sector.

F. Disposal

The landfill disposal technique of waste materials with dearth of treatment processes and open dumping possesses increasing public health hazards to human lives, animals and plants. However, the evolutions of poisonous gases such as methane and carbon-dioxide causes alteration of weather, leading to climate change.

VI. Knowledge Management Challenges in Municipal Waste Management in Nigeria

A. Cultural Belief

Wastes are viewed as an invaluable and useless materials rather than wealth. Wastes are not seen as valuable materials that can be recycled for actual use, material recovery and energy recovery. The value of waste to people enhances the actualization of the process involved in the management of waste. The conception of waste as worthless is inherently linked with societal organized cultural systems of where things belong [29]. However, consumer's activities are largely a function of common societal cultural values and norms [21].

B. Communication Channels

The dearth of an effective communication channels affects the knowledge acquisition of municipalities in the management of waste. Communication channels such as mass media and posters are often adopted in the transfer of new information rather than the face to face which involves one on one practical interaction process.

C. Collaboration with International Solid Waste Management Organization/Agencies

The existence of limited collaboration with International Solid Waste Management organizations impedes rapid sustainable development within the Waste sector. Interaction with International waste agencies is rarely a focus area for waste management.

D. Centralized Waste Collection Containers

In Nigeria centralized municipal storage containers are not in place. This presents the municipalities with placement challenges of sorted and recycled materials of different categories. The need for centralized municipal collection points are not viewed as a means to a solution for recycling and material recovery. Thus such agenda are not included in platform for waste management. The available funds are not directed to meet purchase of the waste storage containers for managing waste management. Purchase of municipal storage containers for different collection point is indeed necessary.

E. Packaging and Product Producer Involvement

The involvement of packaging producer in the management of waste is limited. Producers' interests are mainly in the production of content packages rather than the management of these packages. Due to the low level of material and energy recovery, thus material cost are not maximized and this directly affects cost of packaging production. With the increasing effect of improper waste management, the manufacturing sector interest lie mainly on profitability rather than waste reduction [5].

F. Personnel Morale

Field workers in charge of waste collection and transportation often have low morale. There performance is determined with the extent of stigmatization encountered on the job, poor remuneration and stagnant promotion. Field staffs are not also encouraged with the consumer's manner of habitual waste storage.

VII. Proposed Knowledge Management Solutions

The presentation of knowledge management solutions in the management of municipal waste in this context is not only in terms of technology centered approach but rather a people centered approach.

With respect to Municipal waste management the people centered approach focuses on individuals that falls within the municipal waste management chains. This includes municipal waste generators, packaging firms or producers and waste management companies while the technology centre approach focuses on the use of ICT's as knowledge and information repository in the management of municipal waste.

People should be orientated knowledgably to conceive waste as being a valuable resource for material and energy recovery, and also on the environmental consequences of waste dumps on drainage channels, streams, pathways and roadsides.

The more interaction with international waste agencies is required to close up existing gaps between developed and developing countries, and to ensure efficient municipal waste management. This interaction would open doors to new coping strategies of managing waste effectively in Nigeria, among which is knowledge management.

World Academy of Science, Engineering and Technology
International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering Vol:7, No:6, 2013

The need for information flow between waste generators, producers and waste management companies is vital in bridging the knowledge gaps. The communication and exchange of knowledge is facilitated between waste generators and producers of recyclable packages such as plastic, tins, and cartons provided comprehensive descriptive logos or label are inscribed with expressions in English and three major languages on such containers as been recyclables. Recovery process of these recyclables from consumers will be possibly not challenging if certain incentives are attached to the return of such items. These incentives are consumer generated incentives that are derived at the point of purchase as the cost of the actual containers is already added to the purchasing cost of the items.

The transfer of information and knowledge to municipalities should be undertaken by waste management (social workers) companies through an effective communication channels involving face-to-face communication. Aside other means of communication, the face- to face channel of communication should be employed by the municipal waste management companies to interact with and orientate members of the municipalities on disposal habits, sorting and storing of waste in an environmental friendly manner. The importance and benefits attached to waste separation, proper storage, collection and effective waste management needs to also be communicated. The eye contact and interaction between the sender and receiver helps achieve the desired goal to a large extent. Efficient management of waste is promoted if municipal storage containers are available at subsidize price. The storage containers should be of different colours indicating the various category of municipal waste for a particular storage container.

In bridging the knowledge gap existing between packaging and product manufacturers; and waste management companies, the need to deliberate and share knowledge on what ought to and can be re-use and recycled to produce the actual container or alternative containers and energy is paramount. A cohesive collaboration between the packaging manufacturer and waste companies will enhance the prerequisite knowledge and information transferred to communities. Hence, some level of participation is required of them in order speed up actualization process.

TABLE II
PROPOSED KNOWLEDGE MANAGEMENT SOLUTIONS IN MUNICIPAL SOLID WASTE MANAGEMENT

Stakeholders	Stakeholder's Roles	Municipal Waste Management Problems	Source	Proposed Knowledge Management Solutions
Municipal Waste Sources • Households • Industries • Commercial Institutions • Non commercial Institutions	Partake in the primary management of waste. Respond and abide to waste management rules and regulation. Prompt Payment of waste collection dues.	Indiscriminate dumping. Low level of public education in waste management. Poor sorting at source. Absence of storage facilities. Public attitude towards waste management.	[15], [18], [20]	Estsblish face- to-face information sharing for waste generators. Persistent use of Information Communication Technology (ICT's) to disseminate information.
Municipal Waste Management Agencies	Collection, transportation and application of different disposal techniques. Facilitate awareness programmes. Record waste generated per capita/day and annually	Unfriendly environmental disposal technique. Poor funding, un skilled and limited manpower. Poor maintenance of vehicles. Inadequate waste collection vehicles and equipments. Limited collaboration with international waste management agencies.	[13], [14] [22]	Establish local and international networks. Utilize both tacit and explicit knowledge. Set up information repositories for data storage. Application of diverse knowledge sharing methods for staffs.
Municipal Authorities Legislators	Establish monitoring programs Specify waste disposal sites. Specify waste disposal and treatment.	Policies lack clear strategies. Obsolete policies. Inadequate and poorly implemented waste management policies.	[27],[28]	Begin international collaboration mechanism. Initiate and implement motivational factors that promote peoples adoption of material reuse, recovery and recycling.
Informal waste sector	Waste brokers between the waste generators and manufacturers/middlemen Resource recovery.	Limited formal education. Highly unskilled workers.	[24]	Set up data base and information management system for information capturing.
Producers	Collaborate with waste management to promote recovery, reuse and recycling. Establish motivational scheme.	Dearth of involvement in municipal waste management issues.	[5]	Waste agencies collaboration with research and development institutions.

VIII. CONCLUSION

In Nigeria Cultural belief is a major barrier to efficient waste management. Other barriers includes packaging and product manufacturers' involvement and interventions in curbing waste management, ineffective communication, poor personnel morale, absence of centralized waste collection containers, limited collaboration with international organization. Conclusively, the focus of municipal solid waste management should not only be technology centered strategies but also people centered.

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Int. J. Environment and Waste Management, Vol. 19, No. 4, 2017 297

Proposed solutions in municipal solid-waste management

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Abstract: Waste is one of the major contributing factors to serious environmental problems in both developing and developed nations. This paper proposes two approaches to tackle waste management, specifically in Nigeria. The first approach is focused on product design and the second is on the knowledge-management solutions. These approaches can be adopted in other countries as well. The paper also presents a review of existing literature on Nigeria, municipal waste management challenges and designing a recycling solution using axiomatic design. The poor management of waste is the result of a combination of a number of challenges. The paper aims to ensure efficient and sustainable waste management in Nigeria.

Keywords: municipal solid waste; waste management; waste; sustainable waste management; design; knowledge management; Nigeria.

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1 Introduction

Unsustainable management of waste is one of the key contributing causes in increasing global environmental pollution and serious environmental challenges both in developing and developed nations. These environmental problems and impacts are pressing and simultaneous, and vary from climate change, air pollution, water pollution, soil pollution and aesthetic issues. All of these can have direct effects on humans, animals and plants resulting to detrimental conditions. These impacts are recognised in international and national environmental policies and regulation such as the EU's Waste Framework Directive and England's Waste strategy (Burney et al., 2011).

The goal of sustainable waste management is global environmental quality, and environmental quality is a pre-condition for an increase in per-person welfare over a period of time (Ayininuola and Muibi, 2008). Invariably an increase in per-person welfare is directly proportional to an increase in per-person socio-economic status. The continuous management of waste is a global issue involving extensive research and development work towards discovering newer applications for sustainable and environmentally sound management (Bari et al., 2012).

In most developing countries the existing system of waste management is primitive, thereby inefficient to attain desired goals. In Nigeria, waste-management problems raise concerns related to human health, air, water and land pollution, climate change, and economic growth; particularly in overcrowded modern cities where it can present severe effects (Anikwe and Nwobodo, 2002). Analysis of the major obstacles to the efficient management of municipal waste is crucial for evolving a workable intervention in an emerging economy like Nigeria.

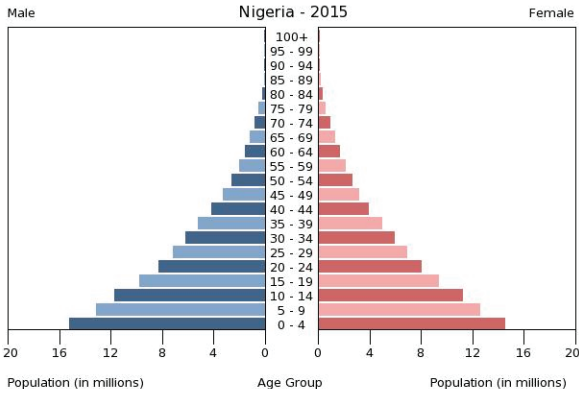
The constant and unmethodical disposal of municipal solid waste is rising, due to poverty, poor governance, urbanisation, population growth, poor standards of living, and low levels of environmental awareness (Adewuyi et al., 2009; Ezeah and Roberts, 2014), as well as inadequate management of environmental knowledge. As municipal solid-waste are generated from different sources, it is noteworthy that most waste generated from urban domestic-sources constitutes 40–60% of household waste (Ayotamuno and Gobo, 2004; Ogwueleka, 2013). This may be because household wastes are produced on daily basis from a large population. This infers the possibility of municipal solid-waste to be generated at continuous alarming rate as compared to other solid-waste types. In order words, municipal solid-waste management is a relevant part of urban infrastructure that guarantees' the protection of environment and human health (Aliyu, 2010). The persisting problems of municipal solid-waste management in Nigeria reveal a need for communicating innovations and knowledge to achieve desired change and overcome socio-economic and environmental challenges. The need to alleviate environmental pollution is essential due to its direct impacts on humans, plants and animals, and its increasing contribution to climate change. Furthermore, energy conservation, energy generation, and resource and material recovery are achievable through advanced municipal waste management.

The paper attempts a synthesis of current trends in municipal solid-waste management challenges in Nigeria and proposes substantial solutions for ensuring efficient and sustainable waste management. The paper also covers a review of existing literature on Nigeria, municipal waste management techniques and policies.

1.1 Nigeria

Nigeria, located in West Africa, is known as the 'giant of Africa' owing to its large population and economy. It is the most populous African country, with an estimated population of over 180 million people, and the eight most populous countries in the world having 47.8% urban population of the total population and urbanisation rate of 4.66% annually. The country has a total area of 923,768 km^2 consisting of 910,768 km^2 land mass and 13,000 km^2 water (CIA, 2016). The country comprises 36 states, excluding the federal capital territory (FCT), Abuja. It shares borders with the Republic of Benin in the West, Chad and Cameroon in the East and Niger in the North. Nigeria is Africa's energy giant that is richly endowed with diverse natural energy resources varying from crude oil, natural gas, coal and lignite, hydro power, solar radiation, wind, biomass (fuel wood animal and plant waste) nuclear among others (Oseni, 2012). It is the continents most prolific oil-producing nation, which along with Libya accounts for two thirds of Africa crude oil reserves. It ranks second to Algeria in natural gas (Oyedepo, 2012).

Figure 1 Population pyramid (see online version for colours)



Source: CIA (2016)

In Nigeria, "contemporary urban settlements are characterised by a decentralisation of both population and economic activity emplaced with low density metropolitan areas" (Bloch et al., 2015a). It is noteworthy, that the people living in urban locations in Nigeria, suffer from immense challenges that differ from population growth rates, immigration, public housing provision, water management, poverty, crimes and insecurity, food insecurity, unemployment, environmental problems and climate change (Oloyede et al., 2015; Ofem, 2012); and waste management inclusive. However, considering poverty, urban areas appear to have experienced measurable progress in poverty reduction (Bloch et al., 2015b).

According to the FAO (2012) there were tremendous population increases of 46,913,000 to 57,357,000, 58,745,000 to 75,543,000, 77,604,000 to 97,552,000,

99,986,000 to 123,689,000, and 126,705,000 to 158,423,000 in the periods 1961–1970, 1971–1980, 1981–1990, 1991–2000 and 2001–2010, respectively. Since 1961 the annual population has had an approximately equal proportion of men and women. Furthermore, Figure 1 explicitly reveals that men and women population are symmetrical within an age group at the interval of 4.

1.2 Municipal solid-waste generation

In Nigeria, presently there is no record of actual estimate of municipal solid-waste generation; albeit an empirical estimate for the year 2012 reveals that there is approximately 18 million tonnes of municipal solid-waste generation annually and 204 kg/cap annually. Following the 2012 annual generation trend, municipal solid-waste generation has been projected to attain nearly 41 million tonnes annually and 292 kg/cap annually by the year 2025 (Scarlat et al., 2015). On a yearly basis there have been continuous increases in the rate of municipal solid waste generated. In Nigeria and other countries, municipal waste generators include households, commercial enterprises, industries, agriculture, institutions, and yard and street sweepings. Waste generation and composition vary between urban areas and rural areas, and also from state to state. Waste generated is directly proportional to population, socio-economic status and level of urbanisation (Adeoye et al., 2011; Adewole, 2009; Olanrewaju and Ilemobade, 2009) and its composition is directly proportional to socio-economic status, industrialisation and commercialisation.

Table 1 Municipal solid-waste generation for some cities

Cities	*Population*	*Waste generation kg/cap/day*	*Waste generation (tonnes/month)*	*Waste generation density (kg/m^3)*
Lagos	8,029,200	0.63	255,556	294
Ibadan	307,840	0.51	135,391	330
Ado-Ekiti	241,200	0.71	9,518	-
Akure	369,700	0.54	-	-
Abeokuta	529,700	0.66	-	-
Nsukka	100,700	0.44	12,000	370
Onitsha	509,500	0.53	84,137	310
Aba	784,500	0.46	236,703	-
Port Harcourt	1,053,900	0.60	117,825	300
Warri	500,900	-	66,721	-
Uyo	102,400	-	20,923	-
Abuja	159,900	0.66	14,785	280
Markurdi	249,000	0.48	24,242	340
Ilorin	756,400	-	-	0.43
Kano	3,248,700	0,56	156,676	290
Kaduna	1,458,900	0.58	114,433	320
Maiduguri	971,700	-	850,000	-

Source: Abila and Kantola (2013)

Following the trends of municipal waste generation across Nigeria in line with the data provided in Table 1, Lagos the most densely populated city produces the largest quantity of waste as compared to other states, and then followed by Kano, Port Harcourt, Kaduna and other cities respectively. In Table 1 there are instances in which population is directly proportional to waste generation rate in some cities. Conversely, comparing cities with close population estimate Port Harcourt and Kaduna; and Uyo and Abuja population are inversely proportional to waste generation rate either in kg/cap/day or tonnes. Furthermore, Port Harcourt and Uyo are less populated as compared to Kaduna and Abuja respectively, however Port Harcourt and Uyo generates more quantity of waste. This may be due to the high economic status and high standard of living in Port Harcourt and Uyo with the fact that both cities are significantly endowed with crude oil as compared to Kaduna and Abuja respectively that are not endowed.

Table 1 highlights some cities with their population, waste generation in kilogram per capita per day and tonnes per month and waste generation density in kg/m^3 respectively.

1.3 Knowledge management

Knowledge-management definitions vary from author to author in accordance with the specific context. It incorporates the systematic efforts of an organisation to manage its personnel's knowledge through a broad range of direct and indirect methods such as specific types of ICT, management of social processes, organisational structuring, or particular cultures and people-management practices (Hislop, 2009). Overall, though, it focuses on both technology and people-centred strategies. According to Haapalainen and Pusa (2012), knowledge management is the accessing and utilisation of different resources to create an environment where individuals acquire, share and utilise information to build on existing knowledge. According to Liebowitz and Megbolugbe (2003), "knowledge management is the process of creating value from an organization's intangible assets". It addresses policies, plans of action and techniques to objectively support organisational limitations by optimising the conditions required for effective improvement, innovation and cooperation among employees (Nevo and Chan, 2007).

2 Literature review

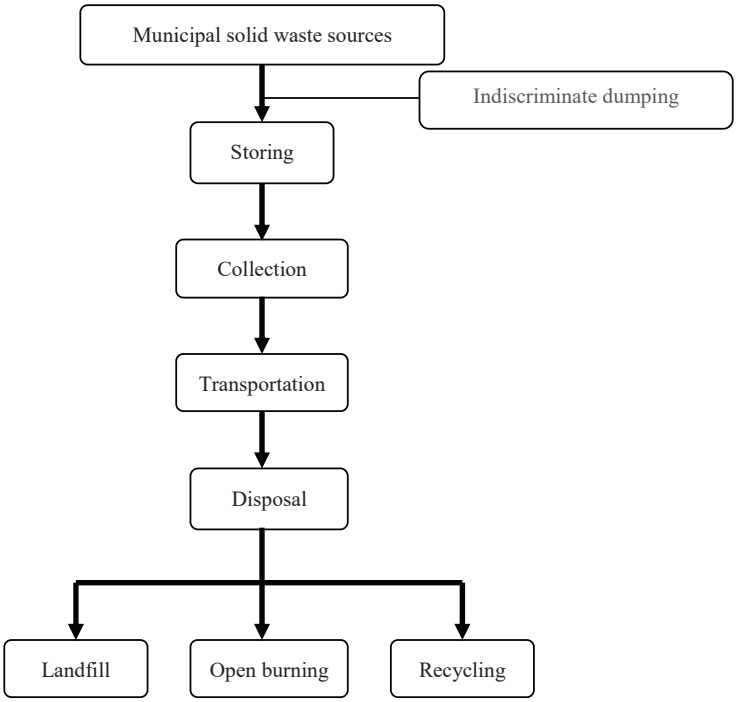
Over the years a number of studies have been conducted in Nigeria with a focus on sustainable waste management. Waste management is still faced with a number of key challenges in the country, particularly in relation to municipal solid waste being generated in large quantities on a daily basis. A review of previous studies on waste-management processes, policies and regulations and challenges in Nigeria is provided in this section.

2.1 Waste-management practices in Nigeria

The municipal management of waste involves the combined processes of sorting, storage, collection, transportation, processing, resource recovering, recycling and disposal. In Nigeria, wastes are usually dumped on roadsides, in available open pits, flowing gully waters and drainage channels (Babayemi and Dauda, 2009; Onwughara et al., 2010). This is an increasingly common practice in some urban locations in Nigeria. In rural

communities the quantities of municipal solid-waste are less and are managed in household backyards by burning and composting, given as feed to animals or occasionally disposed of at dump sites.

Figure 2 Municipal solid-waste management flowcharts for Nigeria



According to Igbinomwanhia (2011), a number of methods of disposal and management of municipal solid waste are put to use, but the most prominent ones are landfill, incineration, composting and anaerobic digestion and recycling. In Nigeria specifically, the most common disposal and management techniques are open dumping and landfill, followed by open burning; incineration is rarely used. Incineration is a cost-effective municipal waste disposal option, but is rarely applied in Nigeria's hospitals, for example, where medical waste is incinerated on a minimal scale (Ogwueleka, 2009). Landfill is the cheapest and simplest disposal and management method. The environmental impact of landfills is huge but could be mitigated provided sanitary precautions are undertaken and waste reduction is advocated. It has been estimated that landfills were responsible for 49% of England's methane emissions in 2007 (Burney et al., 2011). Implementation of the three Rs (reduce, re-use, recycle) has not been fully adopted. With the absence of a formal recycling sector in Nigeria waste is recycled informally by scavengers. This involves the buying of valuables from individuals and searching for re-usable and recyclable materials at legal and illegal dump sites.

An in-depth review of waste management practices across Africa has concluded that the most sustainable technique to manage waste in majority of urban communities is to:

- take away dry recyclables by scavenging, through door to door collection, and /or a recyclable material recovery facility (MRF)

- compost the remaining biogenic waste in windrows, utilising the matured compost as a substitute fertiliser
- dispose reject fossil carbon (metals, plastics, synthetic textiles) and inert waste in sanitary landfills. If biogenic waste is eliminated the landfills should not require biogas extraction system as the wastes will comprise mainly inert and fossil carbon waste (Couth and Trois, 2012).

2.2 Challenges in policy and regulation

The Federal Government of Nigeria has propagated waste-management policies and regulations to guide and mitigate the continuous disposal and dumping of waste in rivers and water channels, on pathways and at illegal dump sites. The Government enacted Decree number 58 for the establishment of a Federal Environmental Protection Agency (FEPA) on 30 December 1988. In the year 2000, FEPA was advanced to an environmental department with a cabinet minister at the Federal level. As a result of these institutional reforms, waste-management in Nigeria is currently discharged by the Federal Ministry of Environment, Housing and Urban Development at the Federal level (Ezeah and Roberts, 2014). In Nigeria waste-management operates on all governmental levels: local government, state government and federal government. For instance Lagos, which is one of the most fastest growing cities across the world and densely populated, the main government institutions responsible for environmental protection are the Lagos State Waste Management Agencies (LAWMA), the Lagos State Environmental Protection Agencies (LASEPA), Local Government Councils (LCGs) and the Ministry of Environment and Physical Planning (MEPP) (Kofoworola, 2007). At state level, the state environmental protection agencies and waste-management agencies are in charge of municipal waste management. Presently, waste is managed by each respective state environmental protection agency and waste-management agency in the urban cities and big towns. Municipal solid waste collected at the generation point is loaded into waste trucks and transported to designated dump sites. Consequently, the collection of municipal waste by the state environmental agency requires the payment of a certain amount by each household. The size of an apartment determines the allocation of monthly waste-collection charges. As a result of income status some households cannot afford the monthly payment. This financial limitation promotes indiscriminate dumping of refuse.

The Federal Government of Nigeria's policy objectives include:

- Secure environment to promote the health and well-being of all Nigerians;
- Raised public awareness and promotion of understanding of the importance of the relationship between environment and development; and
- Encouragement of individual and community participation in environmental protection and improvement efforts (USEPA, 2010).

The laws enacted by local, state and federal environmental protection agencies are similar and include the following:

- the national protection management of solid and hazardous wastes regulation of 1991

- the pollution abatement in industries and facilities generating waste regulation of 1991
- the general guidelines for pollution abatement in industries 1991 (Adedeji and Ako, 2009; Imam et al., 2008; USEPA, 2010).

A practical implementation of the regulation is the monthly environment sanitation practice enforced since 1997. This practice which has been held in Nigeria involves peoples' participation in the cleaning of their environment last Saturday of every month for three hours, 7 am to 10 am precisely. Implications of this clean up exercise is the reduction in disposal of municipal solid waste into running water and drainages, increase communal cleanliness collaboration, civic moral orientation and municipal solid waste management consciousness.

2.3 Challenges

The challenges of municipal-waste management in Nigeria are diverse and numerous; these challenges are related to economic, technological, psychological and political factors. They vary from poor funding, poor legislation and implementation of policy, to limited infrastructures and professionalism, low awareness levels, and poor recovery and recycling programs and disposal techniques (Dauda and Osita, 2003; Ezeah and Roberts, 2012; Okot-Okumu and Nyenje, 2011). These challenges are interconnected and usually complex in municipal solid-waste management systems (Al-Khatib et al., 2010).

2.3.1 Poor funding

Poor funding is a major challenge constraining the waste-management sector (Ezeah and Roberts, 2012). Inability to purchase new waste-collection trucks, limited staff, poor vehicle maintenance, unsubsidised waste-storage containers, inability to purchase equipment, and other factors can all be attributed to shortage of capital.

2.3.2 Cultural belief

Wastes are viewed as worthless and useless materials rather than valuable materials that can be recycled for actual use, material recovery and energy recovery. The value of waste to people enhances the actualisation of the processes involved in the management of waste. The conception of waste as worthless is inherently linked with societally organised cultural systems of 'where things belong' (Zender, 2012). Consumers' activities are largely a function of common societal cultural values and norms (Nnorom et al., 2009).

2.3.3 Limited infrastructure and professionalism

Lack of solid-waste infrastructure and professionals is one of the major challenges of waste management in Nigeria. Waste-agency workers do not have the required skills and knowledge. The state environmental protection agencies have inadequate trained personnel (Ezeah and Roberts, 2012).

2.3.4 Extended producer responsibility

The non-involvement of producers in the management of waste is a key limitation on improvement. Producers' interests are mainly in production rather than management of waste. Due to the low level of material and energy recovery, material costs are not maximised and this directly affects the cost of packaging production. With the increasing effects of improper waste management, the manufacturing sector's interests lie mainly in profitability rather than waste reduction (Abila and Kantola, 2013).

2.3.5 Awareness level

The level of awareness on sustainable waste management is low among Nigeria's population. Municipal members are not well informed about either the adverse effects of indiscriminate and improper disposal of waste or the benefits of the opposite course. Hence, information is not disseminated and publicity is low.

2.3.6 Centralised waste containers

In Nigeria there are few centralised municipal storage containers. This presents municipalities with placement challenges for sorted and recycled materials of different categories. Centralised municipal collection points are not viewed as a potential solution for recycling and material recovery. Thus such agendas are not included in platforms for waste management. The available funds are not directed to purchasing waste-storage containers.

2.3.7 Material recovery and recycling

Gaining access to possible recyclable material poses great difficulties due to limited recycling programs. Informal recycling programs involve a difficult search for recyclable items. Presently, the informal sector renders the service of recovering and recycling materials in Nigeria (Oguntoyinbo, 2012). The introduction of a formal recycling program could present positive and accelerating outcomes for municipal waste management.

2.3.8 Poor legislation and implementation of policy

This area plays a key role in the efficient management of waste. The constitutional strength of policy on municipal waste management is weak; it is also poorly structured and tends to be ineffective. Policies are yet to aim at the consolidation of the three Rs of waste management – reduce, reuse and recycle.

2.3.9 Disposal techniques

The disposal techniques of landfill without treatment processes and open dumping pose increasing public-health hazards. Emissions of poisonous gases such as methane and carbon dioxide also cause alteration in weather patterns and climate change.

2.3.10 Communication channels

The dearth of effective communication channels affects the knowledge acquisition of municipalities in the management of waste. Communication channels such as mass media and posters are often adopted in the transfer of new information rather than the face-to-face approach, which involves practical one-on-one interaction.

2.3.11 International collaboration

Limited collaboration with international solid-waste management organisations impedes rapid sustainable development within the waste sector. Interaction with such agencies is rarely a focus area for waste management.

2.3.12 Personnel morale

Workers responsible for waste collection and transportation often have low morale. Their performance is influenced by the extent of the stigmatisation faced on the job, poor remuneration and stagnant promotion prospects. Staffs in the field are also not encouraged by consumers' habits of waste storage.

2.3.13 Law implementing agencies

The staffs of law implementing agencies attempt irregular visit to assess municipalities, however not all municipalities are covered. However, Individuals involve in the disruption of law in visited municipalities, are overlooked, rarely apprehended and punished due to staff's personal gains.

3 Designing a recycling solution using axiomatic design

The process of product and service design needs to begin with a profound analysis and then move onto a comprehensive synthesis (Suh, 2001). Observations need to open up the possibility of designing and developing solutions to the problems. The 'push-style' of design and development of products and services is aimless and does not usually lead to anything other than wasted resources.

Suh first defined the 'principles of design' (Suh, 1990) and the 'axiomatic design approach' (Suh, 2001). The latter is based on the former and has its origins in mechanical engineering. According to Suh, design can be summed up simply in the questions 'What do we want to achieve?' and 'How do we achieve it? The two design axioms developed by Suh are as follows:

1 the independence axiom: maintaining the independence of functional requirements (FRs)

2 the information axiom: minimising the information content of the design.

According to Suh, axiomatic design always:

1 seeks creative solutions

2 gets rid of trial and error and design work that result in random future solutions

3 determines the best solution from among a set of proposed solutions.

An axiomatic design process systematically maps four different domains to each other:

1 customers

2 FRs

3 design parameters

4 process domains.

Thus, design work proceeds from the goal to alternative and realistic optional solutions.

The key is to specify independent FRs for the design, and develop parameters for achieving them. A classic textbook example is the freezer door. The FRs of the freezer door is:

a to keep food cold

b to provide access to food.

If an insulated vertical door on the side of the freezer is used, the above requirements do not stay independent. When the door is opened, the cold gets out. If an insulated horizontal door on the top of the freezer is used, the requirements remain separate. When the horizontal door is opened, the cold stays inside the freezer.

It is important to aim for designs where FRs remain independent. In an ideal situation the WHAT corresponds to the HOW in the design. Thus, changes in one part of the design do not require the re-designing of other parts. These principles also apply to software, systems, manufacturing systems, organisations and services.

The consequences of bad design are generally misunderstood. Inappropriately designed products and services are difficult to implement and difficult to update. As a result, the allocation of resources to projects can be difficult or impossible. Resource needs, timetables, and costs are very difficult to manage. If the design is done effectively the first time, changes can be managed in the future. However, if the design is ineffective, it will be difficult and expensive to manage changes in the future. Product and service design determines the basis for life-time costs and value creation.

The general objective of this research is to develop a design for a waste-classification method for products attachment that will enhance the sorting of municipal waste at the source. This design will help individuals in the identification and sorting of waste. This objective will have a snowball effect on the costs incurred by the government and waste-collection companies in waste management. The focus is on households because they generate a large proportion of waste; specifically, the design focuses on household products.

3.1 Background research

The entire concept of waste is subject to the value judgement of the primary holder or potential consumer (Sha'Ato et al., 2007). The Finnish Waste Act stated that waste includes all biodegradable and non-biodegradable objects or substances which the holder discards, intends to discard or is legally obliged to discard (MoE, 2012a). Waste generated from a variety of sectors, including the municipal sector, the mining and

quarrying sector, the industrial sector, the manufacturing sector, the institutional sector and others can be classified as solid, liquid or gaseous.

Several tons of municipal solid wastes are disposed of in sanitary landfills, unsanitary landfills and dump sites daily around the world (USEPA, 2010). These municipal solid wastes can be classified into kitchen waste, glass and bottles, metal, landfill waste, paper and cardboard, and hazardous waste (Stormossen Waste Management Company, 2002).

The efforts of waste-management companies to efficiently manage waste have not resulted in a conclusive solution. Certain lapses emerge in waste sorting at the source due to the challenges faced by the individuals involved in the sorting process; such lapses have a direct effect on the secondary management of waste. Waste generators must deal with a great number of time-consuming tasks in directing waste to the correct classification. Remembering different substances for distinct waste classification obviously and increasingly contributes to sorting problems. "The resource value of waste cannot be realized unless separation of waste is practised effectively at the source" (Shanghai Manual, 2012). The most efficient and easy way of sorting waste at the source would be to design classified waste labels for products and packages.

The management of municipal waste is the primary duty of consumers or waste holders (MoE, 2012b). It is a consumer service that has both economic and environmental impacts. Sorting of municipal waste at source makes further processing of waste materials easy and eliminates any uncertainty as to origin (Oyetola and Babatunde, 2008). The efficient sorting of waste at the source is pertinent to guarantee and enhance energy recovery, material recovery, and recycling, and reduce landfill waste disposal. This design will follow the process outline in the axiomatic design.

In the customer domain, there are two customer categories in waste sorting: primary and secondary. Primary customers are the generators of waste, while secondary customers are the waste-management companies. The emphasis here is on the primary customers. Efforts have been made by the government and global leaders to manage waste efficiently, but there are still bottlenecks at the source with regard to ease of identification and classification of waste. In the customer domain, waste generators are looking for easy and efficient methods of waste sorting. Customers identify the knowledge gap and language as the most important barriers to proper waste sorting. Customers need easy and efficient waste sorting.

3.2 Design solutions

This design followed the process of mapping four different domains to each other according to the axiomatic design approach.

3.2.1 Customer domain (what domain) – what do we want to achieve?

1 Customers need an easy and efficient method of waste sorting.

2 CN1 = easy and efficient sorting of waste.

3.2.2 Functional domain (FRs) (what domain)

According to the axiomatic design theory, in the functional domain the customer needs are specified in term of FRs and constraints. The customer needs must be mapped to the FRs. The FR represents the minimum set of independent requirements that absolutely characterise the design goal. In this theory each FR is independent of other FRs as they are established. Easy identification is crucial from the customer perspective. The FR is further decomposed as follows:

- FR1 = easy identification
- FR11 = easy identification of category for adults
- FR12 = easy identification of category for children
- FR13 = easy identification of category for visually challenged.

In Table 1 is an illustration of mapping customer needs to FRs:

Table 1 Mapping one CN to three FRs

	FR11	*FR12*	*FR13*
CN1	X	X	X

3.2.1 Physical/solutions domain (DPs) (how domain)

This is the conceptualisation stage in the design process, where the key physical / logical variables that characterise the design satisfy the specified FRs. This is the domain that shows how to achieve each independent FR. The design parameters to satisfy the decomposed FR are as follows:

- DP1 = attachment in the object
- DP11 = logo
- DP12 = colour
- DP13 = shape.

Table 2 Design matrix

	DP11	*DP12*	*DP13*
FR11	X	X	X
FR12	X	X	X
FR13	O	O	X

The above matrix shows that this design is coupled and therefore a complex design. So, the design has to be rethought. FRs for adults and children can be combined. Thus, the following matrix is derived:

- FR11 = easy identification of category for adult and children
  DP11 = coloured logo

- FR12 = easy identification of category for visually challenged
  DP12 = shape.

Table 3 Improved design matrix

	DP11	*DP12*
FR11	X	X
FR12	O	X

We can re-arrange the design matrix as follows:

Table 4 Reorganised design matrix

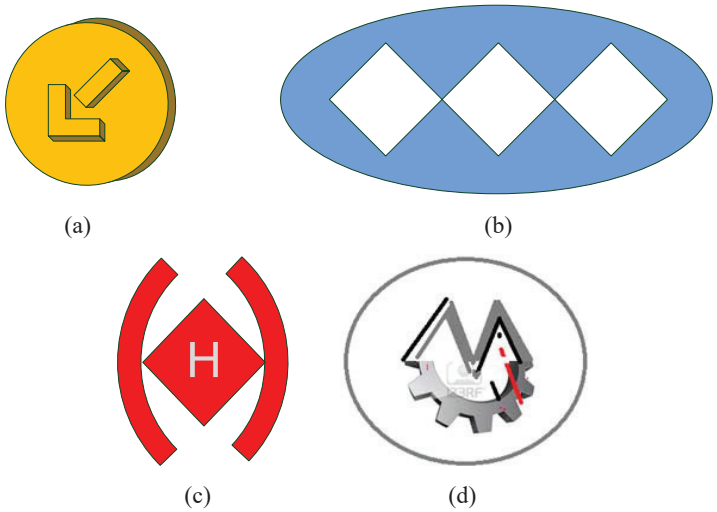
	DP11	*DP12*
FR11	X	O
FR12	X	X

The above matrix shows that the design is appropriately decoupled.

3.2.1 Proposed design solutions

The following designs are the proposed 3D design solutions to meet customer needs. These designs are limited to a certain classification of waste that is difficult to separate. The design for the classification of waste in this paper includes landfill waste (i.e., waste that cannot be recycled and is not hazardous. Examples are porcelain, ceramic, light bulbs, wall papers, hoses, mirrors, lead glass, glass fibre, glass wool, dust bags from vacuum cleaners, clothes and textiles, rubber and leather (shoes, gloves, etc.), nets, video and audio tapes, etc.), glass and bottle waste, hazardous waste and metal waste (see Figure 2). Figure 3 demonstrates how the proposed design solution can be applied to real products. Corresponding designs will be placed in the recycling bins.

Figure 2 Designs for (a) landfill waste, (b) bottle and glass, (c) hazardous waste and (d) metal waste (see online version for colours)



Source: Abila and Kantola (2014)

Figure 3 Design application in a product (see online version for colours)

Source: Abila and Kantola (2014)

At the initial phase of this design conceptualisation, benchmarking of the existing waste design was conducted. During this process it was discovered that existing waste designs lack easy means of identification. As shown, the FR was further decomposed to provide easy visual identification for children and adults, as well as for visually challenged persons. The colour and logos are the design parameters for children and adults, while the shape is that for the visually challenged. Both children and adults can easily identify and sort on the basis of colour and logo. The shape is intended to serve visually challenged individuals who also contribute to mass waste, enabling them to identify and sort according to the feeling of the shape.

3.2.2 Process variables

This is the process domain with the key variables that characterise and generate the specified DPs, i.e., the process of fulfilling the specified DP. Within the scope of this paper, we will not discuss this domain. However, we can say that it is not difficult to introduce the design solutions proposed in this paper to new products and to products that already exist. Tags can be printed, for example.

4 Proposed knowledge-management solutions

Knowledge-management solutions for mitigating municipal solid-waste challenges are presented as technology-centred and people-centred approach.

The people-centred approach focuses on individuals within the municipal waste management chains. This includes municipal waste generators, packaging firms or producers, as well as waste-management companies. The technology-centred approach focuses on the use of information and communication technology (ICT) as a knowledge and information repository in the management of municipal waste.

A better interaction with international waste-management agencies is required to close knowledge gaps between developed and developing countries. The beneficial outcome of such interaction would be to open doors to new coping strategies for managing waste effectively in Nigeria.

Table 5 Proposed knowledge-management solutions

Stakeholders	*Stakeholders' roles*	*Municipal waste management problems*	*Proposed knowledge management solutions*
Municipal waste sources: • residential • industries • commercial • institutional.	Partake in the primary management of waste. Respond to and abide by waste-management rules and regulations. Prompt payment of waste-collection dues.	Indiscriminate dumping. Low level of public education in waste management. Poor sorting at source. Absence of storage facilities. Public attitude towards waste management.	Establish face-to-face information sharing for waste generators. Persistent use of Information Communication Technology (ICT) to disseminate information. Establish local and international networks.
Municipal waste-management agencies	Collection, transportation and application of different disposal techniques. Facilitate awareness programs. Record waste generated per capita/day and annually	Environmentally unfriendly disposal technique. Poor funding, unskilled and limited manpower. Poor maintenance of vehicles. Inadequate waste-collection vehicles and equipment. Limited collaboration with international waste-management agencies.	Utilise both tacit and explicit knowledge. Set up information repositories for data storage. Application of diverse knowledge sharing methods for staff. Establish international collaboration mechanisms. Initiate and implement motivational factors that promote adoption of material re-use, recovery and recycling.
Municipal authorities, legislators	Establish monitoring programs. Specify waste-disposal sites. Specify waste disposal and treatment.	Policies lack clear strategies. Obsolete policies. Inadequate and poorly implemented waste-management policies.	Set up database and information-management system for information capturing.
Informal waste sector	Waste brokers between waste generators and manufacturers/ middlemen. Resource recovery.	Limited formal education. Highly unskilled workers.	Collaboration of waste agencies with research-and-development institutions.
Producers	Collaborate with waste management agencies to promote recovery, reuse and recycling. Establish motivational scheme.	Dearth of involvement in municipal-waste-management issues.	

Source: Abila and Kantola (2013)

Information flow between waste generators, producers and waste-management companies is vital in bridging the knowledge gaps. The communication and exchange of

knowledge between waste generators and producers of recyclable packages, such as plastic, tins, and cartons, is facilitated for example through descriptive logos or labels inscribed with expressions in English and three major languages. The recovery process of these recyclables from consumers may be less challenging if certain incentives are attached to the return of such items. These incentives can be consumer-generated, derived at the point of purchase when the cost of the actual containers is added to the purchasing cost of the items.

The transfer of information and knowledge to municipalities should be undertaken by waste-management companies through effective communication channels involving face-to-face communication. Alongside other means of communication, the face-to face channel should be employed for interaction with and orientation of members of the municipalities on disposal habits and the sorting and storing of waste in an environmentally friendly manner. The importance and benefits attached to waste separation, proper storage, collection and effective waste management need to be communicated. Eye contact and interaction between sender and receiver greatly help in achieving the desired goal. Efficient management of waste is promoted if storage containers of different colours are provided to indicate the various categories of municipal waste for a particular storage container.

It is of paramount importance to bridge the information gap between packaging and product manufacturers and waste-management companies to ensure that the actual label of a product is based on consensus. A cohesive collaboration between the packaging manufacturer and waste companies will enhance the prerequisite knowledge and information transferred to communities. Hence, some level of participation is required in order to speed up the actualisation process.

In general, Table 5 shows the stakeholders' in municipal waste and their roles; municipal waste management problems and presents proposed knowledge management solutions.

The factors presented in the proposed knowledge-management solutions (Table 5) which captures both technological-centred approach and people centred approach can be linked to criteria in the integrated sustainable waste management approach. The integrated sustainable waste management approach comprises of the services and value chains for the transfer of solid waste materials from the point of generation to final disposal, stakeholders that have interest in the management of solid waste and an enabling aspect via which system is actualised (Guerrero et al., 2013; ISSOWAMA Consortium, 2009).

5 Conclusions

In Nigeria inefficient management of waste has a significant effect on both the environment and economic growth. The poor management of waste is the result of a combination of a number of challenges. Population growth is one of the major contributing factors to increasing waste generation, particularly municipal solid waste. Nevertheless, it is pertinent for the government to revisit, reaffirm and restructure waste policies and regulations, and provide adequate waste infrastructures. Amidst other requirements, the application of knowledge-management solutions is critical for sustainable change.

The sorting of waste as the primary duty of the waste holder is an important process in the management of municipal waste. It is the basis for other processes in municipal waste management. The generation of an explicit and comprehensive design for waste classification (labelling) on products or packages guarantees the possibility of directing waste easily to the correct classification. In essence, the design solution is targeted to meet customers' needs in attaining an efficient municipal waste management. The design is important as it provides instant aid for waste generators (also the visually impaired) in waste segregation, as well as bridging the knowledge gaps that exist between the waste-management companies and waste generators. However, we are still in the process of improving the final design.

- This article has proposed two approaches to tackle waste-management problems in Nigeria. These approaches can be adopted in other countries as well. The first approach focuses on product design and the second approach is based on knowledge-management solutions.

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Waste management: relevance to environmental sustainability

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Abstract: Waste generation and its management present universal challenges related to negative impacts on the environment. Municipal solid waste generation in large quantities on daily basis constitutes serious environmental problems. This paper presents a review of extant literature in the management of municipal waste across a range of countries alongside waste management hierarchy that guide legislations and policies for developed and developing countries. This paper assesses the environmental consequences emanating from the influence of either the presence or absence of contaminants-based diverse management options for municipal solid waste; thereby facilitating policy makers and waste management companies informed choice(s) for the management of municipal waste sustainably. The outcome from the evaluation of environmental effect reveals that incineration; the most common waste-to-energy implementation for municipal solid waste is accompanied with the emission of greenhouse gases, Nitrogen oxides, ammonia, sulphur dioxide contributing to climate change and air acidification. Environmental concern is a critical indicator for determining the best appropriate waste management option(s). The need to encourage the increasing recycling of municipal solid waste to facilitate a global sustainable environment as well as boosting the circular economy and green cities is recommended.

Keywords: waste management; municipal solid waste; environmental sustainability; waste management hierarchy; pollution.

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1 Introduction

Waste management is a fundamental issue across the continents with varying degree of challenges such as increasing volume of waste and environmental consequence. These challenges are however more pressing, peculiar and prominent in developing countries due to incomplete institutional arrangements and poor handling of waste. Waste management can be characterised on the basis of aspects ranging from practices, strategies, goals, control, monitoring and regulation of the production, financial and marketing aspects, to environmental assessments of various treatments, evaluation and policy. These aspects can be used in a holistic approach to mitigating challenges emanating from waste, its management and various treatments. The primary focus of literature on waste management has been on instituting equilibrium between the dual objectives of conserving natural resources and ensuring environmental protection (Gharfalkar et al., 2015).

''Sustainable development encompasses the reduction of polluting emissions and the establishment of sustainable waste management practices'' (Coelho and Lange, 2018). The UN Sustainable Development Goal 6.3 targets to achieve environmentally sound management of all waste, particularly hazardous waste either chemical or biological hazardous waste. Sustainable waste management is one of the most important global environmental agendas in the 21st century (Zaman and Swapan, 2016). Sustainable waste management is considered a precondition to mitigating environmental challenges across the globe. The management of waste sustainably aims at environmental quality, which is a prerequisite for per-capita well-being over a period of time (Abila and Jussi, 2013). Massaruto (2007) writes, for instance, that "European waste policies have mostly resulted from environmental considerations; they have aimed at reducing emissions, controlling waste shipments, avoiding illegal dumping or export to standard countries". Also findings from Abila (2018) study on households' perception of financial incentives in endorsing sustainable waste management in Nigeria revealed that the most important driver for household willingness to recycle waste is its detrimental environmental impacts.

Municipal solid waste as well as its management presents varying degree of concerns for waste management. The management of municipal solid waste is one of the priority issues regarding the protection of the environment and conservation of natural resources.

Municipal solid waste is one of the main components of pollution as it contaminates the ground as well as surface water and increases air pollutants, leading to miserable living conditions for people (Sanjeevi and Shabudeen, 2015). Aside its environmental concern, the continuous and increasing generation of MSW is at alarming rate as well as its diversity in composition. According to the projection of (World Bank, 2018) with rapid population growth and urbanisation, municipal solid waste production will rise to 2.2 billion tonnes by 2025. The composition of MSW differs over time and from country to country, due to difference in lifestyle, consumption pattern and waste management practices (Margallo et al., 2015).

The increasing concern on environmental sustainability in current years has led to the development of strategies to reduce waste, improve waste recovery, resource recycling of waste and diversion of waste from landfills for a sustainable living environment (Mmereki, 2018). Albeit, the European regulation proposed waste reduction, recycling and re-use and finally waste incineration and landfilling as fundamental principles to waste management (Margallo et al., 2014). The environmental concerns emanating from unsustain waste disposal and management approaches are evitable consequence when sustainable options are fully put to practice. A shift to a green environment is paramount as it secures the ecosystem while maintaining a green economy and social equity among present and future generations; and depends on the promotion of recycling, particularly if it enables reducing environmental impacts from raw material extraction and materials processing (Ferrao et al., 2014).The evaluation of environmental sustainability of waste treatment approaches, systems and processes is critical, given the growing global importance of environmental concerns (Rada et al., 2014).

Generally, municipal waste management strategies focus on environmental, health, aesthetic, land-use, resource and economic concerns (Marshall and Farahbakhsh, 2013). Since 1990, the main focus has shifted to environmental apprehension, particularly in relation to climate change (Habib et al., 2013). One of the most important anthropogenic sources of greenhouse gases (GHGs) is improper disposal and treatment of municipal waste (Tian et al., 2013), though considerable improvements are being made in some countries. It is pertinent to determine the reason waste management is focusing more on environmental sustainability rather than economic and societal sustainability. This paper aims to evaluate the environmental consequences resulting from the influence of either the presence or absence of contaminants for different management strategies for municipal solid waste. This paper presents a comprehensive review of municipal solid waste management for different countries and considers waste management hierarchy for developed and developing countries. It further presents an explicit view to aid decision makers in their understanding on the informed choice of sustainable options for the management of municipal waste.

2 Literature review

2.1 Municipal waste management in different countries

The management of waste systems in Poland has been built on the basis of the Communal Cleanliness and Order Maintenance Act of 13 September 1996. According to the amendment act of 1 July 2011 the organisation of waste is the responsibility of the municipalities, which tackle all activities affecting local communities (Mesjasz-Lech,

2014). Similarly, in Kolkata, a metropolitan city and capital of the state of West Bengal in eastern India, the management of municipal solid waste is the responsibility of the Kolkata municipal corporation. Here, processes involved in the management of municipal solid waste include primary collection of waste from households and streets, dumping at collection points, transportation to disposal sites, and disposal (Hazra and Goel, 2009). In the UK, landfill is the most common technique of municipal waste management, accounting for 49% of municipal solid waste disposal in 2009 (Al-Salem et al., 2014). In Spain, the town of Castellon de la Plana bases household collection on the selective selection of glass, paper, cardboard and packaging at material banks and street-side collection of all other waste (Bovea et al., 2010). In Hanoi, the capital of Vietnam and its second largest city, municipal solid waste is collected without sorting and deposited directly in landfills (Thanh et al., 2015). In Limbe municipality in Cameroon, waste is moved from generation points and deposited into municipal waste bins, which are later collected, transported and finally disposed of in open dumps (Manga et al., 2008). The most common municipal solid waste disposal and management approaches in Nigeria are open dumping, landfill, open burning; incineration is seldom used (Abila and Kantola, 2017). Municipal solid waste in Guadalajara, Mexico, is separated and recycled by mostly unregulated groups known as scavengers, while collection and transportation is the sole responsibility of the municipality; waste disposal strategy is based upon the burying of 98% of municipal waste (Berneche, 2003). Waste separation and recycling is not efficiently conducted in China, and incineration is limited as compared to landfill, which is the predominant technique for the management of municipal solid waste (Zhang et al., 2010).

> "However, two major ministries are involved in municipal solid waste management, as stipulated in the law. The first is the Ministry of Construction (MOC), which supervises and administers the cleaning, collection, storage, transportation, and final disposal of municipal solid waste. The second is the Ministry of Environmental Protection (MOEP), which administers and monitors the collection, treatment, and final disposal of hazardous waste, waste trade, and secondary pollution generated by the construction and operation of municipal solid waste treatment and disposal facilities." (Chen et al., 2010)

In some developed countries such as Finland, the sorting, storage and deposition of municipal waste at central waste bins are the primary duties of consumers, while collection, transportation and treatment are the responsibility of municipal authorities (European Environment Agency, 2013). Currently, in integrated solid waste management, an effective and comprehensive programme is applied. Management of municipal solid waste in Greece is in contrast to the European Union's policy on waste: in a case where a high number of open dump sites (reduced from over 5,500 in 1990 to 1,260 in 2004) constitute the most negative element and the percentage of useful material recovered is low (Erkut et al., 2008). In Phuket, an island province in the south of Thailand collected and transported municipal solid waste undergoes secondary segregation at treatment and disposal centres rather than undergoing primary segregation at source (Liamsanguan and Gheewala, 2008). Solid waste management in Singapore has conventionally been handled by the Ministry of Environment. Solid waste incineration has top priority over other waste disposal methods (Bai and Sutanto, 2002). Similarly, in

France incineration still remains (and can be expected to remain) the main waste treatment option for municipal solid waste (Beylot and Villeneuve, 2013). In Botswana, 60% of the waste is disposed by indiscriminate dumping, 38% by landfill and 1% is by open burning and recycling (Mmereki, 2018).

2.2 Waste management hierarchy

2.2.1 Waste management hierarchy in developed countries

"The waste hierarchy generally lays down a priority order of what constitutes the best overall environmental option in waste legislation and policy, while departing from such a hierarchy may be necessary for specific waste streams when justified for reasons of, inter alia, technical feasibility, economic viability and environmental protection" (Cucchiella et al., 2014). The waste management hierarchy depicts the prioritised strategies in the management of waste. Developed nations such as those in Europe and Japan tend to implement a hierarchical approach to solid waste management, including final waste disposal options (Dijkgraaf and Vollebergh, 2004). These differently prioritised strategies focus on environmental protection. Environmental concerns have been considered ever-increasing significance in the municipal solid waste decision-making process (Batool and Chuadhry, 2009). In essence, the aim of waste policies is to promote the use of natural resources and ensure waste does not pose a health or environmental hazard (Ministry of Environment, 2013; Brunner and Rechberger, 2015).

The application of the waste management hierarchy is voluntary for European member states, albeit with the expectation of adoption into national waste management laws (Williams, 2015). Each Member State has its own pre-determined goals for waste management. For instance, in the case of Swiss waste management policy, preferences include prevention of waste at source, reduction of pollutants both in production processes and finished goods, reduction of waste by improving recovery, and improvement of the environmental compatibility of remaining waste (Joos et al., 1999).

Figure 1 European Union waste management hierarchy (see online version for colours)

Source: European Commission (2015a)

European Union waste management hierarchy

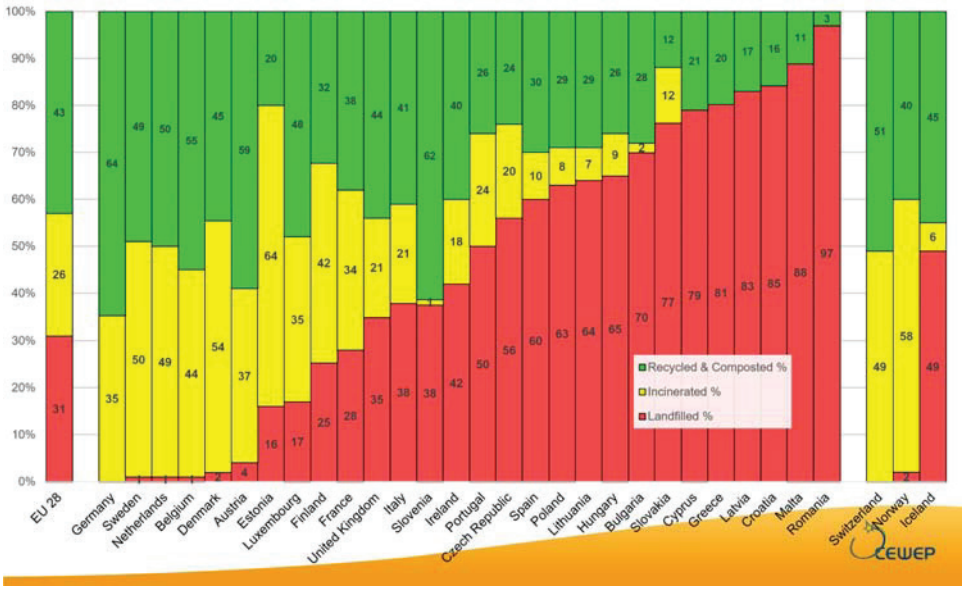
Aside waste prevention, reduction, re-use and recycling, other management of municipal solid waste still links to major environmental concerns (Moy et al., 2008). The EU waste hierarchy prioritises waste reduction and volume reduction both at primary and at secondary sources.

- *Prevention:* waste prevention, also known as waste reduction, applies to both manufacturers and waste generators. At the manufacturers' end, such a policy can be termed 'primary-source prevention', and in relation to waste generators 'secondary-source prevention'. The use of this strategy at the manufacturers' end helps minimise the production of heavy packaging materials, while for waste generators it can promote the purchasing of reusable products (USEPA, 2015a). Prevention is the highest priority in waste policy in several regions (Gentil et al., 2011).
- *Re-use:* this is defined as the further use of products, materials or substances for the end to which they were conceived (Nehrenheim, 2014). Re-use happens at the point of waste generation at the manufacturer's end. Preventing waste through re-use is often related to ideas of stewardship, conservation and preservation.
- *Recycling:* this is the process of sorting, collecting, preparing, reprocessing and remanufacturing used, re-used, or unused materials into new or original forms (Mohee et al., 2015). This ensures conservation of energy and materials, and mitigates pollution and emission of green-house gases. Recycling makes a considerable contribution to environmental benefit, proving that source separation will be more and more important in dealing with municipal solid waste in future (Song et al., 2013).
- *Recovery:* this is the recovery of energy in the form of heat, electricity and fuel from non-recyclable materials through the application of various processes including combustion, pyrolisation, gasification and anaerobic digestion (USEPA, 2015b). Energy recovery from waste is one viable alternative source of energy.
- *Disposal:* This involves the transfer of waste to landfill. This is the most common waste management strategy, though the least preferred and most unsustainable. According to the waste management hierarchy, landfill is the least preferable option and should be limited to the necessary minimum. Where waste needs to be landfilled, it must be sent to landfills which comply with the requirements of Directive 1999/31/EC on the landfill of waste (European Commission, 2015b).

2.2.2 Waste management hierarchy in developing countries

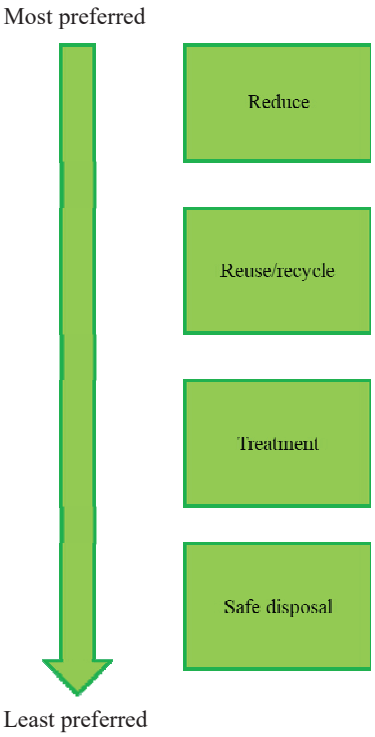
Waste management hierarchy is a widespread element of national and regional policy and is often considered the most fundamental premise of contemporary management practice for municipal solid waste (Jibril et al., 2012).

Figure 2 Graph of municipal waste treatment in Europe in 2013 (see online version for colours)



Source: Confederation of European waste-to-energy plants (CEWEP, 2015)

Figure 3 Waste management hierarchy in Botswana (see online version for colours)



Source: Mmereki (2018)

In developing countries there seems to be the absence of a consensual adopted or stipulated waste management hierarchy in regions. Thus waste management hierarchy is often country specific rather than regional with little or no disparity among countries and or between regions. Comparatively, developing countries waste management hierarchy works towards similar goals as the developed countries. In Mozambican documentation the definition of Waste hierarchy is not clear as per the priority order between prevention, reduction, reusing, recycling and other forms of recovery or disposal. Waste hierarchy does not seem to be relevant because the preferred option is considered to be the one that uses the best available technologies at sustainable cost (Ferrari et al., 2016). The core legal framework for waste management in Botswana is the Botswana waste management strategy which stated waste hierarchy as a solution towards sustainable waste management in the country with disposal being the least preferred disposal option, and re-use, recycling etc. being the highest priorities (Mmereki, 2018). Nevertheless, the waste management hierarchy operates inversely in practice; landfill is still the most used option (Mmereki, 2018). Invariably there seems to be gap in the actualisation of waste management hierarchy in theory to its application in practise.

3 Emissions emanating from municipal solid waste disposal and management

Climate change is rapidly and currently manifesting its effects of global warming and melting ice across the globe. The increasing production and quantity of waste contributing to anthropogenic sources of GHG emissions is one of the vital and huge drivers. In many nations, the main emissions of anthropogenic source of methane are from landfills (Couth et al., 2011), particularly from developing nations. Globally, about 50% of methane emissions from solid waste disposal options are emitted from ten countries (Barton et al., 2008), of which annually about 10–19% of global emissions are generating from landfills (Chen et al., 2008). Cherubini et al. (2008) analysed scenarios from urban waste management and they revealed that landfilling is the most polluting option at the global scale since it generates many different emissions such as methane, carbon dioxide, hydrogen sulphide, hydrogen chloride, nitrogen, and phosphorus inorganic compounds; and it appears that pollution problems cannot be mitigated by any of investigated options ranging from landfills, anaerobic digestion and incineration. Dioxins have been emitted from incineration plants and conventionally been highlighted as one of the most significant sources of toxic emissions and heavy metals (Nzihou et al., 2012). Considering composting, emissions of ammonia alongside volatile sulphur compounds of hydrogen sulphide, methyl mercaptan, dimethyl sulphide, carbon disulphide, dimethyl disulphide, methane, nitrous oxide and volatile organic compounds (VOC) are components of this waste management option (Moreno et al., 2014; Maulini-Duran et al., 2014).

4 Environmental effects associated with municipal solid waste management

Environmental effects arising from the management approaches for municipal solid waste can either be positive or negative. These negative and positive environmental effects are

outcomes or consequences from impacts or influence of either the presence or absence of contaminants that unfold over a period of time. Negative effects result in declines both in human health and in the health of other living organisms. “The perils associated with inappropriate solid waste disposal, and associated environmental health impacts, should therefore be of utmost concern to waste management experts” (Ayomoh et al., 2008).

Table 1 Environmental effects of municipal solid waste management

Environmental effect	*Contaminant*	*Municipal solid waste management technique*	*Source*
Air pollution	Gas emissions such as methane	Landfill	Aljaradin and Persson (2012), Vrijheid (2000), Dijkgraaf and Vollebergh (2004)
Explosion hazards	Gas emissions such as methane and hydrogen	Landfill	Aljaradin and Persson (2012)
Water pollution	Leachates with high content of carbon and ammonium	Landfill	Aljaradin and Persson (2012), Vrijheid (2000), Dijkgraaf and Vollebergh (2004) and Kirkeby et al. (2007).
Nuisance odour	Fungi and bacteria bioaerosols	Landfill composting	Ulfik and Nowak (2014).
Soil pollution	Heavy metals such as lead, cadmium, mercury, copper, iron and zinc	Landfill	Ulfik and Nowak (2014), Anikwe and Nwobodo (2002), Vrijheid (2000) and Dijkgraaf and Vollebergh (2004)
Global warming	Gas emissions such as methane, nitrous oxide, carbon dioxide, nitrogen oxides	Backyard burning, landfill, incineration, anaerobic digestion	USEPA (2015b), Kirkeby et al. (2007, 2006) and Banar et al. (2009)
Ozone layer depletion	Ethylene, nitrogen oxides	Backyard burning, landfill	USEPA(2015b) and Kirkeby et al. (2007).
Air acidification	Sulphur dioxide, nitrogen oxides, ammonia, nitrous oxide	Backyard burning, landfill, incineration, composting	USEPA (2015b), Kirkeby et al.(2007) and Banar et al. (2009)
Eutrophication	Nitrate, nitrogen, phosphorus	Landfill and composting	Kirkeby et al. (2007) and Banar et al. (2009)

Table 1 Environmental effects of municipal solid waste management (continued)

Environmental effect	*Contaminant*	*Municipal solid waste management technique*	*Source*
Smog formation	Nitrogen oxides	Backyard burning	USEPA (2015b)
Conservation of natural resources, reduces pollution, reduces the toxicity of waste, reduces greenhouse gas emissions and helps sustain the environment for future generation.	_	Reduction	Jibril et al. (2012) and USEPA (2018)
Reduces the quantity of waste directly disposed of to landfill, ensures the conservation of virgin materials and eliminates chances of emissions.	_	Recycling	Abila (2018), Cherubini et al. (2008) and Emery et al. (2007)
Minimises the amount of waste that will need to be recycled or sent to landfills and incinerators, prevents pollution, reduces greenhouse gas emissions and helps sustain the environment for future generation.	_	Reuse	Cooper and Gutowski (2017) and USEPA (2018)

Landfill, the most conventional means of waste treatment, is the least desirable option because of the many possible adverse impacts it can present. The most serious of these is the production and release into the air of methane, a powerful greenhouse gas 25 times more potent than carbon dioxide (European Commission, 2010). GHG from waste management contribute immensely to climate change, and these emissions have been recognised as an important environmental issue in the waste sector (Menikpura et al., 2013). Apart from its global warming potential, methane also contributes to depleting the ozone layer (Johari et al., 2012).

Comparably, the climatic benefits of waste prevention and recycling far outweigh the benefits from any waste-treatment technology such as anaerobic digestion, waste to energy (WtE), pyrolysis, gasification, or even energy recovered during the process (Couth and Trois, 2012). One of the most important measures to inform decision-making on the most sustainable options for municipal waste management is the evaluation of environmental impacts (Al-Salem et al., 2014).

Table 1 highlights adverse environmental effects associated with different municipal solid waste management techniques and contaminants.

5 Conclusions

Global sustainable management of waste is worth the effort it requires, considering its short- and long-term effects on the environment. Re-use and recycling strategies may be the best environmentally-friendly options for municipal waste management so as to ensure environmental sustainability. According to Cherubini et al. (2008) “recycling is a rewarding practice requiring least environmental support”. It limits the quantity of waste

diverted to landfill, reduces the depletion of natural resources, improves energy efficiency and eliminates chances of emissions.

Environmental consequences are one of the most critical indexes for determining the best waste management options. Considering the consequences of inappropriate waste management, environmental evaluation is very important to inform decision-making. The outcome from the evaluation of environmental effects reveals that the management treatment options for energy recovery from municipal solid waste is accompanied with the release of certain gases contributing to climate change and acidic rain.

The sustainable management of municipal waste translates into a sustainable environment which guarantees sustainable development for present and future generations. However, sustainability in terms of waste management and environment requires a global effort. Environmental concerns demand prompt solutions to ensure the stability of the natural world and human existence.

This study is relevant to policy makers and waste management companies in guiding their choice(s) of management for municipal solid waste management.

It is paramount for extended producers to develop green manufacturing production all through the production phase thereby utilising materials or substances that are composed mainly for recycling possibilities.

The role and participation of stakeholders at each phase of waste management is a prelude to the attainment of a sustainable waste management.

Increasing generation of waste can barely be reduced substantially as population growth and industrialisation are driving forces; it is imperative to consider, emphasise, and conform to increasing recycling as an outstanding management option for municipal solid waste besides environmental gains but for the boosting of a circular economy and green cities.

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recycling

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The Perceived Role of Financial Incentives in Promoting Waste Recycling—Empirical Evidence from Finland

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Abstract: Placing emphasis on promoting the reduction, reuse, recycling, recovery and repair of waste has been a critical aspect of the sustainable waste management agenda. Considering recycling, an environmentally friendly and sustainable waste management option, monetary rewards are in place for certain recyclable municipal waste materials in Finland. The study investigates consumers' perception about the role of financial incentives in effecting the recycling of municipal solid waste materials in Finland. The study also considers drivers for recycling municipal solid waste on the basis of behavioural change factors, such as environmental risk, behavioural economics, resource value, economic benefit, convenience, knowledge, legislation and belief. It further determines the association between income-earning consumers and non-income-earning consumers in their perception of financial incentives for recycling. The empirical results from the study confirm that the role of financial incentive is important in accelerating the recycling of municipal solid waste. A weak-to-positive relationship exists between drivers for recycling municipal solid waste and recycling behaviour. There exists no statistically significant difference in the means of the perceived role of financial incentives for recycling in the two groups. The introduction of financial incentives for other recyclable wastes is required in order to boost consumers' participation in the recycling of municipal solid waste. The need to pay more attention to intrinsic and extrinsic factors, as they affect the participation members of the society in the recycling of municipal solid waste, is paramount. This has become necessary in ensuring sustainable waste management in Finland.

Keywords: financial incentives; behaviour change; recycling; waste management; Finland; consumer perception; sustainable waste management

1. Introduction

The quest for attaining sustainable waste management has led to the creation of a waste hierarchy. This waste hierarchy, which provides a classification of waste management into different management options, is based on the benefits for, as well as welfare and interests of, the environment, society and the economy. These management options, which in some countries have evolved into strategies relating to process, infrastructure, legislation and stakeholders, among others, include the five Rs of waste management. These five Rs—reduce, reuse, recycle, recovery and repair—are increasingly important for attaining sustainable waste management [1]. The efficient application of strategies emanating from the five Rs is taking place via different methods. Key among the methods is motivating different stakeholders in the waste management or generation chain to participate responsibly in attaining efficient waste management goals. Examples include executing campaigns or advocacy programmes for citizens, establishing knowledge forums for waste experts, initiating workshops and seminars

for waste managers, job satisfaction and promotion of workers in waste management companies, and providing monetary incentives for recyclables.

In developed countries, research on waste recycling focuses on technical applications (such as models and tools), policy analysis (such as command-and-control, social-psychological and economic incentives) and, to a great extent, the psychological and socio-economic influence on human behaviour [2]. In attaining the goals of minimizing the proportion of waste which enters the waste management chain, and indeed the proportion and composition of waste finally disposed in landfills, key stakeholders within the waste management chain in different countries have implemented various tools, such as waste information and sorting guides, and waste and recycling apps and labels. These tools help in increasing the sensitization of households, such that they can make informed decisions on the implementation of the five Rs in the case of municipal solid waste, determining what is considered waste, what is disposed of in kerbside containers, and what is taken to reverse vending machines, among others. Aside from these tools, other strategies include providing financial incentives for households to participate in the recycling, reuse or recovery of waste. In most countries, reward, penalty and pricing standards for several types of waste materials, including packing materials, plastics, glass bottles and cans, already exist. Accordingly, Reference [3] reported on the implementation of a scheme known as "pay as you throw" (PAYT), a reward process for particular waste items which are disposed of in designated recycling sheds or centres. This reward and pricing system is currently being implemented for drink containers in Finland, particularly containers of soft and alcoholic drinks.

In attaining the sustainable management of waste, there is a tendency towards implementing recycling drivers, such as monetary incentives, consequences, proximity to recycling facilities, to influence consumers' recycling behaviour. The extent of recycling drivers instituted may enhance consumer behaviour, which in turn affects the recycling rate. Therefore, in essence, consumer behaviour and recycling drivers are not mutually exclusive.

Considering the significant benefits derived from recycling waste, particularly by striving towards a circular economy, EU countries are expected to recycle 50% of their municipal waste by 2020 [4], as well as achieve of target of 65% for recycling municipal waste by 2030 [5]. In the case of Finland, the municipal solid waste recycling rate substantially lies far behind these targets, at 41% [6].

The quantity of municipal waste has been 2.4 to 2.8 million per year in Finland since the turn of the millennium [7], while growing to around 2.9 million tonnes in 2016 [8]. The Finnish municipal solid waste management systems are mainly based on source separation and separate collections of recoverable waste fractions [6]. In Finland, households are responsible for the primary management of municipal solid waste, which involves the sorting, packaging and disposing of municipal solid waste into kerbsides containers, the delivery of certain household waste items to waste management companies, as well as the deposition of polyethylene terephthalate (PET) plastic bottles, glass bottles and drink cans into reverse vending machines, all of which constitutes a major consumer service [9]. On the other hand, property owners are obliged to organize waste collection points for household waste, while municipal authorities usually organize waste transportation through agreements with private waste companies, as well as mandated to organize the utilization and treatment of the waste they are responsible for [10].

This study investigates consumers' perception about the role of financial incentives for executing the recycling of municipal solid waste in Finland. Specifically, the study aims to determine the relationship between consumers' perception about financial incentives for recycling and recycling behaviour as well as drivers for recycling and recycling behaviour. The study also ascertains the key motivational factors behind recycling and determines the association between the perception of income-earning consumers and that of non-income-earning consumers concerning financial incentives for recycling.

This study centres on the PAYT scheme as a system of financial incentives, as it is the only system of this kind available for the management of municipal solid waste and more directly aligned to facilitating the recycling of specified municipal solid waste in Finland.

This paper comprises the following sections: Section 2 reviews the literature on PAYT schemes, Section 3 discusses the materials and methods applied in the study, Section 4 presents the results and discussion, and Section 5 highlights the conclusions and makes recommendations based on the study.

2. Literature Review—PAYT Schemes

In recent years, different waste management schemes, such as waste disposal fee and PAYT schemes, have been introduced and implemented to promote the management of solid waste across the globe [11]. In Europe, the German city of Dresden was the first to launch an electronic identification and pricing system for the billing of waste charges [12]. Likewise, Austria was the first country to commence the implementation of the principle of individual waste charging, as far back as 1945, although significant advances in applying PAYT did not begin until the 1980s [13,14]. The city of San Francisco in the US also practised a kind of PAYT scheme from 1932 [13]. Similar to the PAYT scheme, various financial incentive schemes have been implemented in most developed countries to facilitate recycling. PAYT is a strategy in which consumers are provided economic incentives to decrease the waste they discard [15]. It plays a non-simultaneous dual role in terms of rewards and penalties, encouraging consumers to adapt to waste management policies put in place.

PAYT schemes are common practices in most European countries, with Spain being one of the few exceptions. The growth of PAYT in Europe has prompted Spain to take a step toward the adoption of variable charging [16,17]. In France and Ireland, waste policies were recently revised to allow for the consideration of PAYT for municipal waste [13]. In France, the current investigation has identified between 14 and 20 local authorities committed to the application of incentive fees, whereas, in 2001, seven local authorities were identified [18]. In the US, PAYT has led to an increasing rate of recycling and a mean reduction rate of 28% for landfilled waste [19]. In Japan, 954 municipalities had implemented PAYT for residential combustible waste and 686 for residential incombustible waste as of 2003 [20]. Several other countries, including Australia, Canada, the UK and Mexico, have also introduced PAYT programmes [20]. Similarly, in Finland, the recycling policy in place for certain municipal solid waste items is a PAYT scheme, which has been adopted to ensure recyclables are properly disposed of. That said, the PAYT scheme is limited to PET plastic bottles, drink cans and glass bottles in Finland. It is fundamental to increase recycling in Finland, considering that its high domestic material consumption (DMC) per person is about 39.3 tonnes per annum [9]. Moreover, it is pertinent to increasingly adopt recycling, which is a more environmentally friendly disposal option, apart from its economic benefits in terms of limiting the costs of purchasing virgin materials and saving energy [21], as well as the economic benefits of reducing processing costs. In addition, recycling is socially beneficial because it generates jobs, both directly and indirectly [22].

There are different research contributions on incentives for recycling municipal solid waste across the globe. A study conducted in Reference [23] discussed a new market-incentive recycling system for packaging waste in Taiwan. Reference [24] also examined the willingness to accept economic incentives for solid waste in Ghana. An empirical study conducted in Reference [25] assessed the potential of financial incentives to enhance recycling behaviour in the UK. Moreover, Reference [21] investigated an incentive scheme in Hong Kong in order to determine whether it has worked in promoting domestic waste recycling. Evidence from the literature confirms that various efforts and strategies have been adopted in different countries to enhance the recycling of waste. This study aims to provide empirical evidence that monetary incentives for recycling play critical roles in the actualization of the goal of waste management in Finland.

3. Methodology

The study was carried out in Vaasa, a municipality on the west coast of Finland. Data for the study were collected from five higher institutions, namely, the University of Vaasa, Vaasa University of Applied Science, Novia University of Applied Science, Abo Akaedemi University and Hanken School of Economics. A cluster sampling technique was used to obtain a representative sample for the

study. This technique refers to a group of population elements, which constitutes the sampling unit. The sampling unit for this study comprises the aforementioned higher institutions in Vaasa.

A structured questionnaire was designed to elicit information on the perceived role of financial incentives in promoting waste recycling in Finland. The questionnaire was explicitly written in a simple format of close-ended questions, consisting of both categorical and ordinal variables. The ordinal variables were ranked on a five-point Likert scale, as follows: strongly agree = 1, agree = 2, undecided = 3, disagree = 4, strongly disagree = 5. A number of studies was reviewed to develop questions related to the role of financial incentives for recycling, as well as questions focusing on drivers for recycling. Questions regarding the perceived roles of financial incentives for recycling were listed for respondents to score on the five-point Likert scale. These statements considered the roles of financial incentive, such as stimulating knowledge for the recycling of waste, waste reduction and increased recycling. Other roles considered were behavioural change, critical motivational factors for recycling, influencing the desire to recycle waste, influencing current positive trends for recycling waste, tangible benefits for recycling waste, feasible goals for recycling waste, a sustainable approach for recycling waste, raising awareness for recycling waste, and promotion of recycling best practices.

Subsequently, questions focusing on drivers for recycling were listed, reflecting behavioural change drivers, including: Environmental risk, behavioural economics, resource value, economic benefit, convenience, knowledge, legislation and belief. Furthermore, questions bordering on recycling behaviour pertaining to various types of recyclable waste were also asked, in order to be rated on the five-point Likert scale.

A face-to-face interview was adopted for administering the questionnaires to 123 respondents. All 123 questionnaires were administered to students and staff across the five higher institutions located in Vaasa.

The first section of the questionnaire included questions focusing on the personal characteristics of respondents, while subsequent sections of the questionnaire included questions centred on the role of financial incentives for recycling from consumers' perspective, motivational factors for recycling and recycling behaviour. The data collected from the survey were analysed using the Statistical Package for Social Science (SPSS) software, version 24 (IBM Corporation, Armonk, UY, USA). Both descriptive (frequency table, percentage, mean and standard deviation) and inferential statistics (Spearman's rank-order correlation and *t*-test) were used to analyse the data.

The frequency table is used to display the number of times an event or characteristics occurred in this study. Percentage is also adopted for displaying explicit differentiation and analysis. Standard deviation is used to indicate the extent of variability. The mean is used as a measure of central tendency. Furthermore, the choice of Spearman's rank-order correlation in this study is made on the basis that it is the appropriate statistical method for determining the strength and direction between two variables at the ordinal level. The *t*-test is the applicable statistical method for determining whether there is a significant difference in the mean of two groups.

4. Results and Discussion

4.1. Descriptive Statistics

4.1.1. Socio-Economic Characteristics

The socio-economic status of the respondents is shown in Table 1. In the study, more than one third of the participants are male (41.5%), while more than half are females (58.5%). It is also worthy of note that females constitute the highest proportion of shoppers, as this reflects the gender roles of housekeeping and family care, among others [26]. More than 87% of the respondents are single. Further analysis will help to assess how the marital status of respondents is reflected in their response to incentives for recycling. 71.0% of the respondents have completed tertiary education. A study on the adaptation of environmental anticipation in the case of an educational computer game in Reference [27] identified knowledge as a key driver for influencing participation in recycling. Approximately half of

the participants earn income (49.6%). Most of the respondents (82.1%) fall within the age interval of 20–29 years.

Table 1. Socio-economic characteristics of respondents.

	Category	Frequency	Percentage
Sex	Male	51	41.5
	Female	72	58.5
Marital status	Single	108	87.8
	Married	14	11.4
	Widow	1	0.8
	Widower	-	-
Educational level	High school	48	39.0
	Bachelor	54	43.9
	Master	14	11.4
	Doctor	7	5.7
Age in years	20–29	101	82.1
	30–39	17	13.8
	40–49	5	4.1
	50 and above	-	-
Earned income	Yes	61	49.6
Non-earned income	No	62	50.4

4.1.2. Perceived Role of Financial Incentives for Recycling

The results in Table 2 indicate the perceived role of financial incentives for the recycling of municipal solid waste on a five-point Likert scale in the range from strongly agree (1) to strongly disagree (5). See Table 3 for the variables and definitions of the perceived role of financial incentives for recycling.

More than half (62.6%) of the participants agreed that financial incentive is the main consideration in the case of behavioural change, while 52.8% of the participants agreed that financial incentive stimulates knowledge for recycling waste. About one third (38.2%) of the participants agreed that financial incentive is a tangible benefit for recycling waste. Less than one quarter (24.4%) of the participants disagreed that financial incentive is a critical motivational factor for recycling, while 19.5% of the participants strongly agreed that financial incentive influences the desire to recycle waste.

The findings from the survey of consumers on the perceived role of financial incentives for the recycling of municipal waste show that effecting behavioural change (mean rank = 2.20) is the major outcome. This infers that financial incentives are crucial towards leveraging existing behavioural patterns and perceptions for increasing the recycling of municipal solid waste. This result agrees with the findings of Reference [28], which found that financial incentives can promote pro-environmental behaviour and contribute to sustained behaviour. Likewise, the minor role is that financial incentive is a tangible benefit for recycling (M = 2.58). The hierarchy of all items is identified through the ranking of their respective mean rank, with consideration for behavioural change at the apex, followed by influencing current positive trends for recycling waste, playing a significant role in reducing waste, increasing recycling, influencing the desire to recycle waste and so on. The mean rank of most items which measure the role of financial incentive for recycling fell below the set midpoint (2.50). This finding infers that the role of financial incentives is indispensable to the sustainable recycling of municipal solid waste. Thus, the debut of financial incentives for the recycling of other municipal solid waste, besides PET bottles and drink cans, is required for boosting consumer participation in the recycling of municipal solid waste.

Table 2. Perceived role of financial incentives for recycling.

Roles	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean Rank	Standard Deviation
1	14(11.4)	65(52.8)	28(22.8)	15(12.2)	1(0.8)	2.38	0.873
2	21(17.1)	64(52.0)	26(21.1)	11(9.0)	1(0.8)	2.24	0.872
3	14(11.4)	77(62.6)	26(21.1)	5(4.1)	1(0.8)	2.20	0.724
4	24(19.5)	44(35.8)	24(19.5)	30(24.4)	1(0.8)	2.51	1.089
5	24(19.5)	59(48.0)	21(17.1)	17(13.8)	2(1.6)	2.30	0.991
6	23(18.7)	65(52.8)	20(16.3)	13(10.6)	2(1.6)	2.22	0.919
7	12(9.8)	47(38.2)	47(38.2)	15(12.2)	2(1.6)	2.58	0.887
8	13(10.6)	55(44.7)	40(32.5)	14(11.4)	1(0.8)	2.49	0.853
9	17(13.8)	50(40.7)	44(35.8)	11(8.9)	1(0.8)	2.42	0.868
10	17(13.8)	64(52.0)	24(19.5)	16(13.0)	2(1.6)	2.37	0.934
11	10(8.1)	56(45.5)	39(31.7)	16(13.0)	2(1.6)	2.54	0.880

Table 3. Variables and definitions for the perceived role of financial incentives for recycling.

Variable	Definition
1	Financial incentive stimulates knowledge for recycling waste.
2	Financial incentive plays a significant role to reduce waste and increase recycling.
3	Financial incentive is a consideration for behavioural change.
4	Financial incentive is a critical motivational factor for recycling.
5	Financial incentive influences the desire to recycle waste.
6	Financial incentive influences current positive trends for recycling waste.
7	Financial incentive is a tangible benefit for recycling waste.
8	Financial incentive is feasible for the goal of recycling waste.
9	Financial incentive is a sustainable approach to recycling waste.
10	Financial incentive promotes awareness of recycling waste.
11	Financial incentive promotes recycling best practices.

Percentages are in parentheses.

4.1.3. Drivers for Recycling

The results concerning drivers for the recycling of municipal solid waste are shown in Table 4. See Table 5 for the variables and definitions of the drivers for recycling.

About half of the participants (45.5%) strongly agreed that they deposit recyclable materials at designated points because of their belief in the benefits of recycling. Meanwhile, 61.8% of the participants agreed that they deposit recyclable materials at designated points by considering the detrimental environmental impacts of not doing so, while 44.7% agreed that they deposit recyclable materials at designated points in relation to the extent of information provided. The findings from the survey of consumers on the drivers for the recycling of municipal solid waste indicate that the most important driver is a belief in the benefit of recycling. This is in line with a study reported in Reference [29], in which beliefs about the importance of recycling were positively related to the tendency to recycle. Likewise, the least important driver is related relatively to its attached financial incentives. Ranking the mean rank of all items presents a hierarchy of drivers, with a belief in the benefits of recycling at the pinnacle, followed by consideration of the detrimental environmental impacts, the culture of stewardship, conservation and preservation, value and so on. The mean rank of some drivers for recycling municipal solid waste which fell below 2.50 is found to be an intrinsic factor and vice versa. This infers that consumers' behaviour for recycling is more driven on the basis of socio-psychological factors in the study area. This is supported by the findings from a study on behaviour change in post-consumer recycling, as reported in Reference [30]. This study applied agent-based modelling in a social experiment which identified social norms as a decisive effect, irrespective of whether an area starts recycling or not.

Table 4. Drivers for recycling.

Drivers	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean Rank	Standard Deviation
1	27(22.0)	76(61.8)	13(10.6)	5(4.1)	2(1.6)	2.02	0.799
2	21(17.1)	48(39.0)	33(26.8)	17(13.8)	4(3.3)	2.47	1.035
3	23(18.7)	50(40.7)	28(22.8)	13(10.6)	9(7.3)	2.47	1.133
4	9(7.3)	37(30.1)	42(34.1)	20(16.3)	15(12.2)	2.96	1.119
5	22(17.9)	53(43.1)	20(16.3)	15(12.2)	13(10.6)	2.54	1.223
6	12(9.8)	55(44.7)	38(30.9)	10(8.1)	8(6.5)	2.57	1.001
7	11(8.9)	53(43.1)	26(21.1)	15(12.2)	18(14.6)	2.80	1.212
8	56(45.5)	49(39.8)	7(5.7)	8(6.5)	3(2.4)	1.80	0.981

Table 5. Variables and definitions for drivers for recycling.

Variable	Definition
1	I drop off recyclable materials at designated points out of consideration of the detrimental environmental impacts.
2	I drop off recyclable materials at designated points due to my culture of stewardship, conservation and preservation.
3	I drop off recyclable materials at designated points because they are valuable.
4	I drop off recyclable materials at designated points relative to the available financial incentives.
5	I drop off recyclable materials at designated points due to the closeness of recycling facilities.
6	I drop off recyclable materials at designated points relative to the extent of information provided.
7	I drop off recyclable materials at designated points due to stipulated policies and regulations.
8	I drop off recyclable materials at designated points because of my belief in the benefits of recycling.

Percentages are in parentheses.

4.1.4. Consumers' Recycling Behaviour

The results concerning consumers' recycling behaviour are shown in Table 6. More than 50% of the respondents always recycle newspapers (65.0%), magazines (56.9%), PET plastic bottles (57.7%) and glass (52.8%). The mean rank for all other recyclable materials falls below the set midpoint (2.50), with the exception being tetra packs (M = 2.68). This implies that there is a high tendency towards the recycling of newspapers, mixed papers, magazines, cardboard, glass, PET plastic bottles and metals. The most recycled materials are newspapers (M = 1.58) and the least recycled materials are tetra packs (M = 2.68). The disparity in responses about recycling behaviour between other recyclables and tetra packs may be due to convenience and effort involved in folding tetra packs into more compacted forms prior to recycling. Although the results show that there is evidence of recycling among the respondents, the proportion is not as impressive for a developed country with a recycling framework in place for these materials. Therefore, there is a need to encourage more members of the population to recycle materials where there is a recycling channel already in place.

Table 6. Recycling behaviour.

Materials	Always	Often	Sometime	Rarely	Never	Mean Rank	Standard Deviation
Newspapers	80(65.0) *	27(22) *	8(6.5) *	4(3.3) *	4(3.3) *	1.58	0.984
Mixed papers	47(38.2) *	34(27.6) *	31(25.2 *)	7(5.7)	4(3.3)	2.08	1.076
Magazines	70(56.9) *	26(21.1) *	16(13.0) *	7(5.7) *	4(3.3) *	1.76	1.072
Cardboards	43(35) *	31(25.2) *	30(24.4) *	16(13.0) *	3(2.4) *	2.23	1.137
PET plastic bottles	71(57.7) *	24(19.5) *	13(10.6) *	7(5.7) *	8(6.5) *	1.84	1.217
Metals	52(42.3) *	29(23.6) *	27(22.0) *	9(7.3) *	6(4.9) *	2.09	1.174
Glass	65(52.8) *	21(17.1) *	21(17.1) *	10(8.1) *	6(4.9) *	1.95	1.214
Tetra packs	28(22.8) *	31(25.2) *	30(24.4) *	22(17.9) *	12(9.8) *	2.68	1.295

* Percentages are in parentheses.

4.2. Inferential Statistics

4.2.1. Perceived Role of Financial Incentives for Recycling and Recycling Behaviour

A Spearman's rank-order correlation (Table 7) was used to investigate the direction and strength of the relationship between consumers' perceived role of financial incentives for recycling and recycling behaviour. The correlation coefficient of −0.066 indicates that a very weak and negative relationship exists between consumers' perceived role of financial incentives for recycling municipal waste and consumers' recycling behaviour. This infers that an increase in the perceived role of financial incentives for recycling municipal solid waste is associated with a decrease in recycling behaviour and vice versa. The p-value of 0.470, compared to an α-value of 0.01, proves that there is no significant relationship between the perceived role of financial incentives for recycling and recycling behaviour since the p-value is greater than the α-value.

Table 7. Spearman correlation between perceived roles of financial incentives and recycling behaviour.

			PRFI	RB
Spearman's rho	PRFI	Correlation coefficient	1.000	−0.066
		Sig. (two-tailed)		0.470
		N	123	123
	RB	Correlation coefficient	−0.066	1.000
		Sig. (two-tailed)	0.470	
		N	123	123

4.2.2. Drivers for Recycling and Recycling Behaviour

A Spearman's rank-order correlation (Table 8) was used to examine the direction and strength of the relationship between drivers for recycling and recycling behaviour. The correlation coefficient of 0.265 show that a weak-to-positive relationship exists between drivers for recycling municipal solid waste and recycling behaviour. This implies that an increase in drivers for recycling municipal solid waste is accompanied by an increase in recycling behaviour; likewise, an increase in recycling behaviour is accompanied by an increase in drivers for recycling municipal solid waste. The p-value of 0.003, as compared to an α-value of 0.01, confirms that there is a significant relationship between drivers for recycling municipal solid waste and recycling behaviour since the p-value is less than the α-value. This suggests that behavioural change factors for the recycling of municipal solid waste influence consumers' recycling behaviour. Motivation is one of the strongest variables shaping recycling behaviour [31].

Table 8. Spearman correlation between drivers for recycling and recycling behaviour.

			DFR	RB
Spearman's rho	DFR	Correlation coefficient	1.000	0.265 **
		Sig. (two-tailed)		0.003
		N	123	123
	RB	Correlation coefficient	0.265 **	1.000
		Sig. (two-tailed)	0.003	
		N	123	123

** Correlation is significant at the 0.01 level (two-tailed).

4.2.3. Income-Earning and Non-Income-Earning Consumers

An independent sample t-test (Table 9) was used to compare the means of the perceived role of financial incentives for recycling for two independent groups (income-earning consumers and non-income-earning consumers) in determining whether there is statistical evidence confirming that the associated population means are significantly different. The non-income-earning consumers group

(N = 61) is associated with its mean for the perceived role of financial incentives for recycling M = 2.39 (SD = 0.469) (see Table 10). By comparison, the income-earning consumers group (N = 62) is associated with its numerically bigger mean for the perceived role of financial incentives for recycling M = 2.40 (SD = 0.627). Furthermore, the assumption of the uniformity of variance was tested and satisfied via Levene´s F test (Table 9), F (121) = 3.40, P = 0.68, at a level of significance of 0.05 (where $p > 0.05$). The independent sample *t*-test is associated with no statistically significant effect, t (121) = −0.123, P = 0.90, at a level of significance of 0.05 (where $p > 0.05$). Hence, there is no significant difference in the means of the perceived role of financial incentives for recycling for the two groups. This implies that both groups of consumers show an interest in financial incentives. This is line with previous research which found that both non-income-earning consumers and income-earning consumers are very sensitive to economic incentives [32]. Cohen´s D was estimated at 0.02. This infers a small effect according to Cohen´s guidelines [33]. The 95% confidence interval was −0.210 to 0.186.

Table 9. Independent sample *t*-test for income-earning and non-income-earning consumers.

									95% Confidence Interval of The Difference	
		F	**Sig.**	**t**	**df**	**Sig. (Two-Tailed)**	**MD**	**SE**	**Lower**	**Upper**
GMPRFI	EVA	3.400	0.68	−0.123	121	0.903	−0.01227	0.09999	−0.21023	0.18569
	EVNA			−0.123	112.944	0.902	−0.01227	0.09976	−0.20992	0.18537

Table 10. Income-earning and non-income-earning consumers.

	NIAIC	**Number**	**Mean**	**SD**	**SEM**
Group means of the perceived role of FI	No	61	2.3892	0.46901	0.06005
	Yes	62	2.4015	0.62726	0.07966

FI = financial incentive.

4.3. Cronbach Alpha

Cronbach alpha is a reliability test which measures the internal consistency of a scale. In particular, it measures the variance of measure for the variance of response in one item with the overall variance [34]. The Cronbach alpha for the perceived role of financial incentives for recycling was 0.834, while that for the drivers for recycling was 0.601 and that for recycling behaviour was 0.817. The perception that alpha should be greater than 0.7 has been disputed in [35]. This was the case with the Cronbach alpha value of 0.601 for drivers for recycling. The Cronbach alpha values of 0.834, 0.601 and 0.817 for the perceived role of financial incentives for recycling, drivers for recycling and recycling behaviour, respectively, are indicative of the accuracy of the measures and the elimination of random errors.

5. Conclusions

The study examined consumers' perception about the role of financial incentives in effecting the recycling of municipal solid waste materials in Vaasa, Finland. The findings of the study confirm the effectiveness of monetary incentives in promoting recycling.

The empirical results revealed that the role of monetary rewards for municipal solid waste cannot be overemphasized. Thus, financial incentives are prerequisites for attaining the stipulated EU recycling rate for municipal solid waste in Finland. The major driver for the recycling of municipal solid waste is a belief in the benefits of recycling. The minor driver for the recycling of municipal solid waste is relative to its attached financial incentive. With relevance to the aforementioned key factor, it is expected that a strict adherence to and conformity with Finnish waste policies should be aligned

to EU waste policies, which state that recycled waste intended for material recovery and reuse should not be diverted for energy generation.

The study also found that, although mechanisms already exist for the recycling of some waste materials, including newspapers, magazines, mixed papers, cardboard, PET plastics bottles, metals, glass and tetra packs, the level of participation in the recycling of these materials is barely above the average proportion of the population. Therefore, there is a need to put in place interventions which will increase the participation of many more members of society in the recycling of municipal waste materials, such as tetra packs and glass, which are generated in enormous quantities on a daily basis in Finland. These are used in the package of food and involve a with high daily consumption rate among households. The interventions for promoting an increase in recycling should be anchored to key drivers for recycling. Interventions, drivers and incentives are interrelated, as their goal is geared towards motivating people in the course of events.

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Households' Perception of Financial Incentives in Endorsing Sustainable Waste Recycling in Nigeria

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Abstract: Recycling is viewed as a central aspect in sustainability and mainly as pro-environmental consumer behavior. The purpose of this study is to examine the perception of households on financial incentives in endorsing sustainable recycling for municipal solid waste in Nigeria. The study was conducted in the Shomolu Local Government Area, Lagos State, Nigeria. The study also covers drivers for household willingness to recycle municipal solid waste on environmental risk, behavioral economics, resource value, economic benefit, convenience, knowledge, legislation, and belief. The result from the study asserts the hypothesis that financial incentives for recycling are vital for reducing and managing municipal solid waste sustainably. The most important driver for household willingness to recycle municipal solid waste is the detrimental environmental impacts. A moderate to positive relationship exists between households' perception of financial incentives for recycling and drivers for household willingness to recycle municipal solid waste. The study recommends adopting the extended producer responsibility (EPR) model, reverse vending options, amongst other approaches, in an effort to promote recycling culture among citizens and residents in Nigeria.

Keywords: solid waste management; recycling; financial incentives; behavior change; Nigeria

1. Introduction

The goals of waste management cannot be separated from those of sustainable development. This is because the principles of sustainable development aim to achieve economic development, social development, and environmental protection. The perpetually increasing flow of household waste is an enormous environmental issue [1]; however, social and economic issues cannot be discounted. Recycling, a sustainable strategy in addressing these problems, reduces the amount of waste directly disposed of in landfills, and has the potential to reduce disposal costs and waste transport costs. It prolongs the life span of landfill sites [2], and reduces the energy costs associated with the use of non-virgin materials during production [3], as well as ensuring the conservation of virgin materials. In other words, the effective management of waste has major potential benefits to society [4], the economy, and the environment.

Waste composition analyses suggest that over two-thirds of household waste can be recycled or composted [5]. Furthermore, findings [6] from a study on solid waste generation and characterization in the University of Lagos revealed that the recyclable potential of waste is very high, constituting about 75% of the total waste generated. Despite this, an investigation conducted in Nigeria, by the Lagos state Waste Management Authority on residents of Lagos Island revealed that about 89.0% of the respondents were aware of waste recycling, but only 47.8% were devoted to recycling [7]. Waste management with source segregation is more likely to succeed through using financial incentives to induce behavioral change than by engaging in efforts to strengthen social norms [1]. There is a possibility for increasing the number of individuals who are devoted to recycling at household level when intrinsic and extrinsic factors required for proper waste management are met. These intrinsic and extrinsic factors are

aligned to different aspects of socio-psychology, technology, policy and legislation, as well as the economy [8]. These intrinsic factors are socio-psychological motivation factors such as moral or social norms (belief in the benefit of recycling), environmental concerns, and behavioral economics (culture of stewardship, conservation and preservation as well as resource value), while extrinsic factors include financial incentives and other convenience factors [9]. These intrinsic factors are motivations that are internally generated within the individual through passion, personal satisfaction, and self-determination. Conversely, the extrinsic factors are motivations that arise from outside the individual through rewards, obligations, and/or demands. This paper examines the perceived importance of financial incentives versus other behavioral change drivers in the adoption of sustainable recycling for municipal solid waste in Lagos state, Nigeria.

This paper includes four subsequent sections: Section 2 reviews the literature on recycling and solid waste management in Nigeria; Section 3 discusses the materials and methods applied in the study; Section 4 presents the results and discussion; and finally, Section 5 highlights the conclusion and recommendations from the study.

2. Recycling and Solid Waste Management in Nigeria

Nigeria typifies the many developing countries that have done less in implementing sustainable solid waste management due to the numerous barriers impeding municipal solid waste management [10]. One of these barriers is the absence of a formal recycling platform. Recycling is viewed as a fundamental aspect in sustainable waste management and mainly as pro-environmental consumer behavior; because of this sustainability and recycling behavior are intertwined [11]. As sustainability and recycling behavior are interrelated, it is relevant to examine households' perception of monetary incentives as well as the key drivers or motivational factors for sustainable waste recycling in Nigeria.

Since a formal advocacy platform for the recycling of municipal solid waste is yet to be launched in Nigeria, individuals and corporate bodies are promoting and establishing avenues for increasing the recovery of recyclable items. An instance is the University of Lagos Recycling Project, which provides a venue for returning plastic bottles and in turn monetary rewards are given to the recyclers. Another instance is *Wecyclers*, a social enterprise involved in the collection of recyclable items from low-income areas in Lagos state using an incentive-based model [12].

Different scholars have conducted recycling related studies for solid waste management in Nigeria [3,7,13,14]. Research findings revealed that environmental preservation is the highest ranked benefit of recycling among the four elements of perceptions about recycling benefits to households in Kaduna, Northern Nigeria; namely environmental preservation, resource and cost conservation, monetary reward, and environmental awareness [7]. The study noted that environmental awareness is a prelude to environmental preservation and monetary reward. It considered the analysis of environmental awareness in three sub-components: ease of waste disposal, nurturing values and awareness, and inculcating environmental sanitation among young people. This study affirms the assumption that financial incentives are one of the most important factors for promoting the recycling of municipal solid waste at household level in Nigeria.

Findings from a study on the analysis of barrier and success factors affecting the adoption of sustainable management of municipal solid waste in Abuja, the capital city of Nigeria, point towards sustained public education on waste prevention and reuse as being the solution to waste problems in Nigeria [10]. This has become necessary owing to the growing population of the city. Underpinning this result is an economic factor. A segment of the population that engages in or participates in the recycling chain derives some utility in extending the useful life of the waste materials. Putting in place financial incentives for recycling, among other drivers, will be pivotal for Nigeria as the country transitions from a predominance of informal actors to full participation of formal actors in waste management. Although informal actors in the waste management chain play a vital role in championing reduce, reuse, and recycling in Nigeria, the participation of formal actors with accompanying institutionalization and legislation will fast track behavioral change—particularly waste separation at the source. In addition,

the inability of the informal actors to muster the required human capacity, as well as the financial, technological, and other resources necessary for efficient waste management is a major disadvantage. Informal waste management continues to be bogged down by problems such as the occupational and public health hazards caused by poor waste processing, inefficiency in handling high volumes of waste in a growing city, uncontrolled pollutant flow, and child labor among others [15].

The management of solid waste is an enormous challenge in Nigeria particularly in urban areas with increasing populations. For instance, Lagos State which is the most populous and one of the most industrialized cities in the country, albeit having the smallest land area, produces approximately 11 thousand tons of waste per day [3,16]. Waste generation rates differ from city to city based on diverse factors such as population size, the level of urbanization, the level of development, and social and economic activities. Findings from a survey conducted in parts of Markurdi, the capital of Benue State in Central Nigeria, showed that waste generation rates for households were 0.54 kg/capita/day [17]. A study on household waste composition and quantities in Abuja revealed that the average daily per capita household waste production was 0.634 kg/capita/day [18]. These all point to the problem of increasing waste generation in Nigeria.

The numerous problems associated with poor state of solid waste management in Nigeria have been discussed in different studies [10,19–22]. The problems include: unfavorable economic conditions, poor institutional arrangements, the lack of the necessary legislative backing and poor implementation of waste management laws, as well as other technical and operational constraints. Another major constraint, which affects the level of recycling in Nigeria is the lack of a framework for extended producer responsibility (EPR). Nigeria currently does not have an EPR legislation in place, which implies that manufacturers of products are not obligated nor involved in any voluntary scheme that promotes reuse and recycling

Despite the massive problems affecting waste management in Nigeria, the country has the capacity and there exist incentives to adopt effective recycling practices similar to those that have been adopted in most developed countries. A review on plastic recycling based on previous studies carried out in different countries concluded that economic, environmental, and social factors are key to driving the sustainable development of recycling systems [23]. Economic, environmental, and social factors will remain crucial in driving Nigeria towards adopting sustainable recycling systems for municipal solid waste. A study conducted by [24] assessed the adoption of energy recycling within the European Union as part of the circular economy approach for sustainably managing municipal solid waste.

3. Materials and Methods

3.1. Data Collection

The study was conducted using primary sources of data. Primary data were collected through closed-ended questionnaires on the perception of financial incentives for households in endorsing sustainable waste recycling in Nigeria. The first section of the questionnaire included questions that focused on the personal characteristics of respondents, while subsequent sections of the questionnaire included questions that focused on the role of financial incentives for recycling from the consumers' perspective and drivers for household willingness to recycle including both intrinsic and extrinsic factors. The questionnaire included nominal and ordinal variables. The ordinal variables were ranked on a five point Likert Scale namely: strongly agree = 1; agree = 2; undecided = 3; disagree = 4; strongly disagree = 5. Questions regarding the perception of financial incentives as a driver for recycling were considered in an itemized list on the roles of financial incentives on a five point Likert Scale. These statements viewed roles such as stimulating knowledge for the recycling of waste, waste reduction and increased recycling, consideration for behavioral change, critical motivational factors for recycling, influencing the desire to recycle waste, present positive trends for recycling waste, the tangible benefits for recycling waste, feasible goals of recycling waste, a sustainable approach for recycling waste, promotion of awareness for recycling waste, and promotion of recycling best practices.

In addition, questions covering drivers for willingness to recycle were considered in an itemized list reflecting drivers encompassing environmental risks, behavioral economics, resource value, economic benefit, convenience, knowledge, legislation, and belief. Answers were provided to the questions as respondents were asked to indicate ´´X" for the response best applicable to the statements. The survey was conducted in summer, 2017.

3.2. Population and Sampling Technique

The projected population of the Shomolu Local Government Area as of 2015 was 1,361,100 [25], this included 967 households distributed within eight wards [26]. The Shomolu Local Government is one of the 16 Local Governments in Metropolitan Lagos. It has a land area of 14.6 km square and is part of the Ikeja division of Lagos State, Nigeria. To the north it shares boundary with Kosofe, and to the south it shares boundary with the Lagos Mainland Local Government Area (LGA). To the East it shares boundary with the Mushin Local Government Area.

It is a major site of commercial printing activities in Lagos State. It is predominantly a residential suburb with huge problems related to inadequate sanitation, overcrowding, and poor housing.

Using a door-to-door approach for the survey, 135 households were administered questionnaires. The study employed a stratified random technique. This approach guaranteed precision of the samples by avoiding sampling error. The Shomolu Local Government Area was divided into stratums of eight political wards, thereafter, households were randomly approached from each political ward. To ensure a good representation of samples, efforts were made to guarantee a wide geographic spread of the households selected. Efforts were also made to capture households belonging to different socio-economic groups. The survey elicited information only from the heads of households. By means of a sample size calculator, sample size was determined by inputting a projected population of 1,361,100 [25] at a confidence level of 95% and confidence interval of 8%.

3.3. Data Analysis

The data collected were analyzed using the statistical package for the Social Science (SPSS) software. Primary data for the study were analyzed using descriptive (cross tabulation, frequency, percentage, mean, and standard deviation) and inferential statistics (Spearman's rank-order correlation). The unit of analysis for the study was household level.

4. Results and Discussion

4.1. Descriptive Statistics

4.1.1. Households' Perception of Financial Incentives for Recycling

The empirical results in Table 1 depict households' perception of financial incentives for recycling from a scale of strongly agree (1) to strongly disagree (5).

More than one-third of the respondents (40.7%) strongly agreed that financial incentives stimulate knowledge for the recycling of waste. About half of the respondents (46.7%) agreed that financial incentives play a significant role in reducing waste and increasing recycling. More than half of the respondents (51.9%) agreed that a financial incentives influence the desire to recycle waste. A smaller proportion of 12.6% of the respondents were undecided about financial incentives being feasible for the goal of recycling waste. Furthermore, none of the respondents (0.0%) strongly disagreed that financial incentives present positive trends for recycling waste. Less than one-tenth of the respondents (8.1%) disagreed about financial incentives being a sustainable approach for recycling waste.

The mean scores of all items that measure households' perception of financial incentives for recycling ranged from 1.87 to 2.11. This infers that in the Somolu Local Government Area of Lagos State, financial incentives for recycling municipal solid waste from a household perspective plays

a significant role in reducing waste and increasing recycling. Similarly, the minor role of financial incentives for managing municipal solid waste is a tangible benefit derivable from recycling waste.

The mean scores of all items that measure households' perception of financial incentives for recycling fell below the set mid-point (2.50). This finding infers that financial incentives for recycling are important for reducing municipal solid waste.

Table 1. Descriptive statistics of households' perception of financial incentives for recycling.

Statements	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	Standard Deviation
PFIR 1	55(40.7)	60(44.4)	9(6.7)	8(5.9)	3(2.2)	1.87	0.987
PFIR 2	59(43.7)	63(46.7)	2(1.5)	8(5.9)	3(2.2)	1.76	0.916
PFIR 3	41(30.4)	58(43.0)	19(14.1)	16(11.9)	1(0.7)	2.10	0.992
PFIR 4	42(31.1)	63(46.7)	18(13.3)	12(8.9)	0(0.0)	2.00	0.898
PFIR 5	42(31.1)	70(51.9)	13(9.6)	10(7.4)	0(0.0)	1.93	0.839
PFIR 6	40(29.6)	71(52.6)	16(11.9)	8(5.9)	0(0.0)	1.94	0.808
PFIR 7	36(26.7)	67(49.3)	15(11.1)	14(10.4)	3(2.2)	2.11	0.998
PFIR 8	38(28.1)	69(51.1)	17(12.6)	10(7.4)	1(0.7)	2.01	0.881
PFIR 9	39(28.9)	69(51.1)	11(8.1)	11(8.1)	5(3.7)	2.07	1.016
PFIR 10	50(37.0)	69(51.1.)	10(7.4)	5(3.7)	1(0.7)	1.80	0.790
PFIR 11	43(31.9)	68(50.4)	12(8.9)	11(8.1)	1(0.7)	1.96	0.897

Variable	Definition
PFIR 1	Financial incentives stimulate knowledge for the recycling of waste
PFIR 2	Financial incentives play a significant role in reducing waste and increasing recycling
PFIR 3	Financial incentives are a consideration for behavioral change
PFIR 4	Financial incentives are a critical motivational factor for recycling
PFIR 5	Financial incentives influence the desire to recycle waste
PFIR 6	Financial incentives present positive trends for recycling waste
PFIR 7	Financial incentives are a tangible benefit from recycling waste
PFIR 8	Financial incentives are feasible for the goal of recycling waste
PFIR 9	Financial incentives are a sustainable approach for recycling waste
PFIR 10	Financial incentives promote awareness for recycling waste
PFIR 11	Financial incentives promote the best recycling practices

Percentages are in parenthesis.

4.1.2. Drivers for a Households' Willingness to Recycle

The empirical results in Table 2 show the drivers for a households' willingness to recycle municipal solid waste on a five point Likert scale from strongly agree (1) to strongly disagree (5).

More than one-third of the respondents (43.0%) strongly agreed that they would drop recyclable materials at designated points considering its detrimental environmental impact. More than half of the respondents (57.8%) agreed that they would drop recyclable materials at designated points because of the stipulated policies and regulations. Less than one-tenth of the respondents (8.9%) were undecided about dropping recyclable materials at designated points on account of the associated financial incentives. Just fewer than twenty percent (17.8%) of the respondents disagreed with dropping recyclable materials at designated points because of the proximity of recycling facilities. None of the respondents (0.0%) strongly disagreed with dropping recyclable materials at designated points because of their belief in the benefit of recycling.

The mean scores of all items that measure drivers for a households' willingness to recycle municipal solid waste ranged from 1.84 to 2.35. This infers that the most important driver for a households' willingness to recycle municipal solid waste is the detrimental environmental impacts in the Somolu Local Government Area, Lagos state. This is in line with the study by Reference [27] which found that environmental benefits are one of the important factors for promoting consumer participation in waste management. Likewise, the least important driver is proximity to recycling facilities.

The mean scores of all items that measure drivers for a households' willingness to recycle municipal solid waste fell below the set mid-point (2.50). This finding suggests that drivers are indispensable for a households' willingness to recycle municipal solid waste in the Somolu Local government Area, Lagos State.

Table 2. Descriptive statistics of drivers for a households' willingness to recycle.

Statements	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	Standard Deviation
DFWTR 1	58(43.0)	56(41.5)	8(5.9)	10(7.4)	3(2.2)	1.84	0.984
DFWTR 2	43(31.9)	61(45.2)	12(8.9)	17(12.6)	2(1.5)	2.08	1.037
DFWTR 3	38(28.1)	71(52.6)	9(6.7)	16(11.9)	1(0.7)	2.04	0.95
DFWTR 4	25(18.5)	72(53.3)	12(8.9)	23(17.0)	3(2.2)	2.32	1.034
DFWTR 5	34(25.2)	75(55.6)	15(11.1)	24(17.8)	6(4.4)	2.35	1.167
DFWTR 6	34(25.2)	75(55.6)	11(8.1)	9(6.7)	6(4.4)	2.1	0.999
DFWTR 7	29(21.5)	78(57.8)	13(9.6)	12(8.9)	3(2.2)	2.13	0.926
DFWTR 8	53(39.3)	58(43.0)	13(9.6)	11(8.1.0)	0(0.0)	1.87	0.896

Variable	Definition
DFWTR 1	I will drop recyclable materials at designated points considering its detrimental environmental impacts
DFWTR 2	I will drop recyclable materials at designated points due to my culture of stewardship, conservation, and preservation
DFWTR 3	I will drop recyclable materials at designated points because it is valuable
DFWTR 4	I will drop recyclable materials at designated points relative to the associated financial incentives
DFWTR 5	I will drop recyclable materials at designated points due to the proximity of recycling facilities.
DFWTR 6	I will drop recyclable materials at designated points relative to the extent of the information provided
DFWTR 7	I will drop recyclable materials at designated points because of the stipulated policies and regulations
DFWTR 8	I will drop recyclable materials at designated points because of my belief in the benefit of recycling

Percentages are in parenthesis.

4.2. Inferential Statistic

Spearman's Rank Correlation

A Spearman's rank-order correlation (Table 3) was used to investigate the direction and strength of the relationship between the perception of financial incentives for recycling and the drivers for recycling. The correlation coefficient of 0.440 indicates that a moderate to positive relationship exists between households' perception of financial incentives for recycling and drivers for recycling. This infers that as the perception of financial incentives for recycling increases, the drivers for recycling increase, and as the drivers for recycling increase, the perception of financial incentives for recycling increases, respectively. The probability value of less than 0.001, as compared to an alpha value of 0.01, proves that there is a significant relationship between the perception of the role of financial incentives for recycling municipal solid waste and the drivers for household willingness to recycle, as the P-value is less than α value.

Table 3. Spearman's rank-order correlation between perception of financial incentives and drivers for recycling.

			PFI	DFR
Spearman's Rho	PFIR	Correlation Coefficient	1.000	0.440 **
		Sig. (two-tailed)		0.000
		N	135	135
	DFWTR	Correlation Coefficient	0.440 **	1.000
		Sig. (two-tailed)	0.000	
		N	135	135

** Correlation is significant at the 0.01 level (two-tailed). PFIR—Perception of financial incentives for recycling, DFWTR—Drivers for a households' willingness to recycle, Rho (rank correlation coefficient).

4.3. Cronbach Alpha

Cronbach alpha is a reliability test that measures the internal consistency of a scale [28]. The Cronbach alpha for household perception of financial incentives for recycling was 0.776 and willingness to recycle was 0.627. This infers that the respondents' perception of financial incentives for recycling as well as willingness to recycle are consistent. According to Reference [29], "alpha greater than 0.90 most likely indicate unnecessary redundancy rather than a desirable internal

consistency". The usefulness of this result to the study is to ensure accuracy and add validity to the interpretation of data.

5. Conclusions and Recommendations

Nigeria needs to make the transition to a sustainable waste management approach. A key step towards this transition is the adoption of recycling for the management of municipal solid waste, which has been increasing as the population in urban centers in Nigeria increases. The adoption of a recycling approach in waste management will help to reduce the amount of waste that goes to dumps sites, and constitutes health and environmental hazards. The adoption of recycling will also contribute to reducing the energy used in production as well as contributing to enhancing the economy. This paper examined the drivers for the adoption of recycling in Lagos, Nigeria. The study focused on assessing the response of households to financial incentives as a motivation for adopting recycling. Understanding the perception of the household has become critical in designing a set of policies and tools for incentivizing and promoting a recycling culture in Nigeria. Our findings indicate that households will respond to financial incentives as well as an increased understanding of the detrimental impact of inefficient waste management methods, because of this the government and stakeholders must implement keys steps including: adopting the extended producer responsibility (EPR) method, reverse vending options, among other approaches, to work towards promoting a recycling culture among the citizens and resident of Nigeria. The country also needs to move forward in the adoption of a circular economy that prioritizes energy recycling as an approach for sustainably managing municipal solid waste.

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